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VITRUVIUS
ON ARCHITECTURE
BOOKS 6–10



Translated by
FRANK GRANGER

VITRUVIUS (Marcus V. Pollio), Roman architect and engineer, studied Greek philosophy and science and gained experience in the course of professional work. He was one of those appointed to be overseers of imperial artillery or military engines, and was architect of at least one unit of buildings for Augustus in the reconstruction of Rome. Late in life and in ill health he completed, sometime before 27 BC, *De Architectura* which, after its rediscovery in the fifteenth century, was influential enough to be studied by architects from the early Renaissance to recent times.

In *On Architecture* Vitruvius adds to the tradition of Greek theory and practice the results of his own experience. The contents of this treatise in ten books are as follows. Book 1: Requirements for an architect; town planning; design, cities, aspects; temples. 2: Materials and their treatment. Greek systems. 3: Styles. Forms of Greek temples. Ionic. 4: Styles. Corinthian, Ionic, Doric; Tuscan; altars. 5: Other public buildings (fora, basilicae, theatres, colonnades, baths, harbours). 6: Sites and planning, especially of houses. 7: Construction of pavements, roads, mosaic floors, vaults. Decoration (stucco, wall painting, colours). 8: Hydraulic engineering; water supply; aqueducts. 9: Astronomy. Greek and Roman discoveries; signs of the zodiac, planets, moon phases, constellations, astrology, gnomon, sundials. 10: Machines for war and other purposes.

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VITRUVIUS
II

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VITRUVIUS
ON ARCHITECTURE
BOOKS VI-X

EDITED AND TRANSLATED BY
FRANK GRANGER



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PREFACE

IN bringing to completion an attempt to base the text of Vitruvius on a single primary MS. the critical notes below the Latin text of Books VI. to X., continue the evidence of Books I. to V. to the excellence of *H.* While the emphasis of the first five books is upon architecture in the usual sense of the word, the second five books disclose the world of Greek science as a background to engineering and restore the full picture of Vitruvius.

Mr. Frank Richards, M.A., the translator of the *Aeneid*, has given me valuable help in the final revision for the press. Nor must the printer's reader be left without thanks for his continuous and scholarly co-operation.

FRANK GRANGER.

UNIVERSITY COLLEGE,
NOTTINGHAM,
July, 1933.

INTRODUCTION

VITRUVIUS AS THE HISTORIAN OF SCIENCE

It is only in modern times that Vitruvius has been regarded mainly as an architect, and that attention has been almost concentrated upon his exposition of the orders of architecture to the neglect of the major part of his achievement. Not unnaturally the expectation has been raised that his style should exhibit the qualities of order, arrangement and symmetry which he somewhat confusedly traces in architecture, Book I. ii. 1. If with more propriety we follow tradition and approach him as an engineer, the case is altered. As Caspar Barth¹ well puts it according to Morhof: *est styli genus . . . coactim nimirum eruditionem Graecam sapiens, et manum opificis, non ingenium scriptoris, olens.* "His style in a word combines Greek science with the touch of the craftsman rather than the manner of the writer." In this respect he anticipates the two most universal geniuses of the Renaissance. Michael Angelo's "style is obscure, crabbed, ungrammatical."² Again, "Italian scholars declare that Leonardo's grammar is that of the small Florentine shopkeeper."³ But, for

¹ *Polyhistor*, I, Book IV. xi. 17.

² Symonds, *Life of Michelangelo* (1893), Vol. II. 168.

³ Müntz, *Leonardo da Vinci, tr.* (1898), Vol. II. 22.

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all that, he was a brilliant and accurate man of science.¹ Vitruvius, also, illustrates the not infrequent separation of scientific insight from the command of literary expression. Yet his style is well adapted to the needs of the laboratory and workshop.

Like Leonardo, Vitruvius records experiments and their uses: a lighted lamp as a test for foul air in a well, ii. 191; the effects of white lead on those who work it and the consequent danger of lead pipes in the supply of water, ii. 189; the vibration of bronze in response to the use of iron implements in a neighbouring tunnel and the consequent military precautions, ii. 367. Over against such experimental results were the mathematical principles, almost confined to geometry owing to the imperfect notation of numbers, and the resulting cramping of arithmetic. The geometrical achievements of the Greeks were stimulated by the empirical formulae of Egyptian builders and the astronomical observations of the Chaldaeans. But the sense of the universal came first in Hellas to its complete expression and carried geometry no less than metaphysics to levels not often reached in after times and rarely transcended. The inspiration of science no less than that of literature and of art was attributed to the Muses, and Vitruvius adopted this as an article of his creed from a legend about Pythagoras, ii. 203.

The realm of natural science was almost alien to the Athenian mind, so richly endowed in other fields.² The *Clouds* of Aristophanes and Plato's *Apology*, exhibit from two angles, that of the con-

¹ Mach, *Science of Mechanics*, tr. (1902), 520.

² Diels, *Vorsokratiker*, ii. 83, 116.

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servative and that of the moralist the disinclination of the Athenian intellect towards natural science. Plato and Meton are almost the only Athenians whose works appear in the history of science.

Vitruvius, in the preface to Book IX., traces the development of geometry from its beginnings to the solution of the Delian problem, the duplication of the cube. Later on in the same book he enumerates the astronomers in whom he traces the operation of the divine mind, ii. 247. The founders of scientific geography, ii. 175, opened out a subject which still awaits full fruition. If we assign the thinkers whom Vitruvius enumerates to their places of origin we might be led to infer that Asia Minor, Macedonia, Sicily, Southern Italy were more receptive of scientific inspiration than Attica. For the Athenian temper shrank from applying science to the observation of nature, and Plato treated Democritus with silent disapproval, incorporating in the *Timaeus* with the disdain of the abstract thinker, the *specific* observations of Democritus.¹

The legendary wish of Plato to destroy the works of Democritus was countered for the time by their wide circulation; the catalogue made by Thrasyllus, himself a Platonist, contains evidence not to be neglected of their survival into the first Christian century. Hence the importance of Vitruvius as bridging "the gap between the dominating idealism of Plato and Democritus' rational observation of nature with its anticipation of modern theories."² We owe to *H* and its descendant *h* the correct state-

¹ Zeller, *Phil. der Griechen*, II. i. 791.

² Heiberg, *Geschichte der Mathematik u. Naturwissenschaften im Alterthum*, 12.

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ment of Democritus' theory of perspective, ii. 71, which follows from his principle that "things" are not real but dependent upon "atoms": a principle which is parallel to the dependence of things upon the Platonic "ideas," ii. 89. It is the presence of Democritean principles in the background of the *de architectura* that rescues it from a purely archaeological interest. Neither Platonism nor the Church is to blame for the disappearance of Democritus, who was represented in the public libraries of the early empire. Like the greater part of the Greek literary tradition, Democritus disappeared in the confusion which followed upon the assassination of Alexander Severus A.D. 235.

VITRUVIUS AS THE HISTORIAN OF MACHINERY

Compared with Greek science, Greek mechanics was in its infancy.¹ The backward state of metallurgy almost limited the mechanical engineer to the occasional use of bronze. Ancient artillery itself was constructed of wood and operated by elastic tension like a bow. Vitruvius carried his manual to the middle of the tenth book before he thus turned from the service of peace to that of war, ii. 325. The practical character of his definitions is shown by the fact that catapults and balistae have been constructed and operated in modern times by following his rules.² The plates at the end of this volume show how water-power was applied to clocks and organs and other purposes of peace. The application

¹ Mach, *op. cit.*, 520.

² Neuburger, *Technical Arts and Sciences*, 222.

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of water-power to time-pieces and automata was controlled by a balancing weight of sand. The principle of equilibrium involved is correctly named by *H*, ii. 275, but has not been so understood by the editors; it furnishes the difficult problem of virtual velocity. More simple cases are found in the principle of the balance, and of the lever. We must be content with this glimpse into ancient mechanics, of which the theoretical importance went far beyond its achievements in practice. Its weakness in this respect was partly compensated by slave labour which was brought in to work the capstans of pulleys, ii. 285; water-wheels, ii. 303; treadmills, ii. 309.

Generally speaking skilled labour seems to have been free, and to have enjoyed a status somewhat higher than in modern times. The precautions taken against poisoning by gases or by lead have a strangely modern sound, like the baths and public libraries which were soon established even in towns of a moderate size all over the empire.

Building artificers were organised into *collegia* or benefit societies and often worked in gangs of ten, *decuriae*, under a foreman, *decurio*. The plasterers, ii. 95, were probably freemen; the paviours may have been slaves, ii. 83. They were engaged and paid by the works manager, *praefectus fabrum*, a term replaced by "architect." Vitruvius contemplates the case in which the owner acts as his own works manager, ii. 9.

He wrote for the foreman and the works manager, and his book sheds a light upon the social conditions of the early empire comparable to that furnished by the New Testament. The evidence furnished by the latter, however, is blurred in the English Authorised

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and Revised Versions by the mistranslation of *doulos*, which in the 120 places in which it occurs is never correctly translated "slave" in spite of the Latin versions which always give *servus*. Throughout the N.T. the artificer is usually a freeman,¹ and yet he is repeatedly identified with the slave by the use of "servant" for both the slave and the free employee.

It was the free artificer working for Christian employers who created the early Christian art, which came to perfection by the third century, and anticipated the mediaeval art to which Vitruvius' *de architectura* also served as a manual.

¹ Granger, *Legal Status of Labour in the N.T.* Nottingham, J. and H. Bell, 1933.

VITRUVIUS AND THE CRAFTSMEN OF ROME¹

I

THE Roman craftsmen were scarcely disturbed during the first three centuries of the empire by the political catastrophes which transformed the Roman state into an Oriental despotism. They displayed their traditional skill impartially in the service of the imperial religion and of the Christian clients who, as time went on, became its passive opponents. From Augustus to Diocletian the reigning monarch was a patron of the arts and added to the architectural splendours of the capital. Increased knowledge has shown that the church itself fostered no less some of the finest achievements of the Roman tradition.

Over against this conservatism of the capital and indeed of the western provinces, Christian buildings in the east took another turn. For example, the earliest churches of Old Cairo² date at least from the third century. Similarly, Syria, Asia Minor, and North-west Africa seem to have preceded the west generally in the construction of churches as distinct

¹ Many years ago Professor Burkitt called my attention to Richter and Taylor's *Golden Age of Classical Christian Art*. A similar thesis is elaborated in the following pages. The historian of Roman Art must include a survey of the Christian material.

² Butler, *Ancient Coptic Churches of Egypt*, 1. 2.

VITRUVIUS AND THE

from the use of secular buildings for religious purposes. The eastern architects made large use of domed structures, while the architects of the west were able to develop their designs, with but little variation, from the form of the basilica as the Romans knew it. Against such a background Roman craftsmen, not necessarily Christian, felt themselves at home.

Classical Christian art was thus the prophecy of the new world which was to rise upon the ruin of the empire of Augustus. It is the eastern development of Christian architecture which is the basis of theories like that of Josef Strzygowski, which would derive not only architecture but other forms of Christian craftsmanship from Oriental sources. But while we trace the influence of Roman tradition as formulated by Vitruvius, we vindicate for the west a leading part in the painting, sculpture and minor arts of the first three Christian centuries.

The craftsmen who carried out the commissions of Christian clients enjoyed the protection of the State. For the form of imperial government inaugurated by Augustus, the patron of Vitruvius, was directed towards the supremacy of Roman law, not only as embodying Roman traditions but as allied to the universal principles of justice. It was Stoicism that effected this union and spoke from the Roman throne by the lips of Marcus Aurelius. To be a Roman citizen was to enjoy legal protection, extended to every race within the imperial borders, including Jewish artisans like Paul the tentmaker. We can trace the free craftsmen during this time: the architect and the physician no less than the paviour, the mason, the carpenter. For the empire brought freedom not only to artificers but to pro-

CRAFTSMEN OF ROME

fessional men. Cyrus and Chrysippus, two of Cicero's architects, had been slaves; so too Hyginus, the keeper of the Palatine library under Augustus; so too Antonius Musa, the emperor's physician. But this servile status was a passing circumstance due to the subjection of Greece by Sulla in 86 B.C. In the case of "architects," the Latin equivalent *praefectus fabrum* was often used as an honorific title. The extension of Roman citizenship by Caracalla to all communities in the empire was accompanied by the parallel extension of Roman law, thus completing a process already begun by the Julian emperors.

The Roman craftsmen served the extension of the scheme of empire. Vipsanius Agrippa and Asinius Polio¹ were the two greatest administrators of Augustus, and, between them, determined the material outlines of his great design. In order to understand the picture of the Roman world, we must set them in a higher relief than the historical tradition seems at first sight to admit. Agrippa combined in one person the general, the statesman, the savant, the engineer and the loyal friend of Augustus. Six words of Paterculus make the portrait: *uni parens . . . scientissimus . . . consultis facta coniungens*. Polio is the complement of Agrippa. While Agrippa surveyed the geography of the empire, its roads and cities, Polio assembled the literature and science of the time in the first public library in Rome, and thus "made human genius a common possession." His library was also a museum of sculpture and painting, a precedent which was widely followed. Hence he is coupled as an architect

¹ The spelling varies between Polio and Pollio.

with Vitruvius in the *Epitome* of Faventinus. By an extraordinary blunder "Polio" was regarded as the cognomen of Vitruvius!

For the term "architect" which includes the engineer, is also applied to the controller of libraries. Polio like Agrippa and Vitruvius was one of Pliny's authorities for the *Natural History* so far as that describes the state of the empire, its roads and cities, its background of history and craftsmanship. The loss of Polio's history from 60 B.C. to the battle of Philippi is due perhaps to his hostile criticism of Caesar and Cicero, and to an archaizing and rugged style; his masculine grasp of facts, however, left its mark upon later historians—Suetonius, Tacitus, Plutarch,—and his realism was a powerful antidote to the rhetoric in fashion. Through him we understand how Vitruvius and the elder Pliny and above all Augustus himself in the *Monumentum Ancyranum* could dispense with the graces of style in the presence of their mighty theme.

Augustus and Pliny describe the material embodiment of empire as thus realised. Vitruvius furnishes the precepts by which succeeding generations were guided in their undertakings. His work seems at once to have become authoritative, not only as regards the classical orders of Books III. and IV.—his rules, indeed, can be traced in Spain as well as Africa—but rather as a manual of construction and of technical processes generally.

II

The survey of the empire made by Agrippa was exhibited by him in two forms: one in a map (per-

haps plotted on a sphere) in the Porticus Vipsania, the other, by way of description, on the pages of his geographical commentaries. The latter went little beyond statistics, and enumerated the dimensions of known lands and seas, the course of the roads and the sites and distances of cities, as well as of natural features such as rivers and mountains. Agrippa, indeed, furnished much of the material assembled by Pliny the Elder in the geographical books of the *Natural History*, but Pliny often falls into inaccuracy when he leaves the official statistics of the empire. We can trace in his work, however, the material of the itineraries which Vitruvius himself used. The latter defines the position of places by reference to the roads, but we need not assume that he had himself traversed them when he refers to the road to the temple of Ammon¹ or to the road in Cappadocia between Mazaca and Tyana.² The rich and, in the main, accurate geographical references of Vitruvius are on a level with the rest of his work. He blends the scientific geography of Greece with the measurements of Roman surveyors and furnishes the description of the odometer³ by which distances are measured by sea as well as on land. On land the odometer supplemented the measurement by paces of which every thousandth was marked, hence the "mile."⁴ Vitruvius, in his account of pavements,⁵ gives a specification which is appropriate to roads of elaborate construction and uses terms of general application to roadmaking. He also refers to the use of piles upon made ground

¹ Book VIII. iii. 7.

² Book VIII. iii. 9.

³ Book X. ix.

⁴ Strabo, 322.

⁵ Book VII. i. 3.

like those driven by Germanicus¹ over the marshes of Westphalia, an expedient often necessary because the Roman engineers went on their way regardless of marshy ground.

Along with the making of roads came the construction of permanent camps (where there were no towns) to mark the route or destination of these military highways. Vitruvius' rules for fortification, and for laying out the spaces so enclosed,² are not applicable to the small town formed by a permanent camp. He rather lays down the general principles of town-planning.³ But there is one feature in Greek and Roman town-planning which escapes the great blemish in modern colonisation, the loneliness of the settler. Instead of sending the separate colonist or group of colonists to settle where chance might conduct, a suitable site was chosen and a large part of the town laid out and constructed. It is true indeed that the colonies in the provinces under the empire were mainly of a military character, but this does not affect the value of the architectural precedent. Of this Timgad is a complete type. It was founded under Trajan A.D. 100 and completed within twenty years. It lay on the road from Theveste to Lambaesis, and the road itself formed the main highway of the town. The architects who were engaged took with them the methods of construction described by Vitruvius, and the soldiers of the Third Legion laboured upon the works which were to furnish them with a military depot and a home.

The beauty of these foundations took account of

¹ Tac. *Ann.* I. 61.

² Book I. v.

³ Book I. cc. iv, vii; Book II. pref.

practical needs. The successive inventions of the Romans were directed towards the comfort, the warmth and dryness of interiors. The strong brick walls and the few openings which made the private house secure on the outside, passed to the baptistries and basilicas of the church.

The system of heating by "hanging floors" raised upon small pilasters of brick is described by Vitruvius.¹ In the space so formed hot air circulated from a furnace. This contrivance is said to have been invented by L. Sergius Orata,² c. 100 B.C. It was first applied to baths and then to private houses. The numerous remains of Roman villas in Britain suggest that in this way the terrors of our English winters were alleviated. Such an invention would naturally commend itself to the Roman victims of malaria like Maecenas, who indeed is credited with the first hot swimming bath. Agrippa extended the luxury of the bath to the populace by leaving to them in his will his gardens and his baths,³ "so that they might bathe gratis." The baths furnished a popular lounge and were even supplied with libraries,⁴ a circumstance in which architectural evidence supplements the silence of literature.

Yet the farm gained also. There is a typical representation on a mosaic in the museum at Tunis. The farm-houses of the earlier republic were finer than houses in the town,⁵ but the case was reversed under the empire. Vitruvius, even so, has to warn the farmer against allowing his taste for architectural elegance to interfere with the needs of agriculture.⁶

¹ Book V. x.

² Plin. *N.H.* IX. 168.

³ Dio Cass. LIV. 29.

⁴ Platner, 522.

⁵ Varro, *R.R.* I. xiii. 6.

⁶ Book VI. vi.

The decline of the small-holder and the growth of *latifundia* was compensated by the growth of the tenant class, without whom the working of the large estates would have been impossible. The spread of the security which was assured through Roman law brought with it the revival of the country-side. Virgil's picture of the old farmer with his small plot¹ may be taken along with Horace's five tenants who went to market and voted in the elections at Varia.² Vitruvius' instructions about farm-houses are suitable for small as well as large farms.³

But the contrast between the countryman and the townsman was often present to the Roman mind. Not for the countryman, the resources of the larger towns, the baths, the theatre, the libraries, the rhetorical and poetical displays and—for the more general taste—the games in the amphitheatre. Yet the increasing sense of the beauty of landscape and of pastoral life and the enjoyment of a safe obscurity were motives not without effect. The multiplication of colonies throughout the empire furnished markets for farm produce and so enabled the countryman to pay his way. The municipal storehouses were amongst his best customers.⁴

But where the land was worked by slave labour, the contrast for the slave was all in favour of the town. The slaves who performed their duties in the large houses of the great cities were in some respects better placed than the free craftsman or small trader. In the country, slave labour worked the wine and oil presses,⁵ the water-wheels, the

flour-mills.¹ In the town-house, the architect had regard to the convenience of the slave himself.²

III

But Roman comfort was carried to the extreme of luxury. And the greatest minds followed in the train of the sensuous grandee. Cicero's palaces were to be found not only in Rome where he bought Crassus' house on the Palatine, but at Tusculum, where he had a magnificent place which once belonged to Sulla. And there were others at Antium where he kept his library: at Astura, a little island off the coast of Latium, where he retreated for solitude, besides country houses at Arpinum and on the coast of Campania. The sculpture and painting of Greece made the contents of his mansions scarcely less costly than the mansions themselves. All this gives point, perhaps intended, to the contrast severely drawn by Horace between the unhappy splendour of the palace by the sea and his own peaceful farm in a Sabine valley. Augustus ranged himself on the side of Horace. His modest house on the Palatine, his furniture, his home-made clothes verged upon the stingy. Yet his public undertakings were splendid. The marble which he claimed to have substituted for brick at Rome refers not less to the incrustation of interiors than to the columns and sculpture outside. As time went on, public amenities grew out of private undertakings. We shall see the municipal library and the Christian basilica springing from the Roman palace. The basilica is

¹ *Geor.* IV. 125 ff. ² *Ep.* I. 14. 3. ³ Book VI. vi.

⁴ Book V. ix. 8. ⁵ Book VI. vi. 3.

¹ Book X. v. and vi. ² Book VII. iii. 4; iv. 5.

represented magnificently by Sta. Maria Maggiore and its mosaics.¹

It is a strange episode in the history of philosophical sects that Horace and Augustus, who represent the simplicity of private life, should have inclined to an Epicurean standpoint, while Seneca, the eminent Stoic moralist, should have overtopped the monarch himself in the amenities of his parks and the magnificence of his country houses.² Yet it is possible that Roman taste was not immediately offended by the contrast between the profession of the Stoic creed and Seneca's vast accumulations of wealth. Vitruvius in a striking passage³ declares that professors of rhetoric must be housed with distinction and in sufficient space to accommodate their audiences, while high officers of state must have parks and majestic avenues of trees and palaces with libraries and basilicas finished in the magnificence of public buildings. In judging Nero, therefore, we are met by the question whether Seneca by declining the "gardens, the money, the country houses lavished on him"⁴ by Nero would not have lost some of his influence over his pupil. The same passage of Vitruvius illustrates two episodes in the life of Nero's contemporary, St. Paul. After giving a rhetorical display at Athens which sheds some light on the kind of lecture he was to deliver for nearly four years, he taught for eighteen months at Corinth in the mansion of Titius Justus. He also lectured for two years in the "lounge" *schola* of a wealthy citizen of Ephesus, Tyrannus,⁵ who may himself have

been a rhetorician. It is noteworthy that the apostle's second and third journeys almost coincided with the five years in which, under the control of a soldier and a rhetorician, the empire was well governed. Paul's experiences on the sea are a striking evidence of the peace which reigned. To the outer world Paul would present himself at first not so much as a teacher of religion but as an example of the numerous and characteristic class of peripatetic orators whose displays were a popular form of entertainment. Their fees were on the scale of those given to a prima donna in our time. We shall see later how the large apartments in which such shows were held, passed easily into the forms of the church-building.

The rhetorical business, therefore, was one of the most profitable of the day. That Christian teachers should generally (but not always) refuse remuneration brought them into line with other cases, relatively few, found especially among the Stoic sect. But these exceptions did not affect the general view. Hence the silversmiths' trade union at Ephesus would regard Paul from the economic standpoint,¹ as a dangerous rival who threatened a business which furnished useful employment to many persons. That the silversmiths raised the cry "religion in danger" was a natural move. Ephesus gained much from the presence of a widely popular shrine, although it is certain that many who shouted the loudest were, as far as Artemis went, disbelievers at heart. The case of the coppersmith, to whom we owe the exquisite works in bronze like those found at Pompeii and elsewhere, was the same with that

¹ Richter and Taylor, *op. cit.* ² Tac. Ann. XIV. 52.
³ Book VI. v. 2. ⁴ Tac. Ann. XIV. 55.
⁵ Acts xix. 9.

¹ Acts xix. 25.

of the silversmith. The hostility of Alexander the coppersmith¹ towards St. Paul may have had a business basis. But this conflict between the Church and the craftsman was a local and passing phase. In most places the artisans who became Christians continued at their trade and carried over into Christian art the themes of Greek mythology. They also shared in the reaction against the unreality of the public lecture-room with its veneer of philosophic jargon over a rhetorical background. For their growing realism in building and the allied trades went hand in hand with the science of the day: its experiments which anticipated modern chemistry, its advances in mechanics, its presentation of spatial problems in a geometrical rather than an analytic form.

But the new realism which we shall trace in the development of classical Christian art found its fierce background in the service of the arts towards the maintenance of the Roman empire. Vitruvius the engineer was compelled at the end of his work to "turn from the machines which may be carried out for useful purposes or for amusement in times of peace and tranquillity" to "the inventions which serve both to protect against danger and to satisfy the needs of safety." Such was his interpretation of the military engineering which the empire demanded.² Apollodorus, a Greek architect from Damascus, followed this example and after executing some magnificent schemes of Trajan, constructed a military bridge over the Danube for Hadrian, to whom also he dedicated a famous work on siege tactics. The Forum of Trajan had for its focus the

¹ 2 Tim. iv. 14.

² Book X. ix, x.

Column with its spiral relief recording with the detail of a careful historian, and after no long interval, the emperor's Dacian campaigns.

The intention of the sculptors was, so to speak, living portraiture, like the figures at Madame Tussaud's. (It is possible that the column was coloured.) But this masterpiece of realism had been anticipated in the reliefs of the Arch of Titus, in which the figures stood out from the background in such a way as to produce an effect of aerial perspective. The discovery of perspective and its application was made in the time of Pericles.¹ It controlled the dimensions of the Parthenon,² revolutionised painting, and affected the working of gems.³ Perspective anticipated photography in its presentation of the real, and the history of painting and sculpture might be regarded as alternate reactions from, and towards, perspective treatment. In a striking passage Vitruvius demands "imitations taken from reality,"⁴ and thus announces the tendency of imperial Roman art towards the "illusionism" formulated by Wickhoff. But this is more than a technical motive: in the Column of Trajan it is employed to furnish a visible counterpart of the *Monumentum Ancyranum* of Augustus. The artist does not shrink from the full presentation of warfare, its horror no less than its victories. If in one piece Trajan is shown receiving the submission of the Dacians,⁵ in another, Roman army surgeons

¹ Book VII. pref. 11.

² See my article "The Parthenon and the Baroque," *J.R.I.B.A.*, 1931, 735 ff.

³ Pl. K and note.

⁴ Book VII. v. 3.

⁵ Strong, *Roman Sculpture*, Pl. 55.

are shown tending the wounded, whose suffering is indicated by their attitude; and in yet another Dacian women torture Roman prisoners.

Whereas, therefore, oratory had declined into rhetoric with the limitations of political freedom, sculpture and painting took fresh life in the presentation of the real. "Here also is a tear for human lot" in the beauty of the *landscape* against which the human tragi-comedy is presented.¹ But the later editors, following Fra Giocondo, have substituted *gardening*² and thus weakened the emphasis which is demanded. The sculptures of Trajan's Column end with beautiful landscapes, a mountain lake by day and again the goddess Night brooding among forest trees over a lonely shed in which two Dacians are going to their rest.

IV

The garden has been the vestibule to landscape. But gardening was scarcely known to the Greeks, at least in the current sense, until Alexandrian times. In Egypt, however, gardens and parks were found as early as the Old Empire, and beer—the national drink—was accompanied not only by bread but also by the indispensable "flowers of yesterday and to-day."³ Hence the Greek palaces of Alexandria took over into their peristyles the plants which the Egyptian gardeners trained. In the more temperate climate of Italy horticulture was less dependent on

¹ Book V. vi. 9.

² *topiarii* for *topeodi*, with which we may perhaps compare ἀγγειώδης from ἀγγεῖον.

³ Erman, *Life in Ancient Egypt* (tr.), 194.

irrigation. The garden spread out into the park adjoining the house, and the architect in his planning provided windows to overlook the garden.¹ Nor was Persian precedent without its effect. The brilliant city of Cyzicus, long dependent upon Persia, gave its name to large rooms with folding windows and a northern aspect, opening upon gardens. For these the precedent was to be found in the "paradises" of the Persians, first mentioned by Xenophon. That Cyzicus should give a name not only to "oeci" but to "*triclinia*"² was probably due to its architectural tradition.

The city possessed three official architects in control of public buildings and machinery.³ The Greek and Roman architects, therefore, like Kent and Capability Brown and Repton in eighteenth-century England, helped to change the face of the Roman empire to the beauties of Italian and other landscape.

The limitations which we have traced in Attic culture, its alienation from science and its insensibility to nature other than human, were the price paid, and profitably paid, for its unassailable supremacy within the limits marked out by itself. After thus mastering one field, the human spirit went on to fresh conquests. Hellenistic and Roman culture are not, therefore, to be regarded as cases of degeneracy from Atticism, but rather of movement into fresh fields.

We have traced the history of science. The coming of landscape into the human view deserves special consideration. Theophrastus, one of Vitruvius' authorities, reached the highest level

¹ Book VI. iii. 10.

² Book VI. vii. 3.

³ Strabo, 575.

which antiquity attained in descriptive natural science. His botanical works inspired Vitruvius' account of Italian timber,¹ and his mineralogy guided the descriptions of marble and mineral pigments and less precious materials in the seventh book. Vitruvius' interest in gardens is especially shown by two passages² in which he lays down the principles which still govern the lay-out of Italian gardens such as the Pincio, the *collis hortorum*; his insistence on well-constructed paths and on the use of trees for shade is still respected. In the gardens of Jerusalem and neighbourhood, the olive gardens west of Jerusalem in the time of our Lord were of the Italian type and the view of the Temple from Gethsemane anticipated the view of St. Peter's from the Pincian.

Vitruvius' casual references to medicine are rather concerned with regimen. The anatomy of the fauna which along with the flora characterised the landscape, was little understood. Galen³ of Pergamus was still to come, and carry anatomy to the point which was not to be transcended for eleven hundred years—in this respect the Dark Ages beyond doubt—which elapsed before the coming of Mondino at Bologna. The scene on Trajan's Column where an army surgeon attends to the wounds of a soldier discloses the source of the advance in the anatomy of the limbs. Superstition, soon to regain its sway, opposed as far as it could the dissection of the human body.

¹ Book II. ix. x.

² Book V. ix. 5; xi. 4.

³ A.D. 129-199.

V

The elaborate presentation of detail on a large scale that can be traced upon the Column of Trajan and on the scarcely inferior Column of Antoninus served historical purposes. To stigmatise as pedantic this attention to detail is to misunderstand the meaning of the "realist" movement. Rather should we acknowledge the technical mastery which is displayed, first on this large scale, and secondarily in the sarcophagi of the second and third centuries, culminating in the sarcophagus of the Capitol, representing Achilles at the Court of Lycomedes.¹ This sarcophagus also marks the end of the period before us. We can thus trace a period of three centuries from the accession of Augustus to the death of Mamaea, A.D. 235, in which there is advance in science and no trace of degeneracy in craftsmanship.²

¹ There is a cast in the British Museum.

² The traditional identification of the reclining figures on the lid as Mamaea and her son Alexander Severus is obviously incorrect, as regards the latter. The man, according to precedent, is the husband of the woman. Her "hairdress is that of the Princesses of the Emesene dynasty."* I do not think that this fact has been sufficiently regarded. It supports the identification of the woman with Mamaea. In that case the man represents her husband Gessianus, the father of Alexander. The identification of Mamaea has been rendered more difficult by the unfortunate restoration of the bust of Mamaea in the British Museum. Mamaea, if we may judge from the two fine busts in the Louvre,† and from most

* Mrs. Strong, *Roman Sculpture*, 319.

† Nos. 1075, 1336. There is a third bust, 1053, which is doubtful. To pass from the sarcophagus of the Capitol to the first two busts is a convincing proof of the identification proposed.

The reign of Mamaea, A.D. 223-235, was in many respects the most brilliant episode in the history of Roman well-being. Ulpian, the peer of the great jurists whom he succeeded, Salvius Julianus and Gaius, and along with him Dio Cassius, the able historian of the empire, were the ministers of Mamaea in her financial and economic measures. A papyrus fragment¹ adds a third name, Julius Africanus, who filled the post of imperial librarian, a soldier, an engineer, and a Father of the Church. As the Director of the Pantheon library, he was at the head of the movement which provided even small provincial towns with public libraries. In this capacity he advised the empress in other matters as well; the sculpture, for example, which furnished the busts of authors to accompany the library shelves. To him was probably due the placing of the imperial sarcophagus in its hiding-place, the Monte del Grano, where it was preserved for thirteen centuries until its discovery in 1582. The assassination of the empress and her son at Mainz in 235 marked the end of the scheme of empire laid down by Augustus, described by Vipsanius Agrippa, and receiving a material embodiment in accordance with the precepts of Vitruvius.

of the coins which bear her superscription, had a profile not unlike that of Queen Victoria. But the British Museum bust, like so many others, had a broken nose, and the restorer added a nose not unlike Ellen Terry's. Leaving this bust out of account, we may regard the sarcophagus as prepared during Mamaea's lifetime to receive, ultimately, her ashes.

¹ *P. Oxy.* III. 412.

VI

The exterior peace which is so illusive (high prosperity such as that of Mamaea's government preceded the collapse of the old Roman order) passed into an interior peace, that of the Church. But so long as the old order continued, the Christian community made use of the traditional craftsmanship, and of this tradition Vitruvius was a guardian. Two centuries after the death of Mamaea, Sidonius Apollinaris, in his letters,¹ quotes Vitruvius as the typical architect. Amid the general decline of science, the craftsman received a glimmer of light from Vitruvius. To return to art, there was no general prejudice in the early Church against the employment of the Greek and Roman myths as the topics of ornament. Alexander the coppersmith had his Christian successors in the worker in ivory and the marble masons.² Their love of craftsmanship was as high as their pagan rivals. In the same way the house of Titius Justus at Corinth and the *schola* of Tyrannus at Ephesus were doubtless decorated in the current style. In order to understand the representation of Christian subjects we may compare the parallel religions of Mithra and Isis. The Roman tolerance was always ready to welcome foreign worships, and on various grounds Vitruvius assigns the temples of Isis and Serapis to the neighbourhood of the quays.³ A fine bust of a Roman woman, Fundilia Rufa, probably of the early second

¹ IV. 3. 5; VIII. 6. 10.

² Marucchi, *Epigrafia Cristiana*, 290, 291, 293.

³ Book I. vii. 1.

century, has the head-dress of Isis.¹ It was not until the second century that Mithra-worship became influential at Rome: by the end of the same century Commodus, who was represented by the sculptor as Heracles, appeared also as Mithra. The influence of Mithraism on Christian art is therefore negligible.

Christianity in its apocalyptic form could not make terms with the empire any more than Judaism with the Oriental despotism of Antiochus Epiphanes two centuries before. The burning of Rome, A.D. 64, brought this conflict to its first clear expression. Whatever the actual origin of the fire it is certain that Nero and the more fanatical Christians rejoiced at it. Nero found now the opportunity to rebuild his capital; an opportunity which was missed after the fire of London. His architects, who were also engineers, were Severus and Celer,² whom by their names we may presume to have been in the Roman tradition.

The odium which fell upon the Christians as guilty of incendiarism, and therefore enemies of the state, was resented by St. Luke, who seems to have published his two books soon after the fire in order, by an historical narrative, to reassure the new converts or the friends of the rising faith. The imperial government and troops appear as a just and almost kindly background to which the Christian is bound to adjust himself.³ We leave Paul at the end of *Acts* as a theological lecturer who had continued for two years receiving the general public into his own hired mansion (?) "*without let or hindrance.*" The fire of Rome, which brought the

¹ Nemi Collection, Castle Museum, Nottingham.
² *Tac. Ann.* XV. 42.

³ *Rom.* xiii. 1.

martyrdom of SS. Peter and Paul, was attributed by the general judgment to the action of Nero. But externally it left very little mark upon the attitude of the government to the Church.

VII

Hence the artisans of Rome continued to work for Christian employers. It was even possible for members of the Flavian house to attach themselves to the Christian Church. The evidence of the catacombs supplements and interprets the historians. Flavius Clemens, like Polycarp later,¹ was put to death for "atheism" (*ἀθεότης*), to be interpreted as Christianity.² Flavia Domitilla, whose relationship to Vespasian is doubtful, perhaps a niece, gave permission for the excavation of a Christian catacomb. Part of this was used for the burial of her relatives. The decoration of the vaulted roof of one of the apartments consists of a vine trailing with all the freedom of nature over the whole walls.³ The craftsman employs the current methods and exhibits the excellence of the best contemporary work. More than this, Christian painting so advanced that the best surviving examples of second-century painting are done by artists employed on Christian buildings. Vitruvius' demand for "imitations taken from reality"⁴ is satisfied by Christian art not only, as we have seen, in sculpture, but in landscape. After designing the garden, the architect calls upon the painter to portray it. A Roman turn is thus

¹ *Martyrdom*, 9.

² *Suet. Dom.* 15.

³ Northcote, *Roma Sotterranea*, 73.

⁴ *Book VII.* v. 3.

given. Or shall we say that just as Egyptian gardens furnished models to Alexandria, so the Egyptian portrayal of gardens influenced the Alexandrian artists and thus came to Rome? In this case at least Strzygowski's emphasis on Oriental influences is justified.

With the garden the Roman palace is complete. The architect has taken all the instruments of splendour and worked them up into one significant scheme. The definition of Vitruvius is translated into its consequences. "The science of the architect depends upon many disciplines and various apprenticeships which are carried out in other arts."¹ But with the realism which characterises him, he not only recognises the amateur who builds for himself, but gives him encouragement, and suggests,² as one of the main purposes of the *de architectura*, that it should help the amateur. But the impulse to build is instinctive and carried to excess becomes almost morbid. The architectural passion was not confined to Nero: the Golden House as a palace of art was countered by the imagined splendour of the New Jerusalem, as the lines of old Babylon were repeated in the somewhat heavy contours of Ezekiel's vision. But when the ultimate significance of material things reached sublimity in the service of the Church, architecture passed by natural transitions to the achievement of Justinian. The Church of the Holy Wisdom at Byzantium after a millennium corresponded to the Parthenon.

Of this development the Book of Revelation is an anticipation and reveals its mysteries to the western

¹ Book I. i. 1.

² Book VI. pref. 7.

craftsman.¹ Hence its appeal to the western mind over against the suspicion and rejection of the east. The craftsman might not understand the references to Jewish history. But he would understand the throne of the judge and the twenty-four assessors arranged round him circular fashion.² He would at once think of the great halls or basilicas³ in the palaces of wealthy citizens where an apse or semi-circular recess served as a tribunal. He would regard the door which was opened in heaven as the entrance to the hall from the end opposite to the throne, and the "sea of glass like crystal" as a mosaic pavement with its cubes of glass and marble.⁴ The furniture of the building is indicated in some detail—the candlesticks, the censers, the seals, the jewels.

But unfortunately the prophecy of *Revelation* was only realised in part. The later Byzantine and the Mediaeval architects omitted to plan their cities. Their water supplies⁵ were not brought on the lines described by Vitruvius in his eighth book. Their drainage⁶ was not as good even as that of old Jerusalem.⁷ The decline in the fine arts went along with the decline of the useful arts, of the sciences and of medicine. But the mechanical arts were sustained by the valuable and cherished recipes of Vitruvius.

The construction of organs, such as Vitruvius describes, came under the supervision of the archi-

¹ E.g. apse of S. Pudenziana, Rome.

² Rev. iv and v.

³ Vitr. Book VI. v. 2.

⁴ G. G. Scott, *English Church Architecture*, 29.

⁵ Cf. Rev. xxii. 1.

⁶ Rev. xxi. 27.

⁷ Neuburger, *Technical Arts and Sciences*, 438.

tect, who was also a machinist: *machinator*. Severus and Celer, Nero's architects,¹ were in the Vitruvian tradition and doubtless superintended the construction of his organs. Nero "spent part of his day with organs, *organa hydraulica*, of a new and hitherto unknown kind."² They had several stops, up to eight at least.³ They were also supplemented by other instruments, such as the trombone,⁴ especially when they were used in the circus to mark the entrance of the gladiators.⁵ The organ was early used in the Church.⁶ It may be taken indeed that it followed the general law: until the downfall of Alexander Severus the surroundings of Christian worship included all the arts of the day. The organ especially was characteristic of the west and indeed was developed by the Church. Claudian speaks of its deep murmurs and melodies,⁷ and it gave an added beauty to the music of the cathedral of Milan. It is somewhat surprising that most of the current histories of Roman art ignore music altogether.

VIII

By a happy accident we are enabled to bring our survey to a close under the guidance of Sextus Julius Africanus. The fragment from Oxyrhynchus,⁸ in which he speaks of his directorship of the Pantheon library, gains added meaning when we realise that his interest in literature included the Christian future

¹ Tac. *Ann.* XV. 42.

² Book X. viii.

³ Petronius, 36.

⁴ *Manl. Theod. Cons.* 316-319.

⁵ *P. Oxy.* iii. 412. 8.

⁶ Suet. *Nero*, 41.

⁷ Baumeister, fig. 603.

⁸ Tert. *Bapt.* 8.

as well as the past. The library¹ of the Roman palace, along with the basilica, passed into the service of the Church. Christian architecture, literature² and music were to hand on through the Middle Ages the corresponding elements of the classical tradition. But Vitruvius and Africanus were prized also for their military works, to which Vitruvius³ passes with a note of warning already quoted. "Inventions serve both to protect against danger and to satisfy the needs of safety." The brilliant civilisation of Rome was to live only so long as the Roman legions guarded the Rhine, the Danube and the Euphrates. The same secondary cause was also needed to protect the infancy of the Church.

¹ Book VI. iv.; v. 2.

² Kenyon, *Books and Readers in Greece and Rome*, 97, on papyrus codices.

³ Book X. x. 1.

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The *Anthology*¹ (not yet published) of William of Malmesbury, Harl. 3969, fol. 8 v., begins a series of extracts from Vitruvius. The spelling *Victruvius* indicates that they were transcribed from a MS. written at St. Augustine's Abbey, Canterbury, Vol. I. *intro.* xix. The interest of William was mainly aroused by the military engineering of Book X., and by the mechanical devices described in both Book IX. and Book X. To the latter topic he makes a summary reference: *omittantur illa quae sunt quidem ad audiendum grata sed ad intellegendum gravia, quo lesbius (i.e. Ctesibius) hydraulica organa invenit, quo nam ut curru sedens intelligas quot milia vel terrae vel aquae peregisti, quo modo Archimedes furtum illum reprehendit qui argentū auree coronae iunxerit.* William obviously regarded the *de architectura* as a practical manual. It is probable that the builders of the Norman church at Malmesbury, with its fine South Porch (still standing), followed some of its precepts.

A century later Vincent of Beauvais, c. 1250, incorporated into his *Speculum* material taken from Vitruvius. His MS. of Vitruvius was derived from S or G, as is shown by his quoting the interpolation

¹ This reference is due to Dr. M. R. James.

of *S* in Book I. i. 1: *cuius iudicio probantur omnia*. He uses the mediaeval Latin *architectura* for *architectura*, implying "architector" once current in English with its feminine "architectress," a term which might well be revived. Like William of Malmesbury, he is occupied with the practical application of Vitruvius' text-book to mechanics and to building construction and neglects the description of the orders.

We are thus prepared for the fragments of a late MS. of Vitruvius¹ to be found in the Public Record Office to which Mr. Charles Johnson drew my attention: Chancery Bundle 34, File 11, Folios 35-40.

NOTE ON THE SPELLING OF *H*²

The Latin text of this edition is taken from the Harleian MS. 2767. The spelling is therefore not uniform; I have included all the variations which seem to be legitimate. In the *Monumentum Ancyranum* along with more usual forms *apsenti* and *inmisso* occur: *conlegio* with *collega* in the same sentence. This precedent is followed by Munro in his *Lucretius* and Housman in his *Manilius*. Munro has *committere*, v. 782, and *inmissis* below, v. 787. Housman has *inmota*, v. 428, and *immotis*, i. 632. He prints *delabsa* and quotes Ribbeck for *labsus* in thirty places of the

¹ I reported this discovery at greater length, *Journal of Royal Institute of British Architects*, April 1931.

² The circumstance that all extant MSS. of Vitruvius descend from *H*—the case of *G* is dealt with in the next section—makes it possible to follow throughout—subject to the emendations recorded—the spellings current before the Carolingian revision and the changes introduced after the

best MSS. of Virgil, *ad v.* 732. He gives the nom. plur. of the 3rd decl. in *is*, i. 601, v. 222, etc., the acc. plur. in *is* frequently. There are traces of *quoquere* for *coquere* in the best MSS. of Manilius, v. 533 and 683: I have admitted *quoquendum* to the text, V. ix. 8.

I hesitated to write, with *H*, *scribsi scribtum* and the corresponding forms even with the support of the Amiatinus vulgate. But *praescribta* is once found in Lucretius, once also *elabsa*, Munro *ad vi.* 92. I have recorded both *oportunus* and *opportunus*; *obportunus* never occurs.

There is a special reason why *H* should be found thus faithful to older forms. So far as *H* follows the form of specifications, it is of a quasi-legal character. *Lex* represents "specification" twice in Book I. i. 10 and again in Book VII. v. 8. This fact, in my opinion, entirely precludes the extensive recasting of the order of the text proposed by Krohn in his review of my first volume, *Phil. Woch.*, Dec. 24, 1932. Compared with most technical treatises, the ten books on Architecture are much above the average in order and clearness.

THE INTERPOLATIONS IN *G*

There are some fifty cases in which *G* offers readings which are not represented in *H* by corresponding phrases or single words. There are also many cases in which *G* makes useful and obvious corrections in *H*, and not a few corrections which are less obvious and yet convincing. A brief review of these will throw light upon the method of the scribe. They all are made in the spirit of a Ciceronian, as

Ciceronianism was understood after Alcuin. The least valuable corrections are those which assimilate the spelling of *H* to later forms, e.g. *Volturnus* to *Vulturnus*, *formonsos* to *formosos*, nor is there any reason to be grateful for the correction of *imperii* to *imperio* after *potiretur*, VI. i. 11, especially when *G* has *rerum potiretur*, VII. pref. 17. He shows acquaintance with the subject-matter when he corrects *aliis* to *alis*, VI. iii. 4, but in the main his services are grammatical, as when he substitutes *indignans* for *indignus*, VII. pref. 8. He is a better "grammarians" than the scribe of *H* but he is not so faithful. This formula of the copyist is abundantly illustrated in the changes which were made in the Greek text of the N.T.: for the Vulgate we can trace the similar method of Alcuin and his school in dealing with the Amiatinus. The critical notes of Wordsworth and White show the Vallicellanus—the best example of Alcuin's recension—differing from the Amiatinus in the same way as *G* differs from *H*, but not to the same extent. The reason for this difference is the greater difficulty of Vitruvius.

Apart from the introductions to the ten books and from the historical parentheses, the language of Vitruvius is like that of a specification: technical and *elliptical*. The craftsman writing for craftsmen assumes a background of knowledge which is only in part shared by the layman. As Vitruvius himself says: "only those who are experienced in his subject-matter, will find his descriptions easy to understand," X. viii. 6. For the most part, indeed, the interpolations of *G* do not add to our knowledge and are harmless. I have inserted for information the longer interpolations of *G* in the second five

books without translating them. Two of them are obviously caused by the omission of *sunt*: VII. pref. 14 and VII. v. 2. Two are merely duplications of epithets: VIII. i. 2, and IX. pref. 15. IX. ii. 2 is a gloss to explain the reference to the moon.

But two interpolations have seriously corrupted the text. The interpolation of *G*, III. v. 2 destroyed *H*'s description of the Attic base as a roundel above and a sweeping scotia (with its fillets) below. Attic examples of such a base are found in the Temple of Apollo by Ictinus at Bassae and the Nike Temple at Athens. The translation of *H* runs: "taking the plinth away, the remainder is to be divided into four parts; the top part is to be the torus, the remainder is to be the scotia with its fillets." There is an interesting parallel in our Norman, or, as the French more correctly say, Roman architecture. The Norman bases in Canterbury Cathedral exhibit several cases of the roundel and scotia according with the formula of *H*. The tradition of this MS. was specially guarded in the adjoining library of St. Augustine's Abbey, Vol. I. *intro.* xix. The other serious interpolation of *G*, Book III. iii. 7, is both inaccurate and superfluous.

The faults as well as the excellences of *G* are due to its origin. They characterise the revision which all or nearly all Latin MSS. received, in the interest of grammar, along with the revision of all Church books decreed in 789. It is reasonably certain, therefore, that *G* represents the form which Vitruvius took after a similar revision. By the courtesy of the editors of the *Classical Review* a full discussion of the interpolations of *G* and a defence of the primacy of

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VITRUVIUS ON ARCHITECTURE

BOOKS VI—X

VITRUVII
DE ARCHITECTURA
LIBER SEXTUS

1 ARISTIPPUS philosophus Socraticus, naufragio cum eiectus ad Rhodiensium litus animadvertisset geometrica schemata descripta, exclamavisse ad comites ita dicitur: 'bene speremus! hominum enim vestigia video.' Statimque in oppidum Rhodum¹ contendit et recta² gymnasium devenit, ibique de philosophia disputans muneribus est donatus, ut non tantum se ornaret, sed etiam eis, qui una fuerunt, et vestitum et cetera, quae opus essent ad victum, praestaret. Cum autem eius comites in patriam reverti voluissent interrogarentque eum, quidnam vellet domum renuntiari, tunc ita mandavit dicere: eiusmodi possessiones et viatica liberis oportere parari, quae etiam e naufragio una possent enare.³

2 Namque ea vera praesidia sunt vitae, quibus neque fortunae tempestas iniqua neque publicarum rerum mutatio neque belli vastatio potest nocere. Non minus eam sententiam augendo Theophrastus, hor-

¹ Rodum *H.* ² recta *H*: recte *G*, recta via *S*.
³ enare *Gr.*: enarrare *H*.

¹ Aristippus of Cyrene taught that pleasure was the end of conduct.

VITRUVIUS
ON ARCHITECTURE

BOOK VI

PREFACE

1. THE philosopher Aristippus,¹ a follower of Socrates, was shipwrecked on the coast at Rhodes, and observing geometrical diagrams drawn upon the sand, he is said to have shouted to his companions: "There are good hopes for us; for I see human footsteps!" Forthwith he made for the city of Rhodes and came straight to the gymnasium. There he disputed on philosophical topics and was so richly rewarded that he not only fitted himself out, but supplied his companions with clothing and other necessaries of life. When they wanted to go home, and asked him what message he wished them to take, he enjoined on them to say, that men should provide for their children wealth and travelling equipment of such a kind, that, even after shipwreck, it can swim to land along with its owners.

2. For those are the true safeguards of life which are immune from the stormy injustice of Fortune, the changes of politics and the ravages of war. Theophrastus,² indeed, carries that opinion further,

² Theophrastus, the follower and successor of Aristotle.

tando doctos potius esse quam pecuniae confidentes, ita ponit: doctum ex omnibus solum neque in alienis locis peregrinum neque amissis familiaribus et necessariis inopem amicorum, sed in omni civitate esse civem difficilesque fortunae sine timore posse despiciere casus; at ¹ qui non doctrinarum sed felicitatis praesidiis putaret se esse vallatum, labidis itineribus vadentem non stabili ² sed infirma conflictari vita.

3 Epicurus vero non dissimiliter ait: ³ pauca sapientibus fortunam tribuere, quae autem maxima et necessaria sunt, animi mentisque cogitationibus gubernari. Haec ita etiam plures philosophi dixerunt. Non minus poetae, qui antiquas comoedias graece scripserunt, easdem sententias versibus in scaena pronuntiaverunt, ut Crates, ⁴ Chionides, Aristophanes, maxime etiam cum his Alexis, qui Athenienses ait oportere ideo laudari, quod omnium Graecorum leges cogunt parentes <ali> ⁵ a liberis, Atheniensium non omnes nisi eos, qui liberos artibus erudissent. Omnia enim munera fortunae cum dantur, ab ea faciliter adimuntur; disciplinae vero coniunctae cum animis nullo tempore deficiunt, sed permanent ⁴ stabiliter ad summum exitum vitae. Itaque ego maximas infinitasque parentibus ago atque habeo gratias, quod Atheniensium legem probantes me arte erudiendum curaverunt, et ea, quae non potest

¹ ad qui H.

² stabilis H.

³ ait S: aut. H.

⁴ Crates Bondam: eucrates, H.

⁵ add. rec.

¹ Epicurus refined on the morals of Aristippus, and combined them with the atomic philosophy of nature, Diog. X. 144.
² Crates introduced systematic plots into Greek comedy, Arist. Poet. 5.

and exhorts us to trust in learning rather than wealth. He lays down this principle: that, alone of all mankind, the scholar is no stranger in foreign lands; after losing kinsmen and intimates he still finds friends; he is a citizen in every state, and fearlessly despises the awkward chances of fortune; on the other hand, the man who thinks himself fortified and guarded by good fortune rather than by education, steps along slippery paths and struggles with a life unstable and insecure.

3. Epicurus, ¹ too, says in a similar strain: the gifts of fortune to the wise are few but great and indispensable, namely, that they be governed by the judgments of the mind and heart. So also most philosophers have spoken. The poets too of old, who wrote Greek comedies, delivered on the stage the same opinions in their verses: Crates, ² for example, Chionides, ³ Aristophanes, ⁴ but, most of all, Alexis, ⁵ who says that the Athenians deserve praise because the laws of all the other Greeks compel children to maintain their parents, whereas the laws of Athens only applied to those parents who had their children taught a trade. For all gifts of Fortune, as they are bestowed by her, so are they easily withdrawn; but when training is conjoined with mental power, it never fails, but abides secure to the final issue of life. 4. Therefore, I feel and return great and unbounded gratitude to my parents, because they approved the law of Athens and had me trained in a calling, wherein one cannot pass

³ One of the earliest Greek writers of comedy.

⁴ Aristoph. Frag. 540 mentions Eucrates. Cf. H. supra.

⁵ Writer of middle comedy; his plays were translated into Latin.

esse probata sine litteraturae encycloque doctrinarum omnium disciplina. Cum ergo et parentium cura et praeceptorum doctrinis auctas haberem copias disciplinarum, philologis et philotechninis rebus commentariorumque scripturis me delectans eas possessiones animo paravi, e quibus haec est fructuum summa: nullas¹ plus habendi esse necessitates eamque esse proprietatem, divitiarum maxime, nihil desiderare. Sed forte nonnulli haec levia iudicantes putant eo² esse sapientes, qui pecunia sunt copiosi. Itaque plerique ad id propositum contententes audacia adhibita cum divitiis etiam notitiam sunt consecuti.

5 Ego autem, Caesar, non ad pecuniam parandam ex arte dedi studium, sed potius tenuitatem cum bona fama quam abundantiam cum infamia sequendam probavi. Ideo notities parum est adsecuta. Sed tamen his voluminibus editis, ut spero, etiam posteris ero notus. Neque est mirandum, quid ita pluribus sim ignotus. Ceteri architecti rogant et ambigunt, ut architectent;³ mihi autem a praeceptoribus est traditum: rogatum, non rogantem oportere suscipere curam, quod ingenuus color movetur pudore petendo rem suspiciosam. Nam beneficium dantes, non accipientes ambiuntur. Quid enim putemus suspicari, qui rogetur de patrimonio sumptus faciendos committere gratiae per-

¹ nullas G: nulla H.

² putantes eo esse H.

³ architentent H.

¹ orbis doctrinae, Quint. I. 10. 1. 'The unity of the subjects included in a general education,' cf. Book I. 1. 12.

muster without knowledge of letters, and of the 'liberal arts.'¹ When therefore both the care of my parents and the instruction of my teachers had increased my stock of knowledge, I found delight in literary and technical matters and in the works written upon them, thus acquiring mental possessions of which this is the total profit: that there is no necessity of getting more and more, and that property consists in requiring nothing, least of all, riches. But some perhaps make light of these considerations and think that those who are wealthy are thereby wise. Therefore many persons, striving to that end, combine wealth with assurance, and make the further gain of celebrity.

5. But, your Highness, I have not studied with the view of making money by my profession; rather have I held that a slight fortune with good repute is to be pursued more than abounding wealth accompanied by disgrace. Thus little celebrity has come my way. Yet by publishing these volumes,² my name will reach, I hope, to after times. Nor is there cause for wonder why I am unknown to the general. Other architects beg and wrangle to obtain commissions; but I follow a rule laid down by my masters: not to seek employment but to be sought out; since an open countenance³ changes for shame when a request is made of a doubtful character. For the giver of a favour is courted, not the receiver. For what do we think will be suspected by a man who is asked to entrust expenditure at his own cost to the pleasure of the petitioner? Will he not

² The books *de architectura* were probably published at various times.

³ *ingenui voltus puer ingenuisque pudoris*, Juv. XI. 154. Cf. Prop. I. iv. 13.

6 tentis, nisi praedae conpendiique eius causa iudicet
 faciundum? Itaque maiores primum a genere probatis operam tradebant architectis, deinde quaerebant, si honeste essent educati, ingenuo pudori, non audaciae protervitas permittendum iudicantes. Ipsi autem artifices non erudiebant nisi suos liberos aut cognatos et eos viros bonos instituebant, quibus tantarum rerum fidei pecuniae sine dubitatione permitterentur.

Cum autem animadverto ab indoctis et inperitis tantae disciplinae magnitudinem iactari et ab is, qui non modo architecturae sed omnino ne fabricae quidem notitiam habent, non possum non laudare patres familiarum eos, qui litteraturae fiducia confirmati per se aedificantes ita iudicant: si inperitis sit committendum, ipsos potius digniores esse ad suam voluntatem quam ad alienam pecuniae consumere summam. Itaque nemo artem ullam aliam conatur domi facere, uti sutrinam, fullonicam aut ex ceteris, quae sunt faciliores, nisi architecturam, ideo quod, qui profitentur, non arte vera sed falso nominantur architecti. Quas ob res corpus architecturae rationesque eius putavi diligentissime conscribendas, opinans in munus omnibus gentibus non ingratum futurum. Igitur, quoniam in quinto de opportunitate communium operum perscripsi, in hoc volumine privatorum aedificiorum ratiocinationes et commensus symmetriarum explicabo.

¹ The Roman ideal of a gentleman, *ingenuus*, included modesty, and was nearer to the Christian ideal than that of the Stoic, which, in some cases, leaned to a Cynical disregard of decency.

judge that it is to be done for the profit and advantage of the other man? 6. Therefore our forefathers used to entrust commissions to architects of approved descent in the first place; in the second place they inquired if they were well brought up, considering that they should employ men with a sense of honour,¹ rather than persons of a bold and insolent turn. For the craftsmen themselves trained only their own children and kindred, and those apprentices who were so worthy, that large sums could be entrusted without hesitation to their loyalty.

But while I observe that an art of such magnificence is professed by persons without training and experience, by those who are ignorant not only of architecture but even of construction, I cannot refrain from praising those owners of estates who, fortified by confidence in their own erudition, build for themselves, judging that if inexperienced persons are to be employed, they themselves are entitled to spend their own capital to their own liking rather than to that of anyone else. For no one attempts to practise any other calling at home, such as shoe-making or fulling or any other easy occupation, with the one exception of architecture, because persons who profess it are falsely called architects in the absence of a genuine training. And so I considered it a duty to compile with care a system and method of architecture, imagining it would serve a purpose generally acceptable. Therefore since in the fifth book I dealt with the suitable provision of public buildings, in this book I will explain the calculations involved in private buildings and the adjustment of their proportions.

I

CHAPTER I

THE INFLUENCE OF CLIMATE UPON ARCHITECTURE

- 1 HAEC autem ita erunt recte disposita, si primo animadversum fuerit, quibus regionibus aut quibus inclinationibus mundi constituentur. Namque aliter Aegypto, aliter Hispania, non eodem modo Ponto, dissimiliter Romae, item ceteris terrarum et regionum proprietatibus oportere videntur constitui genera aedificiorum, quod alia parte solis cursu premitur tellus, alia longe ab eo distat, alia per medium temperatur. Igitur, uti constitutio mundi ad terrae spatium in inclinatione signiferi circuli et solis cursu disparibus qualitatibus naturaliter est conlocata, ad eundem modum etiam ad regionum rationes caelique varietates videntur aedificiorum debere dirigi conlocationes. Sub septentrione aedificia testudinata et maxime conclusa et non patentia, sed conversa ad calidas partes oportere fieri videntur. Contra autem sub inpetu solis meridianis regionibus, quod premuntur a calore, patentiora conversaque ad septentrionem et aquilonem sunt faciunda. Ita, quod ultra natura laedit, arte erit emendandum. Item reliquis regionibus ad eundem modum temperari, quemadmodum caelum est ad inclinationem mundi conlocatum.
- 3 Haec autem ex natura rerum sunt animadvertenda et consideranda atque etiam ex membris corporibusque gentium observanda. Namque sol quibus locis mediocriter profundit vapores, in his conservat

¹ *signifer orbis*, Lucr. v. 691.

² See diagram of winds, Vol. I. Pl. A.

³ *illud quod cecidit forte, id arte ut corrigas.* Ter. Ad. IV. 7.

1. Now we shall proceed aright herein if first we observe in what regions or latitudes of the world, our work is placed. For the style of building ought manifestly to be different in Egypt and Spain, in Pontus and Rome, and in countries and regions of various characters. For in one part the earth is oppressed by the sun in its course; in another part, the earth is far removed from it; in another, it is affected by it at a moderate distance. Therefore since, in the sun's course through the inclination of the zodiac,¹ the relation of the heavens to the earth is arranged by nature with varying effects, it appears that in like manner the arrangement of buildings should be guided by the kind of locality and the changes of climate. 2. Towards the north, buildings, I think, should be vaulted, thoroughly shut in rather than exposed, and with an aspect to the warmer quarter. On the other hand, where the sun is violent in the southern regions because they are oppressed by the heat, buildings should be open to the air with a northern, or north-eastern,² aspect. Thus we may remedy by art the harm that comes by chance.³ In other regions also, buildings are to be similarly adjusted to suit the relation of climate to latitude.

3. Now these things are to be observed and weighed in the light of Nature, and further to be tested by the figure and physique of different peoples. For in those regions where the sun pours forth a moderate heat, he keeps the body duly tem-

corpora temperata; quaeque proxime currendo deflagrant, eripit exurendo temperaturam umoris; contra vero refrigeratis regionibus, quod absunt a meridie longe, non exhauritur a coloribus umor, sed ex caelo roscidus aer in corpora fundens¹ umorem efficit ampliores corporaturas vocisque sonitus graviores. Ex eo quoque, <quae>² sub septentrionibus nutriuntur gentes, inmanibus corporibus, candidis coloribus, directo capillo et rufo, oculis caesis, sanguine multo ab umoris plenitate caelique refrigerationibus sunt conformati; qui autem sunt proximi ad axem meridianum subiectique solis cursui, brevioribus corporibus, colore fusco, crispo capillo, oculis nigris, cruribus validis, sanguine exiguo solis impetu perficiuntur. Itaque etiam propter sanguinis exiguitatem timidiores sunt ferro resistere, sed ardores ac febres subferunt sine timore,³ quod nutrita sunt eorum membra cum fervore; itaque corpora, quae nascuntur sub septentrione, a febre sunt timidiora et inbecilla, sanguinis autem abundantia ferro resistunt sine timore.

5 Non minus sonus vocis in generibus gentium disparis et varias habet qualitates, ideo quod terminatio orientis et occidentis circa terrae librationem, qua dividitur pars superior et inferior mundi, habere videtur libratam naturali modo circummitionem, quam etiam mathematici *orizonta* dicunt. Igitur cum id habemus certum animo sustinentes, ab labro, quod est in regione septentrionali, linea traiecta ad id, quod est supra meridianum axem, ab eoque altera obliqua⁴ in altitudinem ad summum cardinem, qui

¹ fundans H.

² add. Ro.

³ timore H.

⁴ altera obliqua Laet: -am bis H.

¹ I.e. the bounding-line.

pered; where he comes near and the earth scorches, he burns out and removes the moisture; whereas in the cold regions, because they are far distant from the south, the moisture is not drawn out from their complexions, but the dewy air from the sky pours moisture into the body, enlarges the physique and deepens the voice. Hence, also, the races of the north receive nourishment, and are characterised by tall stature, fair complexion, straight red hair, blue eyes, fullness of blood, owing to the abundance of moisture and the cool climate. 4. Those, however, who are nearest to the southern climes and under the sun's orbit, owing to his violence, have a smaller stature, dark complexion, curly hair, black eyes, strong legs, and thinness of blood. Therefore, also, because of their thin blood, they fear to resist the sword, but endure heat and fever without fear, because their limbs are nourished by heat. Those persons who are born under a northern sky, are weak and more timid in face of fever, but fearlessly resist the sword owing to their fullness of blood.

5. In like manner the sound of the voice has varied qualities which differ with different races. And the reason is that the limits between east and west around the level of the earth (where the upper and lower part of the world is divided) seem to have the circumference naturally levelled, and this the astronomers name the *horizon*.¹ Therefore when we have kept this fixed in our mind, let a line be drawn from the margin which is in the north to the margin which is towards the south, and from the latter a second line² inclined upwards to the pole which is

² The lines of longitude do not follow the curvature of the earth, but are assumed to be drawn in a straight line from the equator to the north pole of the heavens.

est post stellas septentrionum, sine dubitatione animadvertemus ex eo esse schema¹ trigonii mundo, uti organi, quam *sambucen* Graeci dicunt.

6 Itaque quod est spatium proximum imo cardini² ab axis linea in meridianis finibus, sub eo loco quae sunt nationes, propter brevitatem altitudinis ad mundum sonitum vocis faciunt tenuem et acutissimum, uti in organo chorda, quae est proxima angulo. Secundum eam autem reliquae ad mediam Graeciam remissionibus efficiunt in nationibus sonorum cantiones.³ Item a medio in ordinem crescendo ad extremos septentriones sub altitudines caeli nationum spiritus sonitibus⁴ gravioribus a natura rerum exprimuntur. Ita videtur mundi conceptio tota propter inclinationem consonantissime per solis temperaturam ad harmoniam esse composita.

7 Igitur quae nationes sunt inter axis meridiani cardinem ab septentrionalis medio positae, uti in diagrammate⁵ musico medianae vocis habent sonitum in sermone; quaeque progredientibus ad septentrionem sunt nationes, quod altiores habent distantias mundi,⁶ spiritus vocis habentes umore⁷ repulsos ad hypatas et proslambanomenos,⁸ a natura rerum sonitu graviore coguntur uti; eadem ratione medio progredientibus ad meridiem gentes paranetarum⁸ (netarum)⁹que acutissimam sonitus vocis perficiunt tenuitatem. Hoc autem verum esse, ex umidis naturae locis graviora fieri et ex fervidis acutiora,

¹ scaena H.

² cardini rec: -ne H.

³ cansiones H: cantiones h.

⁴ sonitibus rec: sonitus H.

⁵ india grāmata H.

⁶ mundi Kr: admundi (cum ad add.) H.

⁷ umore rec: -rem H.

⁸ acc. pl.

⁹ add. Fea.

¹ A kind of harp: a triangular stringed instrument.

behind the stars of the Great Bear. From this we shall undoubtedly perceive that the world has a triangular lay-out, like the sackbut which the Greeks call *sambucē*.¹

6. Therefore if we take the region in the south which is nearest to the lowest point, the nations which are under that quarter, have vocal sounds which are thin and very shrill, because of the small height towards the limit of the universe, like the string of the instrument which is next to the angle. Next to this, the other strings so far as Greece which is in the middle, produce by their relaxation, the pitch of the voice for each nation. Further, rising regularly from the middle to the height in the furthest north, the national pitch is naturally produced with deeper tones. Thus the whole system of the world because of the slope from south to north seems to be most agreeably adjusted to harmony by the temperature of the sun.

7. Therefore the nations which are placed in the middle between the equator and the north pole have in conversation a middle accent corresponding to the musical diagram; the nations as we move northwards, because they have a greater distance between them and the universe, have a vocal accent driven by greater moisture to the *hypatae*² and *proslambanomenoe*² and are compelled by Nature to use a deeper voice; in the same way as we progress from the middle to the south, the nations have a very shrill accent corresponding to the *paranetae*³ and *netae*.³ 8. We can observe by experiment that heavier and deeper effects arise in damp places, and lighter and shriller

² The lowest notes: see Vol. I. Pl. F.

³ The highest notes: *ib.*

licet ita experiendo animadvertere. Calices duo in una fornace aeque cocti aequoque pondere ad crepitumque uno sonitu sumantur. Ex his unus in aquam demittatur, postea ex aqua eximatur; tunc utrique tangantur. Cum enim ita factum fuerit, largiter inter eos sonitus discrepabit, aequoque pondere non poterunt esse. Ita et hominum corpora uno genere figurationis et una mundi coniunctione concepta alia propter regionis ardorem acutum spiritum aeris exprimunt tactu, alia propter umoris abundantiam gravissimas effundunt sonorum qualitates.

9 Item propter tenuitatem caeli meridianae nationes ex acuta fervore mente expeditius celeriusque moventur ad consiliorum cogitationes; septentrionalis¹ autem gentes infusae crassitudine caeli, propter obstantiam aeris umore refrigeratae stupentes habent mentes. Hoc autem ita esse a serpentibus² licet aspicere, quae, per calorem cum exhaustam habent umoris refrigerationem, tunc acerrime moventur, per brumalia autem et hiberna tempora ab mutatione caeli refrigerata, inmota sunt stupore. Ita non est mirandum, si acutiores efficit calidus aer hominum mentes, refrigeratus autem contra tardiores.

10 Cum sint autem meridianae nationes animis acutissimis infinitaque sollertia consiliorum, simul ad fortitudinem ingrediuntur, ibi succumbunt, quod habent exuctas ab sole animorum virtutes; qui vero refrigeratis nascuntur regionibus, ad armorum vehementiam paratioribus sunt; magnis virtutibus sunt sine timore, sed tarditate animi sine considerantia inruentes sine sollertia suis consiliis refragantur.

¹ nom. pl.

² nom. pl. serpentia, *Vulg. Act. X. 12.*

effects in hot places. Let two cups be taken equally burnt in one kiln of equal weight, and of the same sound when struck. Of these let one be plunged into water and then taken out of the water. Then let both be struck. When this is done, there will be a considerable difference of sound between them, and they will differ in weight. So also the bodies of human beings born of the same shape and under the same conjunction of the heavens will vary: some on account of the heat of the region have, under its influence, an acute or shrill accent, others on account of the abundant moisture, pour forth the heaviest or deepest utterances.

9. Southern nations also, owing to the rarity of the atmosphere, with minds rendered acute by the heat, are more readily and swiftly moved to the imagination of expedients; but northern peoples steeped in a thick climate amid reluctant air, are chilled by the damp, and have sluggish minds. We can observe this in the case of snakes: they move quickest when the heat has drawn away the damp with its chilling effect; but in the rainy and wintry seasons they are chilled by the change of climate, and are sluggish and motionless. Hence we need not wonder if warm air renders the human mind more acute, and a cool air impedes.

10. Now while the southern peoples are of acute intelligence and infinite resource, they give way when courage is demanded because their strength is drained away by the sun; but those who are born in colder regions, by their fearless courage are better equipped for the clash of arms, yet by their slowness of mind they rush on without reflection, and through lack of tactics are balked of their purpose. Since,

Cum ergo haec ita sint ab natura rerum in mundo conlocata et omnes nationes inmoderatis mixtionibus disparatae, vero inter spatium totius orbis terrarum regionisque medio mundi populus Romanus possidet fines. Namque temperatissimae ad utramque partem et corporum membrum animorumque vigoribus pro fortitudine sunt in Italia gentes. Quemadmodum enim Iovis stella inter Martis ferventissimam et Saturni frigidissimam media currens temperatur, eadem ratione Italia inter septentrionalem meridianamque ab utraque¹ parte mixtionibus temperatas et invictas habet laudes. Itaque consiliis refringit barbarorum virtutes, forti manu² meridianorum cogitationes. Ita divina mens civitatem populi Romani egregiam temperatamque regionem conlocavit, uti orbis terrarum imperii³ potiretur.

12 Quodsi ita est, uti dissimiles regiones ab inclinationibus caeli variis generibus sint comparatae, ut etiam naturae gentium disparibus animis et corporum figuris qualitatibusque nascerentur, non dubitemus aedificiorum quoque rationes ad nationum gentiumque proprietates apte distribuere, cum habeamus ab ipsa rerum natura sollertem et expeditam monstrationem.

Quoad potui summa ratione proprietates locorum ab natura rerum dispositas animadvertere, exposui, et, quemadmodum ad solis cursum et inclinationes caeli oporteat ad gentium figuras constituere aedifi-

¹ utroque H.

² (manu) consiliis H (del. Joc.).

³ imperii H : imperio G.

therefore, the disposition of the world is such by Nature, and all other nations differ by their unbalanced temperament,¹ it is in the true mean within the space of all the world and the regions of the earth, that the Roman people holds its territories. 11. For in Italy the inhabitants are exactly tempered in either direction, both in the structure of the body, and by their strength of mind in the matter of endurance and courage. For just as the planet Jupiter is tempered by running in the middle between the heat of Mars and the cold of Saturn, in the same manner Italy presents good qualities² which are tempered by admixture from either side both north and south, and are consequently unsurpassed. And so, by its policy, it curbs the courage of the northern barbarians; by its strength, the imaginative south. Thus the divine mind has allotted to the Roman state an excellent and temperate region in order to rule the world.

12. But if regions differing in climate are assigned to different nations so that the natures of peoples that arise, should vary in mind, and in shape and quality of body, we shall not hesitate to arrange the methods of our buildings also, to suit the characters of nations and peoples, since from Nature herself we have skilled and ready guidance.

As far as I could observe systematically regional characteristics ordained by Nature, I have expounded them, and have said how, in reference to the sun's course and the differences of climate, we ought to determine the style of our house so as to suit the

¹ 'Temperament' corresponds to chemical combination, but applies to physiological and mental combination as well.

² *Laudes*, 'grounds of praise.'

ciorum qualitates, dixi; itaque nunc singulorum generum in aedificiis conensus symmetriarum et universos et separatos breviter explicabo.

II

1 NULLA architecto maior cura esse debet, nisi uti proportionibus ratae partis habeant aedificia rationum exactiones. Cum ergo constituta symmetriarum ratio fuerit et conensus ratiocinationibus explicati, tum etiam acuminis est proprium providere ad naturam loci aut usum aut speciem, adiectionibus temperaturas efficere, cum de symmetria sit detractum aut adiectum, uti id videatur recte esse formatum in aspectuque nihil desideretur.

2 Alia enim ad manum species¹ videtur, alia in excelso, non eadem in concluso, dissimilis in aperto, in quibus magni iudicii est opera, quid tandem sit faciendum. Non enim veros videtur habere visus effectus, sed fallitur saepius iudicio ab eo mens. Quemadmodum etiam in scenis² pictis videntur columnarum proiectiones, mutulorum ecphorae,³ signorum figurae prominentes, cum sit tabula sine dubio ad regulam plana. Similiter in navibus remi, cum sint sub aqua directi, tamen oculis infracti videntur; et quatenus eorum partes tangunt summam planitiem liquoris,⁴ apparent, uti sunt, directi,

¹ species esse v. G: species se v. H.

² scenis G: caenis H, Plin. N.H. XII. 10.

³ ecphorae G: esphorae H.

⁴ liquoris G: liquores H.

¹ Optical adjustments, Book III. iii. 13.

² Architectural style of painting, 80-30 B.C.

needs of the body. It remains now to explain in brief, both generally and particularly, the symmetrical adjustment of the several methods of building.

CHAPTER II

PROPORTION IN BUILDING

1. THE architect's greatest care must be that his buildings should have their design determined by the proportions of a fixed unit. When therefore account has been taken of the symmetries of the design and the dimensions have been worked out by calculation, it is then the business of his skill to have regard to the nature of the site, either for use or beauty, to produce a proper balance by adjustment, adding or subtracting from the symmetry of the design, so that it may seem to be rightly planned and the elevation¹ may lack nothing.

2. For one kind of appearance is seen near at hand; another, in a lofty building; yet another in a confined site; a different one in an open site. And it is the business of a fine judgment to determine exactly what is to be done in these cases. For the eyes do not appear to bring accurate results, but the judgment is often deceived by it: just as when, in the paintings of stages, there seem to be projecting columns, corbelled mutules, outstanding shapes of statues, although the picture is undoubtedly vertical and regular.² Similarly in the case of ships, when the oars are put straight in the water, yet to the eyes they seem broken: until their parts touch the topmost level of the liquid, they appear straight, as indeed they are, but when

cum vero sub aqua sunt dimissi, per naturae per-
 lucidam raritatem remittunt enatantes ab suis cor-
 poribus fluentes imagines ad summam aquae plani-
 tiem, atque eae ibi commotae efficere videntur
 3 infractum remorum oculis aspectum. Hoc autem
 sive simulacrorum impulsu seu radiorum ex oculis
 effusionibus, uti physicis placet, videmus, utramque
 rationem videtur ita esse, uti falsa iudicia oculorum
 4 habeat aspectus. Cum ergo, quae sunt vera, falsa
 videantur et nonnulla aliter quam sunt oculis pro-
 bentur, non puto oportere esse dubium, quin¹ ad
 locorum naturas aut necessitates detractioes aut
 adiectiones fieri debeant, sed ita, uti nihil in his
 operibus desideretur. Haec autem etiam ingenio-
 rum acuminibus, non solum doctrinis efficiuntur.

5 Igitur statuenda est primum ratio symmetriarum,
 a qua sumatur sine dubitatione commutatio, deinde
 explicetur operis futuri locorum unum spatium longi-
 tudinis, cuius semel constituta fuerit magnitudo,
 sequatur eam proportionis ad decorem apparatus,
 uti non sit considerantibus aspectus eurythmiae
 dubius. De qua, quibus rationibus efficiatur, est
 mihi pronuntiandum, primumque de cavis aedium,
 uti fieri debeant, dicam.

¹ quin *G*: quam *H*.

they are let down under the water, owing to the
 transparent thinness of the element, they send back
 images¹ flowing from their substance, which float
 at the topmost level of the water, and being there
 disturbed, they seem to the eyes to produce a broken
 appearance of the oars. 3. Now whether we see
 by the impression of images upon the eye, or by
 the effusion of rays from the eyes, as the natural
 philosophers teach us, both explanations suggest
 that the vision of the eyes gives false judgments.
 4. Since, therefore, what is real seems false, and
 some things are approved by the eyes as other than
 they really are, I do not think it should be doubtful
 that we ought to add or subtract, as needed by
 the nature or requirements of our sites: but this
 is done by native skill and not by rule alone.

5. We must therefore first determine the method
 of the symmetries, from which these modifications
 are to be correctly deduced. Then the unit² of
 length for the site of the future work is to be set
 forth. When the magnitude of this is once deter-
 mined, there will follow upon it the adjustment of
 the proportions to the decor so that the appearance
 of eurythmy³ may be convincing to the observer.
 How this result is to be attained, it is now my duty
 to show, and I will first speak on the right arrange-
 ment of the courtyards of houses.

¹ *imagines* = *simulacra* = *eidola* of Democritus, which are
 supposed to be transmitted from the object to the eye.

² The unit is a practical expedient for furnishing the various
 'scantlings' or dimensions.

³ Eurythmy is the suitable display of details in their context.
 Book I. ii. 3.

- 1 CAVA aedium quinque generibus sunt distincta, quorum ita figurae nominantur: tuscanicum, corinthium, tetrastylon, displuviatum, testudinatum. Tuscanica sunt, in quibus traves in atrii latitudine traiectae habeant interpensiva et collicias ab angulis parietum ad angulos tignorū incurrentes, item asscribus stillicidiorum in medium conpluvium deiectus. In corinthiis¹ isdem rationibus traves² et conpluvia conlocantur, sed a parietibus traves recedentes in circuitione circa columnas componuntur. Tetrastyla sunt, quae subiectis sub trabibus angularibus columnis et utilitatem trabibus et firmitatem praestant, quod neque ipsae magnum impetum coguntur habere neque ab interpensivis onerantur.
- 2 Displuviata autem sunt, in quibus deliquiae aream³ sustinentes stillicidia reiciunt. Haec hibernaculis maxime praestant utilitates, quod conpluvia eorum⁴ erecta non obstant luminibus tricliniorum. Sed ea habent in refectionibus molestiam magnam, quod circa parietes stillicidia defluentia, continent fistulae, quae non celeriter recipiunt ex canalibus aquam defluentem itaque redundantes restagnant, et intestinum et parietes in eis generibus aedificiorum corrumpunt. Testudinata vero ibi fiunt, ubi

¹ corinthiis *G*: corinthii *H*.

³ aream *Gr*: arcam *H*.

² traves *H*.

⁴ eorum *ed*: earum *H*.

¹ *interpensiva*, cross-beams at right angles to main beams; frequent at Pompeii.

² The internal angles where sloping roofs meet.

³ Corinthian has more columns than tetrastyle.

CHAPTER III

ON THE PLAN OF A HOUSE

1. THE courtyards of houses are of five different styles, and the names of them are as follows: Tuscan, Corinthian, Tetrastyle, Displuviate, Vaulted. The Tuscan are those in which the beams which are carried across the atrium have trimmers¹ to them and valleys² running down from the angles of the walls to the angles of the beams; thus there is a delivery of the rainfall from the eaves into the middle of the court. In the Corinthian³ manner, the beams and open space⁴ are arranged in the same way, but the beams, starting from the walls, are fixed upon columns surrounding the open space. The tetrastyle courtyards have angle columns under the beams, which gain thereby in usefulness and strength, because they are not compelled to bear great pressure and are not loaded by the trimmers.

2. Displuviate courtyards are those in which the rafters which support the frame of the opening carry the gutters down.⁵ They are very advantageous for winter apartments because the central openings are raised and do not impede the lights of the triclinia. But there is this disadvantage in the upkeep: when the rain-water flows down, the pipes round the walls receive it, but do not quickly take the water flowing from the channels; as they receive it, they are clogged with the surplus water. Consequently the joiner's work and the walls are damaged. Vaulted courtyards are employed when

⁴ *interdius*, Varro, *R. R.* I. 13. 3.

⁵ See Plate J.

non sunt impetus magni et in contignationibus supra spatiosae redduntur habitationes.

³ Atriorum vero latitudines ac longitudines tribus generibus formantur. Et primum genus distribuitur, uti, longitudo cum in quinque partes divisa fuerit, tres partes latitudini dentur; alterum, cum in tres partes dividatur, duae partes latitudini tribuantur; tertium, uti latitudo in quadrato paribus lateribus describatur inque eo quadrato diagonius¹ linea ducatur, et quantum spatium habuerit ea linea diagonii, tanta longitudo atrio detur. Altitudo eorum, quanta longitudo fuerit quarta dempta, sub traves extollatur; reliquum lacunariorum et arcae supra traves ratio habeatur.

Alis² dextra ac sinistra latitudinis, cum sit atrii longitudo ab³ xxx pedibus ad pedes XL, ex tertia parte eius constituatur. Ab XL ad pedes L longitudo dividatur in partes tres s,⁴ ex his una pars alis detur. Cum autem erit longitudo ab quinquaginta pedibus ad sexaginta, quarta pars longitudinis alis tribuatur. A pedibus LX ad LXXX longitudo dividatur in partes quattuor et dimidiam,⁵ ex his una pars fiat alarum latitudo. A pedibus octoginta ad pedes centum in quinque partes divisa longitudo iustam constituerit latitudinem alarum. Traves earum liminares ita altae ponantur, ut altitudine latitudinibus sint aequales.

⁵ Tablinum, si latitudo atrii⁶ erit pedum viginti, dempta tertia eius spatio reliquum tribuatur. Si erit ab pedibus xxx ad XL, ex atrii latitudine tablino

¹ diagonios Schn: diagonius H.

² alis G: allis H.

³ s add. Ro.

⁴ ad xxx H.

⁵ dimidiam G: dimidia H.

⁶ atrii S: atrium H.

the span is not great, and they furnish roomy apartments in the story above.

3. The length and breadth of the atrium¹ is planned in three ways. The first arrangement is to divide the length into five parts, and to give three of these to the width; the second divides the length into three parts and assigns two to the width; in the third arrangement a square is described upon the width, and the diagonal of the square is drawn: whatever is the size of the diagonal supplies the length of the atrium. 4. The height of the atrium to the underside of the beams is to be three-quarters of the length. The remaining quarter is to be assigned as the dimension of the ceiling and of the roof, above the beams.

The width of the alae or wings, on the right and the left, is to be one-third of the length of the atrium when it is from 30 to 40 feet; from 40 to 50 feet the length is to be divided into three parts and a half, and one is to be given to the alae. When the length is from 50 to 60 feet, a fourth part is to be assigned to the alae. From 60 to 80 feet let the length be divided into four parts and a half: of these one is to be the width of the alae. From 80 to 100 feet the length divided into five parts will determine the breadth of the alae. The lintel beams are to be placed so high, that, in height, the alae are equal to their breadth.

5. The tablinum or alcove, if the breadth of the atrium is 20 feet, must be two-thirds in width. If the breadth of the atrium is 30 to 40 feet, half is to

¹ This and similar terms will be understood by reference to Pl. I.

dimidium tribuatur. Cum autem ab XL ad LX, latitudo dividatur in partes quinque, ex his duo tablino constituentur. Non enim atria minora ab maioribus¹ easdem possunt habere symmetriarum rationes. Si enim maioribus symmetriis utemur in minoribus, neque tablino neque alae utilitatem poterunt habere, sin autem minorum in maioribus utemur, vasta et inmania in his ea erunt membra. Itaque generatim magnitudinum rationes exquisitas et utilitati et aspectui conscribendas putavi. Altitudo tablini ad trabem adiecta² latitudinis octava constituatur. Lacunaria eius tertia latitudinis ad altitudinem adiecta extollantur.

Fauces minoribus atriis e tablini³ latitudine dempta tertia, maioribus dimidia constituentur.⁴ Imagines item alte cum suis ornamentis ad latitudinem sint constitutae.

Latitudines ostiorum⁵ ad altitudinem; si dorica erunt, uti dorica, si ionica erunt, uti ionica perficiantur, quemadmodum de thyromatis in quibus quarto libro rationes symmetriarum sunt expositae.

Conpluvii lumen latum latitudinis atrii ne minus quarta, ne plus tertia parte relinquatur; longitudo, uti atrii pro rata parte fiat.

7 Peristyla autem in transverso tertia parte longiora sint quam introssus.⁶ Columnae tam altae quam porticus latae fuerint peristylorum; intercolumnia

¹ ad maioribus H.

² & ablinii H, et tablini G.

³ adiecta rec: abiecta H.

⁴ constituentur G: -atur H.

⁵ ostiorum Joc: eorum H.

⁶ introssus H: inscrr.

¹ Book IV. vi. 1 ff.

be given to the alcove. When the breadth is from 40 to 60, two-fifths are to be assigned to the alcove. For the smaller atria cannot have the same kind of symmetry as the larger. For if we use the symmetry of the larger atria in the smaller, it cannot be useful for the alcove or the wing. But if we use the symmetry of the smaller in the larger, the details will be huge and monstrous. Therefore I thought that according to their kinds the exact dimensions should be registered with a view both to use and to effect. 6. The height of the alcove to the cornice is to be one-eighth more than its breadth. The panelled ceiling is to be raised higher than the cornices by one-third of the breadth.

The main entrance for smaller atria is to be two-thirds of the width of the alcove; for larger atria, one-half. The portraits with their ornaments are to be fixed above at a height equal to the breadth of the alae.

The relation of the breadth to the height of the doors is to be in the Doric manner for Doric buildings, in the Ionic, for Ionic buildings, as in the case of Greek doorways of which the symmetrical relations have been set out in the fourth book.¹

The width of the opening of the compluvium is to be not less than a fourth, nor more than a third, of the width of the atrium; the length, in proportion to the atrium.

7. The peristyles² lie crosswise, and should be one-third wider than they are deep. The height of the columns is to be the same as the breadth of the colonnade of the peristyle. The inter-columniations

¹ The mediaeval cloister was developed from the peristyle in this sense. Cf. *amplissimum peristylum*. Cic. *Dom.* 116.

ne minus trium, ne plus quattuor columnarum crassitudine inter se distent. Sin autem dorico more in peristylo columnae erunt faciundae, uti in quarto libro de dorico scripsi, ita moduli sumantur, et ad eos modulos triglyphorumque rationes disponantur.

8 Tricliniorum quanta latitudo fuerit, bis tanta longitudo fieri debet. Altitudines omnium conclavorum, quae oblonga fuerint, sic habere debent rationem, uti longitudinis et latitudinis mensura componatur et ex ea summa dimidium sumatur, et quantum fuerit, tantum altitudini detur. Sin autem exhedrae aut oeci quadrati fuerint, latitudinis dimidia addita altitudines educantur. Pinacothecae uti exhedrae amplis magnitudinibus sunt constituendae. Oeci corinthii tetrastylique quique aegyptii vocantur latitudinis et longitudinis,¹ uti supra tricliniorum symmetriae scriptae sunt, ita habeant rationem, sed propter columnarum interpositiones spatiosiores constituentur.

9 Inter corinthios autem et aegyptios hoc erit discrimen. Corinthii simplices habent columnas aut in podio positas aut in imo; supraque habeant epistylia et coronas aut ex intestino opere aut albario, praeterea supra coronas curva lacunaria ad circinum delumbata. In aegyptiis autem supra columnas epistylia et ab epistyliis ad parietes, qui sunt circa, inponenda est contignatio, supra coaxationem pavementum, subdiu ut sit circumitus. Deinde supra epistylium ad perpendicularum inferiorum columnarum inponendae sunt minores quarta parte columna.

¹ latitudinis et longitudinis *Joc*: -nes bis *H*.

¹ Book IV. iii. 3.

are to extend not less than three or more than four diameters of the columns. But if the columns in the peristyle are to be in the Doric style, the modules are to be taken as I described in the fourth book¹ about Doric detail, and the columns and triglyphs arranged accordingly.

8. The length of *triclinia*, or dining-rooms, must be twice their width. The height of all apartments which are oblong must be so arranged that the length and breadth are added together; of this sum half is taken, and this gives the height. But if they shall be *exedrae* or square *oeci*,² the height is to be one and a half times the width. Picture galleries (like *exedrae*) are to be made of ample dimensions. Corinthian and tetrastyle halls and those which are called Egyptian, are to have the same proportion of length and breadth as in the description of the *triclinia*, but owing to the use of columns they are to be more spacious.

9. There is this difference between a Corinthian and an Egyptian *oecus*. The Corinthian has one row of columns placed either upon a stylobate or upon the ground. Above, it is to have architraves and cornices either of fine joinery or plaster, and above the cornices, curved ceilings rounded to a circular section. In the Egyptian saloons, however, architraves are placed above the columns, and floor joists are to be carried from the architraves to the walls opposite. On the floor boards a pavement is to be laid that there may be a balcony in the open. Then above the architrave, and perpendicularly above the lower columns, columns one-fourth shorter

² Large apartments, halls. There was an *exedra* and an *oecus* in the Museum at Alexandria. Strabo XVII. 794.

Supra earum epistylia et ornamenta lacunariis ornantur, et inter columnas superiores fenestrae collocantur; ita basilicarum ea similitudo, non corinthiorum tricliniorum videtur esse.

10 Fiunt autem etiam non italicae consuetudinis oeci, quos Graeci cyzicenos appellant. Hi collocantur spectantes ad septentrionem et maxime viridia prospicientes, valvasque¹ habent in medio. Ipsi autem sunt ita longi et lati, uti duo triclinia cum circumitionibus inter se spectantia possint esse conlocata, habentque dextra ac sinistra lumina fenestrarum valvata,² uti de tectis per spatia fenestrarum viridia prospiciantur. Altitudinis eorum dimidia latitudinis addita constituuntur.

11 In his aedificiorum generibus omnes sunt faciendae earum symmetriarum rationes, quae sine inpeditione loci³ fieri poterunt, luminaque, parietum altitudinibus si non obscurabuntur, faciliter erunt explicata; sin autem inpedientur ab angustiis aut aliis necessitatibus, tunc erit⁴ ut ingenio et acumine de symmetriis detractioes aut adiectiones fiant, uti non dissimiles veris symmetriis perficiantur venustates.

¹ ualbas H G.

² fen. viridia valvata H: viridia del. Joc.

³ loci ed: locis H.

⁴ tunc erit G: tenerit H S.

are to be placed. Above their architraves and ornaments they have panelled ceilings, and windows are placed between the upper columns. Thus the Egyptian halls resemble basilicas¹ rather than Corinthian apartments.

10. Other halls in a foreign manner are those which the Greeks call Cyzicene. These are situated with a north aspect, and especially with an outlook upon gardens; they have folding windows in the middle. The halls themselves are broad and long enough to have two triclinia facing each other, with room to pass round; and these, on both hands, have garden windows with folding lights, so that the guests, under cover,² may have a view of the garden.³ The height of the hall must be one and a half times its width.

11. In buildings of this kind, all the rules of symmetry must be followed, which are allowed by the site, and the windows will be easily arranged unless they are darkened by high walls opposite. But if they are obstructed by the narrowness of the street or by other inconveniences, skill and resource must alter the proportions by decreasing or adding, so that an elegance may be attained in harmony with the proper proportions.

¹ Santa Maria Maggiore at Rome was perhaps a third-century basilica in a private house. At any rate, the later (Liberian) building is of this type.

² tectum quo imbris causa vitandi succederet. Cic. Dom. 116.

³ Cyrus aiebat viridiorum διαφάσεις latis luminibus non tam esse suaves. Cic. Att. II. 3.

1 Nunc explicabimus, quibus proprietatibus genera aedificiorum ad usum et caeli regiones apte¹ debeant exspectare. Hiberna triclinia et balnearia uti occidentem hibernum spectent, ideo quod vespertino lumine opus est uti, praeterea quod etiam sol occidens adversus habens splendorem, calorem remittens efficit vespertino tempore regionem tepidiorum. Cubicula et bybliothecae ad orientem spectare debent; usus enim matutinum postulat lumen, item in bybliotheccis libri non putrescent. Nam quaecumque ad meridiem et occidentem spectant, ab tiniis² et umore libri vitiantur, quod venti umidi advenientes procreant eas et alunt infundentesque umidos spiritus pallore volumina conrumpunt.

2 Triclinia verna et autumnalia ad orientem; tum³ enim praetenta luminibus adversus solis impetus progrediens ad occidentem efficit ea temperata ad id tempus, quo opus solitum est uti. Aestiva ad septentrionem, quod ea regio, non ut reliquae per solstitium propter calorem efficiuntur aestuosae, ea quod est aversa a solis cursu, semper refrigerata et salubritatem et voluptatem in usu praestat. Non minus pinacothecae et plumariorum textrina⁴ pictorumque officinae, uti colores eorum in opere propter constantiam luminis inmutata permaneant qualitate.

¹ apte Fav: actae H.

² tum Schn: cum H.

³ tiniis H: Verg. G. IV. 246.

⁴ textrina S: extrina H.

¹ Varro, R. R. I. 13. 7. Varro by changing doors and windows at Corcyra brought his men safely through a pestilence, *ib.* I. 4. 5.

² cubicula—diurna nocturna. Plin. Ep. I. 3. 1.

ON THE ASPECT OF THE SEVERAL APARTMENTS

1. Now we will explain the adjustments by which the various apartments may look out suitably to their proper aspects.¹ The baths and winter dining-rooms should look towards the winter setting sun, because there is need of the evening light. Besides, when the setting sun faces us with its splendour, it reflects the heat and renders this aspect warmer in the evening. Private rooms² and libraries should look to the east, for their purpose demands the morning light. Further, the books in libraries will not decay. For in apartments which look to the south and west, books are damaged by the bookworm and by damp, which are caused by the moist winds on their approach, and they make the papyrus rolls mouldy by diffusing moist air.

2. The spring and autumn dining-rooms should look to the east. For exposed as they are to the light, the full power of the sun moving to the west renders them temperate at the time when the need to use them is customary. The summer dining-rooms should have a northern aspect. For while the other aspects, at the solstice, are rendered oppressive by the heat, the northern aspect, because it is turned away from the sun's course, is always cool, and is healthy³ and pleasant in use. Not less should the picture galleries, the weaving-rooms of the embroiderers, the studios of painters, have a north aspect, so that, in the steady light, the colours in their work may remain of unimpaired quality.

³ Varro, R. R. I. 4. 5.

1 CUM ad regiones caeli ita ea fuerint disposita, tunc etiam animadvertendum est, quibus rationibus privatis aedificiis propria loca patribus familiarum et quemadmodum communia cum extraneis aedificari debeant. Namque ex his quae propria sunt, in ea non est potestas omnibus intro eundi nisi invitatis, quemadmodum sunt cubicula, triclinia, balneae ceteraque, quae easdem habent usus rationes. Communia autem sunt, quibus etiam invocati suo iure de populo possunt venire, id est vestibula, cava aedium, peristylia, quaeque eundem habere possunt usum. Igitur is, qui communi sunt fortuna, non necessaria magna vestibula nec tabulina neque atria, quod in aliis officia praestant ambiundo neque¹ ab aliis ambiuntur. Qui autem fructibus rusticis serviunt, in eorum vestibulis stabula, tabernae, in aedibus cryptae, horrea, apothecae ceteraque, quae ad fructus servandos magis quam ad elegantiae decorem possunt esse, ita sunt facienda. Item feneratoribus et publicanis commodiora et speciosiora et ab insidiis tuta, forensibus autem et disertis elegantiora et spatiosiora ad conventos excipiundos, nobilibus vero, qui honores magistratusque gerundo praestare debent officia civibus, faciunda sunt vestibula regalia alta, atria et peristylia amplissima,² silvae ambulationesque laxiores ad decorem maies-

¹ neque Perr: quae H.

² Cf. porticum pavimentatam . . . amplissimum peristylum. Cic. Dom. 116.

¹ Crowded vestibule of jurisconsult. Cic. de Or. I. 200.

² Wine-store often in roof to receive the smoke. Hor. Od. III. 8. 11.

CHAPTER V

ON BUILDING SUITABLY FOR DIFFERENT RANKS OF SOCIETY

1. WHEN we have arranged our plan with a view to aspect, we must go on to consider how, in private buildings, the rooms belonging to the family, and how those which are shared with visitors, should be planned. For into the private rooms no one can come uninvited, such as the bedrooms, dining-rooms, baths and other apartments which have similar purposes. The common rooms are those into which, though uninvited, persons of the people can come by right, such as vestibules,¹ courtyards, peristyles and other apartments of similar uses. Therefore magnificent vestibules and alcoves and halls are not necessary to persons of a common fortune, because they pay their respects by visiting among others, and are not visited by others. 2. But those who depend upon country produce must have stalls for cattle and shops in the forecourt, and, within the main building, cellars, barns, stores² and other apartments which are for the storage of produce rather than for an elegant effect. Again, the houses of bankers and farmers of the revenue should be more spacious and imposing and safe from burglars. Advocates and professors of rhetoric should be housed with distinction, and in sufficient space to accommodate their audiences. For persons of high rank who hold office and magistracies, and whose duty it is to serve the state, we must provide princely vestibules, lofty halls and very spacious peristyles, plantations and broad avenues finished in a majestic

tatis perfectae: praeterea bybliothecas, basilicas non dissimili modo quam publicorum operum magnificentia comparatas, quod in domibus eorum saepius et publica consilia et privata iudicia arbitriaque conficiuntur.

3 Ergo si his rationibus ad singulorum generum personas, uti in libro primo de decore est scriptum, ita disposita erunt aedificia, non erit quod reprehendatur; habebunt enim ad omnes res commodas et emendatas explicationes. Earum autem rerum non solum erunt in urbe aedificiorum rationes, sed etiam ruri, praeterquam quod in urbe atria proxima ianuis solent esse, ruri ab pseudourbanis statim peristylia, deinde tunc atria habentia circum porticus pavimentatas¹ spectantes ad palaestras et ambulationes.

Quoad potui urbanas rationes aedificiorum summatim perscribere, proposui; nunc rusticorum expeditionum, ut sint ad usum commodae quibusque rationibus conlocare oporteat eas, dicam.

VI

1 PRIMUM de salubritatibus, uti in primo volumine de moenibus conlocandis scribitur est, regiones aspiciantur et ita villae conlocentur. Magnitudines earum ad modum agri copiasque fructuum con-

¹ pavimentatas *Joc*: pavimenta *H*.

¹ Book I. ii. 5.

manner; further, libraries and basilicas arranged in a similar fashion with the magnificence of public structures, because, in such palaces, public deliberations and private trials and judgments are often transacted.

3. Therefore if buildings are planned with a view to the status of the client, as was set forth in the first book under the head of decor,¹ we shall escape censure. For our rules will be convenient and exact in every respect. Moreover, we shall take account of these matters, not only when we build in town, but in the country; except that, in town, the halls adjoin the entrance, in the country the peristyles of mansions built town-fashion come first, then the atria surrounded by paved colonnades overlooking the palaestra and the promenades.

I have set forth as I am able the general methods of building in town. I will now state the methods of building in the country,² with a view to convenience in use, and especially to the disposition of the site.

CHAPTER VI

ON FARM BUILDINGS

1. AND first with respect to salubrity: the aspects of sites must be examined, and the farm-houses placed, as we have written in the first volume about the positions of town walls.³ The size of a farm-house is to be arranged to suit the amount of land

² illorum (sc. anticorum) villae rusticae erant maioris pretii quam urbanae quae nunc sunt pleraque contra. Varro, *R. R.* I. 13. 6.

³ Book I. iv. Varro, *R. R.* I. 4. 4.

parentur. Chortes magnitudinesque earum ad pecorum numerum, atque quot¹ iuga bouum opus fuerint ibi versari, ita finiuntur. In chorte culina quam calidissimo loco designetur.² Coniuncta autem habeat bubilia, quorum praesepia ad focum et orientis caeli regionem spectent, ideo quod boves lumen et ignem spectando horridi non fiunt; item agricolae regionum inperiti non putant oportere aliam regionem caeli boves spectare nisi ortum solis. Bubili-²um autem debent esse latitudines nec minores pedum denum nec maiores v denum; longitudo, uti singula iuga ne minus pedes occupent septenos. Balnearia item coniuncta sint culinae; ita enim lavationi rusticae ministratio non erit longe. Torcular item proximum sit culinae; ita enim ad olearios fructus commoda erit ministratio. Habeatque coniunctam vinariam cellam habentem ab septentrione lumina fenestrarum; cum enim alia parte habuerit, quae sol calfacere possit, vinum, quod erit in ea cella, confusum ab calore efficietur inbecillum.

³ Olearia autem ita est conlocanda, ut habeat a meridie calidisque regionibus lumen; non enim debet oleum congelari, sed tempore caloris extenuari. Magnitudines autem earum ad fructuum rationem et numerum doliorum sunt faciundae, quae, cum sint cullearia, per medium occupare debent pedes quaternos. Ipsum autem torcular, si non cocleis torquetur sed vectibus et prelo premetur, ne minus longum pedes xl constituatur; ita enim erit vectiario

¹ quod H.² desinetur H.¹ Varro, R. R. I. 13. 1.² Book I. iv. 2.³ Varro, R. R. I. 13. 7.

and of the crops. The farm-yards and their dimensions are to correspond to the number of cattle and the yoke of oxen which are required. In the farm-yard the warmest place must be assigned to the kitchen, and, adjoining this, to the cowhouses,¹ the mangers of which are to look towards the hearth and towards the east, for cattle which face light and heat do not lose their sleekness. And even farmers who are ignorant about aspects, do not think that cattle ought to face any quarter of the sky but the east. ² The width of the stalls should be not less than ten nor more than fifteen feet; lengthwise each yoke should have not less than seven feet. The baths also should be next to the kitchen; in this way the service of baths for the farm will be near by. The oilpress should be next the kitchen, for in this way the service will be convenient for the olive harvest. Next let there be the wine-cellar, having windows with light from the north.² For when light is drawn from a quarter heated by the sun, the wine will be affected by the heat, and thin.

³ The oil store is to be so situated as to receive light from the south and the warm quarter.³ For the oil should not be congealed, but kept thin by the warm weather. The dimensions of the store should answer to the amount of the harvest and the number of the jars. When these contain 20 amphorae, they should occupy four feet each on the average. The press, if it is not turned by a screw,⁴ but is worked by levers and a press-beam, is to be not less than 40 feet long. This will leave room for

⁴ This was a Greek invention. Plin. N. H. XVIII. 317.

spatium expeditum. Latitudo eius ne minus pedum senum denum; nam sic erit ad plenum opus facientibus libera versatio et expedita. Sin autem duobus prelis loco opus fuerit, quattuor et viginti pedes latitudini dentur.

- 4 Ovilia et caprilia ita sunt magna facienda, uti singula pecora areae ne minus pedes quaternos et semipedem, ne plus senos possint habere. Granaria sublinita¹ et ad septentrionem aut aquilonem spectantia disponantur; ita enim frumenta non poterint cito concalescere, sed ab flatu refrigerata diu servantur. Namque ceterae regiones procreant curculionem et reliquas bestiolas, quae frumentis solent nocere. Equilibus, quae maxime in villa loca calidissima fuerint, constituentur, dum ne ad focum spectent; cum enim iumenta proxime ignem stabulantur, horrida fiunt.
- 5 Item non sunt inutilia praesepia, quae conlocantur extra culinam in aperto contra orientem; cum enim in hieme anni sereno caelo in ea traducuntur matutino boves, ad solem pabulum capientes fiunt nitidiores. Horrea, fenilia, farraria, pistrina extra villam facienda videntur, ut ab ignis periculo sint villae tutiores. Si quid delicatius in villis faciendum fuerit, ex symmetriis quae in urbanis supra scripta sunt constituta, ita struantur, uti sine inpeditione rusticae utilitatis aedificentur.
- 6 Omniaque aedificia ut luminosa sint, oportet curari; sed quae sunt ad villas, facilia videntur esse, ideo quod paries nullius vicini potest opstare,

¹ sublinita Gr: sublinata H: cf. liniantur, supra V. x. 3.

¹ Book I. iv. 2.

the man who works the levers. The width of the room must be not less than 16 feet, so that when the men are fully at work, their movements will be free and easy. But if two presses are required in the place, the width should be 24 feet.

4. The sheep and goat folds are to be such a size that each animal occupies not less than 4½ or more than 6 feet. The granaries are to have a concrete floor, and a north or north-east aspect.¹ For in this way the corn will not soon become overheated, but keeps good, being cooled by the draughts. For other aspects produce the weevil and other small creatures, which usually damage the corn. Stables are to be so placed as to have the warmest part of the farm buildings, provided they do not look towards the hearth. For when draught horses are stabled next the fire, they lose their sleekness.

5. Further, mangers are not without their advantages, which are put outside the kitchen in the open on the east. For when the cattle are led up in fine winter weather for their morning feed, they become more sleek by eating their fodder in the sun. Barns, stores for hay and meal, bakehouses, should be outside the farm-house, that they may be more safe from fire. If a touch of elegance² is required in a farm-house, it should be built in a symmetrical manner, which things are described above for town houses, yet without interfering with the needs of agriculture.

6. Care is required that all buildings should be well lighted. This is more easy in farm buildings because there are no party walls to interfere;

² *eleganter aedificet agricola, nec sit tamen aedificator.* Colum. I. 4. 1. Cf. *minus aedificator.* Nepos, Atticus. 13.

in urbe autem aut communium parietum altitudines aut angustiae loci impediundo faciunt obscuritates. Itaque de ea re sic erit experiendum. Ex qua parte lumen oporteat sumere, linea tendatur ab altitudine parietis, qui videtur obstare, ad eum locum, quo oporteat inmittere, et si ab ea linea in altitudinem cum prospiciatur, poterit spatium puri caeli amplum videre, in eo loco lumen erit sine inpeditione.

7 Sin autem officient trabes seu limina¹ aut contignationes, de superioribus partibus aperiatur et ita inmittatur. Et ad summam ita est gubernandum, ut, ex quibuscumque partibus caelum prospici poterit, per ea fenestrarum loca relinquuntur; sic enim lucida erunt aedificia. Cum autem in tricliniis ceterisque conclavibus maximus est usus luminum, tum etiam itineribus, clivis, scalis, quod in his saepius alius aliis obviam venientes ferentes sarcinas solent incurrere.

Quoad potui, distributiones operum nostratium ut sint aedificatoribus non obscurae, explicui; nunc etiam, quemadmodum Graecorum consuetudinibus aedificia distribuuntur, uti non sint ignota, summatim exponam.

VII

1 ATRIIS Graeci quia non utuntur, neque aedificant, sed ab ianua introeuntibus itinera faciunt latitudinibus non spatiosis, et ex una parte equilia,² ex

¹ limina ed: lumina H.

² equilia Joc: aequalia H.

whereas in cities, the heights of party walls or the narrow streets are in the way, and cause lack of light. Therefore trial should be made as follows. In the quarter from which light is required, a line should be drawn from the top of the party wall which seems to obstruct, to the point where light should be admitted. If the amount of open sky seems sufficient when we look up from that line, the light will not be obstructed.

7. But if the light is hindered by beams or lintels or flooring, there must be an opening made above to admit the light. And the whole must be so controlled that from whatever quarter the sky can be seen, window openings must be left there;¹ for in this way the buildings will be well lighted. Now there is special need of light in dining-rooms and other apartments, and also in passages, sloping ways, and staircases, because, in these, persons who come with burdens often run into one another when they meet.

As far as I can, I have explained the arrangement of our buildings that they may not be obscure to our own builders; now I will also explain briefly how buildings are arranged according to Greek custom, so that they too may not be unknown.

CHAPTER VII

ON GREEK MANSIONS

1. THE Greeks,² not using atria, do not build as we do; but as you enter, they make passages of scanty width with stables on one side, and the

¹ per ea, neuter of general reference.

² The reference is probably to the Alexandrian age.

altera ostiariis cellas, statimque ianuae interiores finiuntur. Hic autem locus inter duas ianuas graece *thyroron* appellatur. Deinde est introitus in peristylon. Id peristylum in tribus partibus habet porticus inque¹ parte, quae spectat ad meridiem, duas antas inter se spatio amplo distantes, in quibus trabes invehuntur, et quantum inter antas distat, ex eo tertiam adempta spatium datur introrsus. Hic locus apud nonnullos *prostas*, apud alios *pastas* nominatur.

² In his locis introrsus constituuntur oeci magni, in quibus matres familiarum cum lanificis habent sessionem. In *prostadis*² autem dextra ac sinistra cubicula sunt conlocata, quorum unum *thalamus*, alterum *amphithalamus* dicitur. Circum autem in porticibus triclinia cotidiana, cubicula, etiam cellae³ familiaricae constituuntur. Haec pars aedificii *gynaeconitis* appellatur.

³ Coniunguntur autem his domus ampliores habentes lautiora peristylia, in quibus pares sunt quattuor porticus altitudinibus, aut una, quae ad meridiem spectat, excelsioribus columnis constituitur. Id autem peristylum, quod unam altiorem habet porticum, *rhodiacum* dicitur. Habent autem eae domus vestibula egregia et ianuas proprias cum dignitate porticusque peristyliorum albariis et tectoriis et ex intestino opere lacunariis ornatas, et in porticibus, quae ad septentrionem spectant, triclinia *cyzicena* et pinacothecas, ad orientem autem *bybliotheecas*, exedras ad occidentem, ad meridiem vero spectantes oecos quadrata ostia ampla magnitudine, uti faciliter in eo quattuor tricliniis stratis ministratorum ludorumque operis locus possit esse spatiosus.

¹ inque *rec*: in quae *H*.

² *prostadis* *Joc*: *prostadii* *H*.

³ *cellae* *Gr* (Varro *R. R.* I. 13. 4).

porter's rooms on the other; and these immediately adjoin the inner entrance. The space between the two entrances is called in Greek *thyroron*. You then enter the peristyle. This has colonnades on three sides. On the side which looks southward, there are two piers at a fair distance apart, on which beams are laid. The space behind is recessed two-thirds of the distance between the piers. The recess by some is called *prostas*, *pastas* by others.¹

² As we pass in, there is the Great Hall in which the ladies sit with the spinning women. Right and left of the recess are the bedchambers, of which one is called the *thalamus*, the other the *amphithalamus*. Round the colonnades are the ordinary dining-rooms, the bedrooms and servants' rooms. This part of the building is called the women's quarter, *gynaeconitis*.

³ Next to this is a larger block of buildings with more splendid peristyles; in these the colonnades are equal in height, or else the colonnade which looks to the south has loftier columns. The peristyle which has one colonnade higher is called *Rhodian*. These buildings have splendid approaches and doorways of suitable dignity. The colonnades of the peristyles are finished with ceilings of stucco, plaster, and fine wood panelling. In the colonnades which face the north are *Cyzicene* triclinia and picture galleries; on the east the libraries, the exedrae on the west; halls and square entrances² face the south that there may be ample room for four triclinia, and for the servants who attend them and assist in the amusements.

¹ *Ap. Rh.* I. 789.

² The *quadrata ostia* should perhaps be retained as halls open in front to the air.

4 In his oecis fiunt virilia convivia; non enim fuerat institutum matris familiarum eorum moribus accumbere. Haec autem peristylia domus andronitides dicuntur, quod in his viri sine interpellationibus mulierum versantur. Praeterea dextra ac sinistra domunculae constituuntur habentes proprias ianuas, triclinia et cubicula commoda, uti hospites advenientes non in peristylia sed in ea hospitalia recipiantur. Nam cum fuerunt Graeci delicatiores et fortuna opulentiores, hospitibus advenientibus instruebant triclinia, cubicula, cum penu cellas, primoque die ad cenam invitabant, postero mittebant pullos, ova, holera, poma reliquasque res agrestes. Ideo pictores ea, quae mittebantur hospitibus, picturis imitantes xenia appellaverunt. Ita patres familiarum in hospitio non videbantur esse peregre, habentes secretam
5 in his hospitalibus liberalitatem.¹ Inter duo autem peristylia et hospitalia itinera sunt, quae mesauloe dicuntur, quod inter duas aulas media sunt interposita; nostri autem eas andronas appellant.

Sed hoc valde est mirandum, nec enim graece nec latine potest id convenire. Graeci enim *andronas* appellant oecus, ubi convivia virilia solent esse, quod eo mulieres non accedunt. Item aliae res sunt similes, uti xystus, prothyrum, telamones² et nonnulla alia eius modi. *Xystos* enim est graeca appellatione porticus ampla latitudine, in qua athletae per hiberna tempora exercentur; nostri autem hypaethrus ambulationes xysta³ appellant, quas

¹ post liberalitatem H paginam versam folii 87 vacuum exhibet.

² thalamones H.

³ xysta ed: xysti H.

¹ The paintings of still life by Dutch painters, correspond to the groups of fruit, poultry, etc. in Roman mosaics.
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4. In these halls men's banquets are held. For it was not customary for women to join men at dinner. Now these peristyles are called the men's block, for in them men meet without interruption from the women. Moreover, on the right and left lodges are situated with their own entrances, dining-rooms and bedrooms, so that guests on their arrival may be received into the guest-houses and not in the peristyles. For when the Greeks were more luxurious and in circumstances more opulent, they provided for visitors on their arrival, dining-rooms, bedrooms, and store-rooms with supplies. On the first day they invited them to dinner; afterwards they sent poultry, eggs, vegetables, fruit, and other country produce. Therefore painters, when they portrayed what was sent to guests, called them guest-gifts.¹ Thus the heads of families in a guest-house² do not seem to be away from home when they enjoy private generosity in the visitors' quarters. 5. Now between the two peristyles and the visitors' quarters there are passages called *Mesauloe*, because they are between the two *aulae* or halls. But we call them *Andrones*, the men's quarters.

It is very remarkable that this suits neither Greek nor Latin usage. For the Greeks call *andrones* the halls where the men's banquets take place, because women are excluded. Yet other terms are of like application, such as xystus, prothyrum, telamones, and so forth. For xystus in its Greek signification is a colonnade of ample breadth where the athletes are trained in the winter;³ but we give the name of xysta to promenades in the open, which the Greeks

² *hospitium*, Acts xxviii. 23.

³ Repeated from Book V. xi. 4.

Graeci *paradromidas* dicunt. Item *prothyra* graece dicuntur, quae sunt ante in ianuas vestibula, nos autem appellamus *prothyra*, quae graece dicuntur *diathyra*.

6 Item si qua virili figura signa mutulos aut coronas sustinent, nostri *telamones* appellant, cuius rationes,¹ quid ita aut quare dicantur, ex historiis non inveniuntur, Graeci vero eos *atlantas* vocitant. Atlas enim formatur historia sustinens mundum, ideo quod is primum cursum solis et lunae siderumque omnium versationum rationes vigore animi sollertiaque curavit hominibus tradenda, eaque re² a pictoribus et statuariis deformatur pro eo beneficio sustinens mundum, filiaeque eius *Atlantides*, quas nos *vergiliae*, Graeci autem *pliadas* nominant, cum
7 sideribus in mundo sunt dedicatae. Nec tamen ego, ut mutetur consuetudo nominationum aut sermonis,³ ideo haec proposui, sed uti non sint ignota philologis, exponenda iudicavi.

Quibus consuetudinibus aedificia italico more et Graecorum institutis conformantur, exposui et de symmetriis singulorum generum proportionem perscripsi. Ergo⁴ quoniam de venustate decoreque ante est conscriptum, nunc exponemus de firmitate, quemadmodum ea sine vitiiis permanentia ad vetustatem conlocentur.

¹ ratione H.
² sermones H.

³ re *Joc*: res H.
⁴ ergo *G*: ero H.

call *paradromides*. The Greeks give the name *prothyra* to the vestibules which are in front and serve as the entrance; we call *prothyra* what, in Greek are named *diathyra*.¹

6. Again, if statues of the male figure support brackets or cornices, we call them *telamones*, nor do we find in any treatises what they are and why they are so called. But the Greeks call them *Atlantes*. For, in history,² Atlas is represented as sustaining the universe, because he was the first by his powerful intellect and skill to set forth to mankind the sun's course and the revolutions of the moon and all the stars. And therefore because of this service he is represented by painters and statuary as sustaining the world. His daughters, the *Atlantides*, whom we call *Vergiliae* and the Greeks *Pleiades*, are placed among the constellations in the universe. 7. I have put this forth not with the purpose of changing any nomenclature or language in common use, but I thought that these explanations should not be unknown to scholars.

I have expounded the traditions by which buildings are designed in the Italian manner, and by Greek rules, and have enumerated the proportions which determine the symmetries of the different styles. We have already, therefore, written on grace and propriety in architecture; it remains to deal with stability and the means by which buildings may be planned so as to endure without defect.³

¹ Wicket-gate at the front door.

² Euhemerus, in a work translated by Ennius, taught the doctrine represented here, that the gods were originally famous men.

³ Book I. iii. 2.

¹ AEDIFICIA quae plano pede instituuntur, si fundamenta eorum facta fuerint ita, ut¹ in prioribus libris de muro et theatris nobis est expositum, ad vetustatem ea² erunt sine dubitatione firma. Sin autem hypogaea concamarationesque instituentur, fundationes eorum fieri debent crassiores, quam quae in superioribus aedificiis structurae sunt futurae. Eorumque parietes, pilae, columnae ad perpendicularium inferiorum medio conlocentur, uti solido respondeant; nam si in pendentibus onera fuerint parietum aut columnarum, non poterint habere perpetuam firmitatem.

² Praeterea inter lumina secundum pilas et antas postes si supponentur, erunt non vitiosae. Limina enim et traves structuris cum sint oneratae, medio spatio pandantes frangunt sublisi³ structuras; cum autem subiecti fuerint et subcuneati postes, non patiuntur insidere⁴ traves neque eas laedere.

³ Item administrandum est, uti levent onus parietum fornicationes cuneorum⁵ divisionibus et ad centrum respondentes earum conclusurae. Cum enim extra traves aut liminum capita arcus cuneis erunt conclusae, primum non pandabit materies levata onere; deinde, si quod vetustate vitium ceperit, sine molitione fulturarum faciliter mutabitur.

⁴ Itemque, quae pilatim aguntur aedificia et cune-

¹ ut G: aut H.

² eae H.

³ sublisi e, Sulp: sub lysi H.

⁴ insidera H.

⁵ cuneorum H: cum eorum.

¹ Book I. v. 1.

² Book V. iii. 3.

³ *pendo* = overhang. Lucr. vi. 195.

⁴ *Voussoirs* = wedge-shaped stones of an arch.

1. BUILDINGS which start from the level of the ground, if the foundations are so laid, as we have explained in previous books with reference to city walls¹ and theatres,² will assuredly be solid and durable. But if there are spaces underground and vaulted cellars, the foundations must be wider than the structures in the upper parts of the building. The party walls, the piers, the columns, are to be placed with their centres perpendicularly above the lower parts, so as to correspond to the solid. For if the weight of the dividing walls or of the columns is over open spaces,³ it cannot be permanently sustained.

2. Further, if supports are put for the piers and pilasters between the windows, these faults will be avoided. For when lintels and bressumers are loaded with walling, they sag in the middle and cause fractures by settlement; but when piers are placed underneath and wedged up, they do not allow the beams to settle and injure the structure above.

3. We must also contrive to relieve the weight of the walling by arches with their voussoirs,⁴ and their joints directed to a centre. For when arches, with their voussoirs, are carried outside the beams and lintels, in the first place the wood relieved of its burden will not sag; in the second place, if it decays in course of time, it will easily be replaced without the labour of shoring up.

4. Moreover, when buildings rest upon piers, and

orum divisionibus coagmentis ad centrum respond-
entibus fornice conclusuntur, extremae pilae in his
latiores spatio sunt faciundae, uti vires eae habentes
resistere possint, cum cunei ab oneribus parietum
pressi per coagmenta ad centrum se prementem
extruderent incumbas. Itaque si angulares pilae
erunt spatiosis magnitudinibus, continendo cuneos
firmitatem operibus praestabunt.

5 Cum in his rebus animadversum fuerit, uti ea
diligentia in his adhibeatur, non minus etiam obser-
vandum est, uti omnes structurae perpendiculo
respondeant neque habeant in ulla parte proclina-
tiones. Maxima autem esse debet cura substruc-
tionum, quod in his infinita vitia solet facere terrae
congestio. Ea enim non potest esse semper uno
pondere, quo solet esse per aestatem, sed hibernis
temporibus recipiendo ex imbribus aquae multi-
tudinem crescens et pondere et amplitudine dis-
rumpit et extrudit structurarum saeptiones.

6 Itaque, ut huic vitio medeatur, sic erit faciendum,
ut primum pro amplitudine congestionis crassitudo
structurae constituatur. Deinde in frontibus ante-
rides, sive erismae sunt, una struantur, eaeque inter
se distent tanto spatio, quanta altitudo substructionis
est futura, crassitudine¹ eadem, qua substructio; pro-
currat autem ab imo, pro quam² crassitudo consti-
tuta fuerit substructionis, deinde contrahatur grada-
tim, ita uti summam habeat prominentiam, quanta
operis est crassitudo.

¹ crassitudine *Joc*: -nis *H*.

² pro quam *Ro*: per quam *H*.

¹ In these sections, Vitruvius furnished the mediaeval
builders with the main principles of Gothic architecture. Cf.

arches are constructed with voussoirs and with
joints directed to a centre, the end piers in the build-
ings are to be set out of greater width, so that they
may be stronger and resist when the voussoirs,
being pressed down by the weight of the walling
owing to the jointing, thrust towards the centre and
push out the imposts. Therefore if the angle piers
are of wide dimensions, they will restrain the thrust
and give stability to the buildings.¹

5. When proper attention has been given herein
that such care be taken, we must not less be on our
guard that every part of a building maintains its
perpendicular and that no part leans over. But the
greatest care must be taken in the substructures,
because, in these, immense damage is caused by the
earth piled against them. For it cannot remain of
the same weight as it usually has in the summer:
it swells in the winter by absorbing water from the
rains. Consequently by its weight and expansion
it bursts and thrusts out the retaining walls.

6. To avoid this damage, therefore, we must pro-
ceed as follows. The thickness of the walling must
answer to the amount of earth. Next, supporting
walls or buttresses are to be carried up at the same
time. The interval between them is to be the same
as the height of the substructure, and the thickness
that of the substructure. They are to project at
the base in accordance with the thickness deter-
mined for the substructure. Then they are to be
gradually diminished, so that at the top they may
project as much as the thickness of the walling.

Seneca, *Ep.* 95. 53. *Societas nostra lapidum fornicationi
simillima est: quae casura nisi invicem obstarent, hoc ipso
sustinetur.*

7 Praeterea introrsus contra terrenum coniuncta muro serratim struantur, uti singuli dentes ab muro constructionis; crassitudines¹ autem habeant dentium structurae uti muri. Item in extremis angulis cum recessum fuerit ab interiore angulo spatio altitudinis substructionis, in utramque partem signetur, et ab his signis diagonius² structura conlocetur, et ab ea media altera coniuncta cum angulo muri. Ita dentes et diagonioe³ structurae non patientur tota vi premere murum, sed dissipabunt retinendum⁴ impetum congestionis.⁵

8 Quemadmodum sine vitiis opera constitui oporteat et uti caveatur incipientibus, exposui. Namque de tegulis aut tignis aut asscribus mutandis non est eadem cura quemadmodum de his, quod ea, quamvis sunt vitiosa, faciliter mutantur. Ita quae⁶ nec solidi quidem putantur esse, quibus rationibus haec poterint esse firma et quemadmodum instituantur, exposui.

9 Quibus autem copiarum generibus oporteat uti, non est architecti potestas, ideo quod non in omnibus locis omnia genera copiarum nascuntur, ut in proximo volumine est expositum; praeterea in domini est potestate, utrum latericio an caementicio an saxo quadrato velit aedificare. Itaque omnium operum probationes tripertito considerantur, id est fabrili subtilitate et magnificentia et dispositione. Cum magnificenter opus perfectum aspicietur, a domini⁷ potestate inpensae laudabuntur; cum subtiliter,

¹ crassitudinis *H.*

² diagoniae *H.*

⁵ congestiones *H S.*

⁷ a domini *Meister* :

³ diagonios *Joc* : -nius *H S.*

⁴ retinendo *rec* : -dum *H.*

⁶ itaque *H.*

⁷ ab omni *H.*

7. Further, against the earth on the inside, the wall must have projections like the teeth of a saw, such that the intervals between them are equal to the height of the substructure. The thickness of the teeth must be that of the main wall. Further, in the outer angles of the substructure, taking a distance from the internal angle equal to the height of the substructure, we must mark a point on either side and a diagonal wall is to be built between them, and from the middle of the diagonal wall, another wall is to be built to the interior angle of the main wall. The teeth and the diagonal walls will not allow the full pressure to fall upon the main wall but will distribute the thrust of the earth, which we have to hold in check.

8. How buildings can be carried out so as to avoid failure, and how precautions must be taken in the first stages, has been explained. For the same care is not needful in repairing roof tiling, or principals or rafters, which if faulty are easily repaired, as in the foundations. I have also described how those parts of a building which are not considered to belong to the solid can be made stable, and how they are to be constructed.

9. An architect cannot control the kinds of material which it is necessary to use, for the reason that not all kinds of material occur in all places, as was explained in the last book.¹ Besides, the client decides whether he is to build in brick or rubble or ashlar. Therefore the test of all building is held to be threefold: fine workmanship, magnificence, architectural composition. When a building has a magnificent appearance, the expenditure of those who control it, is praised. When the craftsmanship is

¹ Book V. vi. 7; xii. 5.

offinatoris probabitur exactio; cum vero venuste
 10 proportionibus et symmetriis habuerit auctoritatem,
 tunc fuerit gloria ¹ architecti. Haec autem
 recte constituuntur, cum is et a fabris et ab idiotis
 patiatur accipere se consilia. Namque omnes
 homines, non solum architecti, quod est bonum,
 possunt probare, sed inter idiotas et eos hoc est
 discrimen, quod idiota, nisi factum viderit, non
 potest scire, quid sit futurum, architectus autem,
 simul animo constituerit, antequam inceperit, et
 venustate et usu et decore quale sit futurum, habet
 definitum.

Quas res privatis aedificiis utiles putavi et quemad-
 modum sint faciundae, quam apertissime potui,
 perscripsi; de expolitionibus ² autem eorum, uti
 sint elegantes et sine vitiis ad vetustatem, insequenti
 volumine exponam.

¹ *area Gr*: gloria aria architecti *H*.

² *expolitionibus S*: expoliationibus *H*.

good, the supervision of the works is approved.
 But when it has a graceful effect due to the symmetry
 of its proportions, the site ¹ is the glory of the archi-
 tect. 10. His work is duly accomplished when he
 submits to receive advice from his workmen and
 from laymen. For all men, and not only architects,
 can approve what is good. But there is this difference
 between the architect and the layman, that the
 layman cannot understand what is in hand unless he
 sees it already done; the architect, when once he
 has formed his plan, has a definite idea how it will
 turn out in respect to grace, convenience, and
 propriety.

I have described, as explicitly as I can, the details
 which are useful in private buildings and how they
 are to be carried out. In the next book I will treat
 of the methods of finishing the work, so that they
 may be ornamental, free from defects and permanent.

¹ But the conjecture *area* is doubtful.

BOOK VII

LIBER SEPTIMUS

- 1 MAIORES cum sapienter tum etiam utiliter instituerunt, per commentariorum relationes cogitata tradere posteris, ut ea non interirent, sed singulis aetatibus crescentia voluminibus edita gradatim pervenirent vetustatibus ad summam doctrinarum subtilitatem. Itaque non mediocres sed infinitae sunt his agenda gratiae, quod non invidiose silentes praetermiserunt, sed omnium generum sensus conscriptionibus memoriae tradendos curaverunt.
- 2 Namque si non ita fecissent, non potuissemus scire, quae res in Troia fuissent gestae, nec quid¹ Thales, Democritus, Anaxagoras, Xenophanes reliquique physici sensissent de rerum natura, quasque Socrates, Platon, Aristoteles, Zenon, Epicurus aliique philosophi hominibus agenda vitae terminationes finissent, seu Croesus,² Alexander, Darius ceterique reges quas res aut quibus rationibus gessissent, fuissent notae, nisi maiores praeceptorum comparationibus omnium memoriae ad posteritatem commentariis extulissent.
- 3 Itaque quemadmodum his gratiae sunt agendae,

¹ nequid H.

² croesus H.

¹ Vitruvius, probably, has in view (a) histories *commentarii*; (b) collections of opinions, beginning with Theophrastus' *Opinions of Natural Philosophers*.
² Zeno of Citium in Cyprus, probably a Semite, founded the Stoic philosophy so called from the Frescoed Colonnade *Stoa*

BOOK VII

PREFACE

1. OUR predecessors, wisely and with advantage, proceeded by written records to hand down their ideas to after times, so that they should not perish, but being augmented from age to age and published in book form, they should come step by step in the course of time to a complete and accurate body of knowledge. Hence we must render to them more than moderate thanks, indeed the greatest, because they did not let them all go in jealous silence, but provided for the record in writing of their ideas in every kind.¹

2. If they had not done so, we could not have known the history of Troy, nor the natural philosophy of Thales, Democritus, Anaxagoras, Xenophanes, and the rest; nor should we have been acquainted with the precepts of Socrates, Plato, Aristotle, Zeno,² Epicurus, and other philosophers for the conduct of human life, nor with the actions and policy of Croesus, Alexander, Darius, and other monarchs, unless our predecessors in their records and collections of opinions had published these matters to posterity and the memory of the world.

3. While, then, these men deserve our gratitude,

Poikile, at Athens in which he taught. The Peripatetic (Aristotelian) philosophy derived its name from the Cloisters, *peripatoi*, of the gymnasium in which the master taught.

contra,¹ qui eorum scripta furantes pro suis prae-
tationibus scriptorum nituntur, sed invidis cogi-
aliena violantes gloriantur, non modo sunt repre-
hendendi,² sed etiam, qui impio more sunt repre-
poena condemnandi. Nec tamen hae res non
vindictae curiosius ab antiquis esse memorantur.
Quorum exitus iudiciorum qui fuerint, non est
alienum, quemadmodum sint nobis traditi, explicare.

4 Regis³ Attalici magnis philologiae dulcedinibus
inducti cum egregiam bybliotheam Pergami ad
communem delectationem instituissent, tunc item
Ptolomaeus infinito zelo cupiditatisque incitatus⁴
studio non minoribus industriis ad eundem modum
contenderat Alexandriae comparare. Cum autem
summa diligentia perfecisset, non putavit id satis
esse, nisi propagationibus inseminando curaret
augendam. Itaque Musis et Apollini ludos dedi-
cavit et, quemadmodum athletarum, sic com-
munium⁵ scriptorum victoribus praemia et honores
constituit.

5 His ita institutis, cum ludi adessent, iudices litterati,
qui ea probarent, erant legendi. Rex, cum iam sex
civitatis⁶ lectos habuisset nec tam cito septimum
idoneum inveniret, retulit ad eos, qui supra byblio-
theam fuerunt, et quaesivit, si quem novissent ad

¹ sunt agendaest contra *rec*: sunt agendaest contra *H*.

² repraehendi *H*.

³ regis *H*.

⁴ incitatis *H*.

⁵ sicommunium *H*.

⁶ excivitatibus *G*.

¹ The Attalid dynasty ruled from 280 B.C. to 133 B.C. Eumenes I (263–241), Attalus I (241–197), Eumenes II (197–159) fostered the library. The building which housed it was erected by Eumenes II.

on the other hand we must censure those who plunder their works and appropriate them to themselves; writers who do not depend upon their own ideas, but in their envy boast of other men's goods whom they have robbed with violence, should not only receive censure but punishment for their impious manner of life. And this practice, as we are informed, was duly dealt with by the ancients. It is not out of place to relate the results of these trials as they have been handed down.

4. The Attalid kings,¹ impelled by their delight in literature, established for general perusal² a fine library at Pergamus. Then Ptolemy, moved by unbounded jealousy and avaricious desire, strove with no less industry to establish a library at Alexandria after the same fashion.³ When he had completed it with great diligence, he did not think it enough unless he should provide for its increase by sowing and planting. So he consecrated games in honour of the Muses and Apollo, and established prizes and honours for the successful writers of the day, in the same way as for successful athletes.

5. When the arrangements were completed, and the games were at hand, learned judges had to be chosen to examine the competitors. When the king had chosen six persons from the city and could not quickly find a seventh⁴ person suitable, he consulted the governors of the library whether

² *delectatio* = *voluptas suavitate auditus animum deleniens*. Cic. *Tusc.* IV. 9. 20.

³ Ptolemy Philadelphus built two great libraries to contain his collections, completed by his successor, Euergetes.

⁴ In Greek idiom implies six others.

id expeditum. Tunc ei dixerunt esse quendam Aristophanen, qui summo studio summaque diligentia cotidie omnes libros ex ordine perlegeret. Itaque conventu ludorum, cum secretae sedes iudicibus essent distributae, cum ceteris Aristophanes citatus, quemadmodum fuerat locus ei designatus, sedit. Primo poetarum ordine ad certationem inducto cum recitarentur scripta, populus cunctus significando monebat iudices, quod probarent. Itaque, cum ab singulis sententiae sunt rogatae, sex una dixerunt, et, quem maxime animadverterunt multitudini placuisse, ei primum praemium, insequenti secundum tribuerunt. Aristophanes vero, cum ab eo sententia rogaretur, eum primum renuntiari iussit, qui minime populo placuisset. Cum autem rex et universi vehementer indignarentur, surrexit et rogando impetravit,¹ ut paterentur se dicere. Itaque silentio facto docuit unum ex his eum esse poetam, ceteros aliena recitavisse; oportere autem iudicantes non furta sed scripta probare. Admirante populo et rege dubitante, fretus memoriae certis armariis infinita volumina eduxit et ea cum recitatis conferendo coegit ipsos furatos de se confiteri. Itaque rex iussit cum his agi furti condemnatosque cum ignominia dimisit, Aristophanen vero amplissimis muneribus ornavit et supra bybliotheecam constituit.

¹ impetravit *rec* : imperavit *H*.

¹ Aristophanes the critic 257–180 B.C. The reign of Euergetes (*ob.* 222) fits in with the story.

² Aristophanes probably worked in the library many years before he succeeded Eratosthenes as head.

³ Probably Ptolemy III Euergetes.

⁴ *Armarium*, sometimes recess in wall of library as at Timgad.

they knew anyone prepared for such a duty. They gave the name of Aristophanes,¹ who read each book in the library systematically day by day with comprehensive ardour and diligence. Therefore at the assemblage for the games special seats were allotted to the judges, and Aristophanes, being summoned with the rest, took his seat in the place allotted to him. 6. The competition for poets was first on the list; and when their poems were recited, the whole multitude by its utterances warned the judges what to approve. When, therefore, the judges were asked one by one, the six agreed and gave the first prize to the poet who, they observed, most pleased the audience; the second prize to the person who came next in their approval. Aristophanes,² however, when his opinion was asked, voted that the first place should be given to the candidate who was least liked by the audience. 7. When the king³ and all the company showed great indignation, he rose and obtained permission to speak. Amid a general silence he informed them that only one of the competitors was a true poet; the others recited borrowed work, whereas the judges had to deal with original compositions, not with plagiaries. The assembly were surprised and the king was doubtful. Aristophanes relying upon his memory produced a large number of papyrus rolls from certain bookcases,⁴ and comparing these with what had been recited he compelled the authors to confess they were thieves. The king then ordered them to be brought to trial for theft. They were condemned and dismissed in disgrace, while Aristophanes was raised to high office and became librarian.⁵

⁵ c. 195 B.C.

8 Insequentibus annis a Macedonia¹ Zoilus, qui adoptavit cognomen, ut Homeromastix vocitaretur, Alexandriam venit suaque scripta contra Iliadem et Odyssean² comparata regi recitavit. Ptolomaeus vero, cum animadvertisset poetarum parentem philologiaeque omnem ducem absentem vexari et, cuius ab cunctis gentibus scripta suspicerentur, ab eo vituperari, indignans³ nullum ei dedit responsum. Zoilus autem, cum diutius in regno fuisset, inopia pressum⁴ remisit ad regem postulans, ut aliquid sibi tribueretur. Rex vero respondisse dicitur Homerum, qui ante annos mille decessisset, aevo perpetuo multa milia hominum pascere, item debere, qui meliore ingenio se profiteretur, non modo unum sed etiam plures alere posse. Et ad summam mors eius ut parricidii damnati varie memoratur. Alii enim scripserunt a Philadelpho esse in crucem fixum, nonnulli Chii⁵ lapides esse coniectos, alii Zmyrnae vivum in pyram coniectum. Quorum utrum ei acciderit, merenti digna constitit poena; non enim aliter videtur promereri, qui citat eos, quorum responsum, quid senserint scribentes, non potest coram indicari.

10 Ego vero, Caesar, neque alienis indicibus mutatis interposito nomine meo id profero corpus neque ullius cogitata vituperans institui ex eo me adprobare, sed omnibus scriptoribus infinitas ago gratias, quod egregiis ingeniorum sollertiis ex aevo conlatis

¹ machedonia H.

² iliaden et odissian H.

³ indignans G: indignus H S.

⁴ pressum remisit H S: sc. se esse.

⁵ Chii Salmasius: chiei H G.

8. Some years after, Zoilus, who had taken a surname so as to be called the Scourge of Homer, came from Macedonia to Alexandria, and read his works directed against the *Iliad* and *Odyssey*. Ptolemy, however, observed that the father of poets and the founder of literature was attacked in his absence, and that Zoilus abused one whose works were looked up to by all nations, and in his indignation would not reply to him. Zoilus, however, remaining some time in Egypt, was overcome by poverty and submitted his name to the king for an allowance. 9. The king is said to have replied that Homer, whose death occurred many years before, had through all that age of time furnished a livelihood to many thousands; a man, therefore, who claimed to be of a finer talent should be able to maintain not only one but many others as well. In fine, Zoilus was condemned for parricide, and his death is variously recorded. Some have written that he was crucified by Philadelphus;¹ others that he was stoned at Chios; others that he was thrown alive on a burning pyre in Smyrna. Whichever happened to him, the penalty fitted the culprit. Such seems to be the desert of a man who calls into court those who can no longer reply publicly, when asked what they meant by their writings.

10. But this encyclopaedia, your Highness, is not presented under my own name with the suppression of my authorities, nor have I set out to gain approbation by vituperating any man's ideas. For I owe great gratitude to all those who with an ocean of intellectual services which they gathered from all

¹ This statement supports the currency of the anecdote, and suggests that the critic was not identical with the orator.

abundantes alius¹ alio genere copias praeparaverunt, unde nos uti fontibus haurientes aquam et ad propria proposita traducentes facundiores et expeditiores habemus ad scribendum facultates talibusque confidentes auctoribus audemus institutiones novas comparare.

11 Igitur tales ingressus eorum quia² ad propositi mei rationes animadverti praeparatos, inde sumendo progredi coepi. Namque primum Agatharchus³ Athenis Aeschylo docente tragoediam ad scaenam fecit,⁴ et de ea commentarium reliquit. Ex eo moniti Democritus et Anaxagoras de eadem re scripserunt, quemadmodum oporteat, ad aciem oculorum radiorumque extentionem⁵ certo loco centro constituto, ad lineas ratione naturali respondere, uti de incerta re incertae imagines⁶ aedificiorum in scaenarum picturis redderent speciem et, quae in directis planisque frontibus sint figurata, alia abscedentia, alia prominentia esse videantur.

12 Postea Silenus de symmetriis doricorum edidit volumen; de aede ionica Iunonis quae est Sami Rhoecus et⁷ Theodorus; ionice Ephesi quae est

¹ alius Oudendorp: aliis H.

² agatharcus G, -tarcus H S.

³ ad scaenam fecit e₂, ed: Athenis architectus praerat Dionysiis.

⁴ extentione H S.

⁵ incerta re incertae imagines h: incerta rem c fortasse ex incerta re H.

⁶ text. Gr: de aede iononis quae est Samii dorica zeodorus H, C.R. 1924, 112.

⁷ Institutiones = manual.

time, each in his department provided stores from which we, like those who draw water from a spring and use it for their own purposes, have gained the means of writing with more eloquence and readiness; and trusting in such authorities we venture to put together a new manual¹ of architecture.

11. Because, then, I observed that such beginnings had been made towards the method of my undertaking, I drew upon these sources and began to go forward. For to begin with: Agatharchus² at Athens, when Aeschylus was presenting a tragedy, was in control of the stage, and wrote a commentary about it. Following his suggestions, Democritus³ and Anaxagoras³ wrote upon the same topic, in order to show how, if a fixed centre is taken for the outward glance of the eyes and the projection of the radii, we must follow these lines in accordance with a natural law, such that from an uncertain object, uncertain images may give the appearance of buildings in the scenery of the stage, and how what is figured upon vertical and plane surfaces can seem to recede in one part and project in another.⁴

12. Subsequently Silenus⁵ published a work upon Doric proportions; Rhoecus and Theodorus⁶ on the Ionic temple of Juno which is at Samos;

² Agatharchus, son of Eudemus, of Samos. By introducing perspective, he revolutionised Greek paintings; cf. Plat. Rep. X. 602. The play was the trilogy of the Oresteia.

³ Previously mentioned together, VII. pref.

⁴ For the text and interpretation of this passage, see my article *The Parthenon and the Baroque*, J.R.I.B.A. 1931, 755 ff.

⁵ Not otherwise known.

⁶ Rhoecus and Theodorus worked together, Plin. N.H. XXXV. 152.

Dianae, Chersiphron¹ et Metagenes; de fano Minervae, quod est Prienae ionicum, Pytheos;² arce, Ictinos³ et Carpion; Theodorus Phocaeus in tholo, qui est Delphis; Philo de aedium sacrarum symmetriis et de armamentario,⁴ quod fuerat Piraei portu; Hermogenes de aede Dianae, ionice quae est Magnesia pseudodipteros, et Liberi Patris Teo⁵ monopteros;⁶ item Arcesius⁷ de symmetriis corinthiis et ionico Trallibus Aesculapio, quod etiam ipse sua manu dicitur fecisse; de Mausoleo Satyrus et Pytheos.⁸

13 Quibus vero felicitas maximum summumque contulit munus; quorum enim artes aevo perpetuo nobilissimas laudes et sempiterno florentes habere iudicantur, et cogitatis egregias operas praestiterunt. Namque singulis frontibus singuli artifices⁹ sumpserunt certatim partes ad ornandum et probandum Leochares, Bryaxis, Scopas,¹⁰ Praxiteles, nonnulli etiam putant Timotheum, quorum artis eminens

¹ Chersiphron H.

² Pytheos Schn: phyleos H S.

³ Ictinos H.

⁴ armamentario ed: armentario H.

⁵ Teo Joc: & eo H S, et eo G.

⁶ monopteros G: monocteros H S.

⁷ Arcesius Ro: argelius H.

⁸ Satyrus H: phiteus H.

⁹ singulis artifices H.

¹⁰ scaphas H.

¹ Robertson, *Greek and Roman Architecture*, 94 n.

² Robertson, 148.

³ Lethaby, *Greek Buildings*, 83.

⁴ Robertson, 141.

⁵ Specification recorded C.I.A. II. 1054.

⁶ Lethaby, 208.

Chersiphron and Metagenes on the Ionic temple of Diana which is at Ephesus¹; Pythius on the temple of Minerva in the Ionic style which is at Priene;² Ictinus³ and Carpion on the Doric temple of Minerva which is on the Acropolis at Athens; Theodorus⁴ of Phocaea on the Tholos at Delphi; Philo⁵ <of Eleusis> on the proportions of temples and the arsenal⁶ which was in the harbour of the Piraeus; Hermogenes⁷ on the pseudodipteral Ionic temple of Diana⁸ at Magnesia and the monopteral temple of Father Bacchus⁹ at Teos; Arcesius on Corinthian proportions, and the Ionic temple at Tralles¹⁰ to Aesculapius, whose image is said to have been carved by him; Satyrus and Pythius on the Mausoleum.¹¹

13. And on these last, good fortune conferred the greatest and highest boon. For their works are adjudged to have a merit which is famous throughout the ages and of unfading freshness¹² and they employed distinguished artists on their undertakings. For on the several elevations, different rival craftsmen took their share in decorations wherein they competed: Leochares,¹³ Bryaxis,¹⁴ Scopas,¹⁵ Praxiteles,¹⁶ and some add Timotheus.¹⁷ The out-

⁷ Book III. iii. 8.

⁸ Robertson, 155.

⁹ Robertson, 157.

¹⁰ Ruins described; Fellows, *Asia Minor*, 276.

¹¹ Lethaby, 37 ff.

¹² This eternal freshness was specially attributed to the structures of Pericles, Plut. *vit.* XIII.

¹³ Book II. viii. 11, Plin. *N.H.* XXXVI. 31.

¹⁴ Plin. *N.H.* XXXIV. 73.

¹⁵ Works distinguished by intense expression.

¹⁶ The exquisite finish of his works: Athen. XIII. 591.

¹⁷ Book II. viii. 11; carved draperies very finely.

excellencia coegit ad septem spectaculorum eius operis pervenire famam.

14 Praeterea minus nobiles multi praecepta symmetriarum conscripserunt, uti Nexaris, Theocydes,¹ Demophilos, Pollis, Leonidas,² Silanion, Melampus, Sarnacus, Euphranor. Non minus de machinationibus, uti Diades, Archytas, Archimedes, Ctesibios,³ Nymphodorus, Philo Byzantius,⁴ Diphilos,⁵ Democles, Charias,⁶ Polyidos, Pyrrhos,⁷ Agesistratos.⁸ Quorum ex commentariis, quae utilia esse his rebus animadverti, [collecta in unum coegi corpus, et ideo maxime, quod animadverti]⁹ in ea re ab Graecis volumina plura edita, ab nostris oppido quam pauca. Fufidius¹⁰ enim mirum de his rebus primus instituit edere volumen, item Terentius Varro de novem disciplinis unum de architectura, P. Septimius duo.

15 Amplius vero in id genus scripturae adhuc nemo incubuisse videtur, cum fuissent et antiqui cives magni architecti, qui potuissent non minus eleganter scripta comparare. Namque Athenis Antistates et

¹ theocides *H S.*

² leonidas *G: -des H S.*

³ ctesibios *H S,* et esibios *G.*

⁴ phylobyzanteos *H S.*

⁵ diphilos *H S.*

⁶ charidas *H.*

⁷ pyrrhos *H.*

⁸ agesistratas *H.*

⁹ collecta—animadverti *G: om. H S.*

¹⁰ Fufidius *Schn: Fuficius H.*

¹ Book II. viii. 11.

² Painter, master of Zeuxis, *Plin. N.H. XXXV. 61.*

³ Painter, *Plin. N.H. XXXIV. 91.*

⁴ Made portrait statues, *Plin. N.H. XXXIV. 81.*

⁵ Painter and sculptor, and writer: type of versatile genius.

⁶ Book X. xiii. 3. Polyidos and Diades are named in a list of *mechanici* in a papyrus of about 100 B.C. *Pap. Berol. P. 13044.*

standing excellence of their work caused the fame of the Mausoleum to be included in the seven wonders¹ of the world.

14. In addition to these, many men of less fame have compiled the rule of symmetry, such as Nexaris, Theocydes, Demophilus,² Pollis,³ Leonidas, Silanion,⁴ Melampus of Sarnaca, Euphranor.⁵ Others have written on machinery: Diades,⁶ Archytas,⁷ Archimedes,⁸ Ctesibios,⁹ Nymphodorus,¹⁰ Philo of Byzantium,¹¹ Diphilos,¹² Democles,¹³ Chaerias,⁶ Polyidos,⁶ Pyrrhus,¹⁴ Agesistratus. As to the useful contributions to our subject which I found in their commentaries, many volumes have been published by the Greeks, exceedingly few by our own writers. For Fufidius¹⁵ curiously enough was the first to publish a volume on these topics. Further, Varro included one volume in his work *On the Nine Disciplines*¹⁶; Publius Septimius¹⁷ wrote two volumes.

15. Up to now no one seems to have gone further in this kind of writing, although our citizens of old have been great architects who might have compiled works of equal precision. For at Athens the archi-

⁷ Book I. i. 17.

⁸ Book I. i. 7, 17.

⁹ Book IX. viii. 2; I. i. 7.

¹⁰ "Inventor of scientific toys." *Athen. I. 19.*

¹¹ Wrote on 'mechanics,' contemporary of Ctesibios.

¹² Perhaps architect to Quintus Cicero. *Cic. Q. Fr. III. 1. 1.*

¹³ *Plin. N.H. XXXIV., XXXV.* in list of authorities;

Strabo I. 58.

¹⁴ Wrote on siege engines, *Athen. Math. Vett. 2.*

¹⁵ Probably a friend of Cicero, *Fam. XIII. xi. 3,* and aedile at Arpinum, *Wilm. 2050.*

¹⁶ *Encyclopædia of Education.*

¹⁷ Quaestor of Varro who dedicated to him first three books, *de lingua Latina.*

Callaeschros¹ et Antimachides et Porinos² architecti Pisistrato aedem Iovi Olympio facienti fundamenta interpellationem reipublicae³ incepta eius propter Itaque circiter annis quadringentis⁴ post Antiochus rex, cum in id opus inpensam esset pollicitus, cellae magnitudinem et columnarum circa dipteron conlocationem epistyliorumque et ceterorum ornamentorum ad symmetriam distributionem orna-
sollertia scientiaque summa civis Romanus Quos-
sutius⁵ nobiliter est architectatus. Id autem opus non modo volgo, sed etiam in paucis a magnificentia nominatur.

16 Nam quattuor locis sunt aedium sacrarum marmoreis operibus ornatae dispositiones, e quibus propriae de his nominationes clarissima fama nominantur quorum excellentiae prudentesque⁶ cogitationum apparatus suspectus habent in deorum *sesemasmenois*.⁷ Primumque aedes Ephesi Dianae ionico genere ab Chersiphronē⁸ Gnosio et filio eius Metagene⁹ est instituta, quam postea Demetrius, ipsius Dianae servos, et Paeonius Ephesius dicuntur perfecisse. Mileti¹⁰ Apollini item ionicis symmetriis idem Paeonius Daphnisque¹¹ Milesius instituerunt. Eleusine Cereris¹² et Proserpinae cellam inmani

¹ callescheros *H S.* ² porinos *G*: pormos *H S.*
³ reipublice *G S*: regi publice *H.*
⁴ quadringentis *Meurs.*: ducentis *H.*
⁵ quosutius *H*: quosutius *H^c.* ⁶ prudentis *H S.*
⁷ sesemasmenois *Gr*: sesemaneio *H G*, cf. Plato, *Legg.* 954a.
⁸ ab crespione *H.* ⁹ metagine *H S.*
¹⁰ meleti *H.* ¹¹ daphnis *G*: daphinis *H S.*
¹² cereris *G S*: caeteris *H.*

¹ These names may have been taken from an inscription.
² The correction *quadringentis* for *ducentis* seems necessary.

teets¹ Antistates and Callaeschrus and Antimachides and Porinus laid the foundations for Pisistratus when he was building a temple to Olympian Jupiter. After his death they abandoned his undertaking because of the interruption caused by the republic. About four hundred² years after, king Antiochus undertook the cost of the building. A Roman citizen Cossutius, an architect of great skill and scientific attainments, finely designed the great sanctuary with a double colonnade all round and with the architrave symmetrically disposed. And this building is famous owing to its magnificence not only with the crowd but with the experts.

16. For in four places temples have been erected and finished with marble, whence their names are current and most renowned. Their fine character and the skilful management of their design gains a high regard among the chefs-d'œuvre of religion.³ First of all the temple of Diana⁴ at Ephesus was planned in the Ionic style by Chersiphron of Cnossus and his son Metagenes; afterwards Demetrius, a temple warden⁵ of Diana, and Paeonius⁶ of Ephesus are said to have completed it. At Miletus the same Paeonius, and Daphnis of Miletus, built for Apollo⁷ in the Ionic style. At Eleusis, Ictinus⁸ built the temple of Ceres and Proserpine in the Doric manner,

³ Lit. "sealed." Treasures of the gods were sealed.

⁴ *Ante*, 12.

⁵ Ordinarily *aedituos* = Gk. *neokoros*; cf. *Acts* xix. 35: *neokoros polis*.

⁶ Lethaby, 34.

⁷ Didymaeum; the former temple was burnt by Darius 496 B.C.; this, the new temple, scarcely less than the Artemisium at Ephesus, was never finished.

⁸ His subordinate architects are enumerated, *Plut. Pericles*, 13.

17 magnitudine Ictinos dorico more sine exterioribus columnis ad laxamentum usus sacrificiorum pertexit. Eam¹ autem postea, cum Demetrius Phalereus Athenis rerum potiretur, Philo ante templum in fronte columnis constitutis prostylon fecit; ita aucto vestibulo laxamentum initiantibus² operique summam adfecit auctoritatem. In astry vero ad Olympium amplo modulorum comparatu corinthiis symmetriis et proportionibus, uti s.s. est,³ architectandum Quossutius⁴ suscepisse memoratur, cuius commentarium nullum est inventum. Nec tamen a Cossutio solum de his rebus scripta sunt desideranda sed etiam a G. Mucio,⁵ qui magna scientia confusus aedes Honoris et Virtutis Marianae,⁶ cellae columnarumque et epistyliorum symmetrias legitimis artis institutis perfecit.⁷ Id vero si marmoreum fuisset, ut haberet, quemadmodum ab arte subtilitatem, sic ab magnificentia et inpensis auctoritatem, in primis et summis operibus nominaretur.

18 Cum ergo et antiqui nostri inveniantur non minus quam Graeci fuisse magni architecti et nostra memoria satis multi, et ex his pauci praecepta edidissent, non putavi silendum, sed disposite singulis voluminibus de singulis exponeremus. Itaque, quoniam sexto⁸ volumine privatorum aedificiorum rationes perscripsi, in hoc, qui septimum tenet numerum, de expolitionibus, quibus rationibus et venustatem et firmitatem habere possint, exponam.

¹ eam ed: ea H G.

² initiantibus G: initientibus H S.

³ uti s.s. est H: uti cc ē e₂ cum schol. 'pro notis s.s. e. ut in Blandiniano.' Hae notae in h: cf. Vol. I. xxiii.

⁴ cossutius G S: quosutius H^e.

⁵ A. G. mutio H S.

⁷ perficit H.

⁶ marinianae H S.

⁸ sexto H^e: secto H.

and of an immense size without exterior columns; it was covered in to afford a convenient space for sacrifice.

17. When Demetrius of Phaleron was master of Athens,¹ Philo² erected columns in front before the temple and turned it into a prostyle building. Thus by enlarging the approach he gave space for the initiates and great impressiveness to the building. In the city the Olympeum was designed with Corinthian symmetries and proportions and an ample module by the architect Cossutius, as already described.³ No specification by him is extant. Not only do we miss such a work from Cossutius but also from Gaius Mucius,⁴ who,—in the temple of Honour and Virtue erected by Marius,—relying upon his scientific acquirements, finished off the symmetries of the sanctuary, the columns and the entablature, in accordance with the legitimate rules of art. But if it had been of marble so as to be impressive by a costly magnificence, no less than marked by a skilful precision, it would have a name among the buildings of the first and highest class.

18. While, therefore, our predecessors are found, no less than the Greeks, to have been great architects, and sufficiently many in our own time, few of them have published their methods. Hence I thought we ought not to remain silent, but we should set forth methodically the various branches of the subject in separate volumes. Therefore, after describing in the sixth book the arrangements of private buildings, in this book, which is the seventh, I will explain how they are finished in such a way as to combine durability with elegance.

¹ 317–307 B.C.

³ Ante, 15.

² Ante, 12.

⁴ Book III. ii. 5.

1 PRIMUMQUE incipiam de ruderatione, quae principia tenet expolitionum, uti curiosius summaque providentia solidationis ratio habeatur. Et si plano pede erit eruderandum, quaeratur, solum¹ si sit perpetuo solidum, et ita exaequetur, et inducatur cum statumine rudus. Sin autem omnis aut ex parte congesticius² locus fuerit, fistucationibus cum magna cura solidetur. In contignationibus vero diligenter est animadvertendum, ne qui paries, qui non exeat ad summum, sit extractus sub pavimentum, sed potius relaxatus supra se pendentem habeat coaxationem. Cum enim solidus exit, contignationibus arescentibus aut pandatione sidentibus,³ permanens structurae soliditate dextra ac sinistra secundum se facit in pavementis necessario rimas.

2 Item danda est opera, ne commisceantur axes aesculini quercu, quod quercei,⁴ simul umorem per ceperunt, se torquentes rimas faciunt in pavementis. Sin autem aesculus non erit et necessitas coegerit propter inopiam, querceis⁵ sic videtur esse faciundum, ut secentur tenuiores; quo minus⁶ enim valuerint, eo facilius clavis⁷ fixi continebuntur. Deinde in singulis tignis extremis partibus axis bini clavi figantur, uti nulla ex parte possint se torquendo anguli excitare. Namque de cerro aut fago seu farno nullus ad vestutatem potest permanere.

¹ non solum ante ras. H.

² sedentibus H.

³ quaercis H, quercis G S^o.

⁴ clavis G: clavi H S.

⁵ coniesticius H S.

⁶ querqui H G.

⁷ minum H.

¹ quercus aesculus, II. ix. 9.

² quercus robur, II. ix. 8.

1. FIRST, I will begin with rubble paving, which is the first stage in finishing, so that account may be taken, with special care and great foresight, of a solid foundation. If we must carry out our paving on level ground we must inquire whether the soil is solid throughout; it is then to be levelled, and rubble must be spread over the surface. But if there is a made site, in whole or in part, it must be rammed very carefully with piles. In the case of upper floors great attention must be given, lest any wall in the story below is built right up to the pavement; it is rather to stop short and have the joists carried free above it. For when the wall is taken up solid, if the flooring above dries or sags as it settles, the wall being of a solid structure, necessarily causes cracks, right and left of it, in the pavements above.

2. Attention must also be given not to mix planks of winter oak¹ with common oak.² For common oak, when it becomes moist, warps and makes cracks in the pavement. But if there is no winter oak and need drives, we must work with common oak, using thin planks. For the weaker they are, the more easily will they be kept in their place by nails. Then two nails are to be driven in each joist at the edges of the plank, so that the corners of the planks may not warp and rise up. No plank of Turkey oak,³ beech, or ash⁴ can remain durable.

¹ quercus cerris, II. ix. 9.

² farnus, probably a technical word.

Coaxationibus factis, si erit, flex, si non, palea substernatur, uti materies ab calcis vitiis defendatur. 3 Tunc insuper statuminetur ne minore saxo, quam qui possit manum implere. Statuminationibus inductis,¹ rudus si novum erit, ad tres partes una calcis misceatur, si redivivum fuerit, quinque ad duum mixtiones habeant responsum. Deinde rudus² inducatur et vectibus ligneis, decuriis inductis, crebriter pinsatione³ solidetur, et id non minus pinsum absolutum crassitudine sit dodrantis. Insuper ex testa nucleus⁴ inducatur mixtionem habens ad tres partes unam calcis, ne minore crassitudine pavementum digitorum senûm. Supra nucleum ad regulam et libellam exacta pavimenta struantur sive 4 sectilia seu tesserais. Cum ea exstructa fuerint et fastigia sua exstructionem habuerint, ita fricentur, uti, si sectilia sint, nulli gradus in scutulis aut trigonis aut quadratis seu favis extent, sed coagmentorum compositio planam habeat inter se derectionem, si tesserais structum erit, ut eae omnes angulos habeant aequales; cum enim anguli non fuerint omnes aequaliter pleni, non erit exacta, ut oportet, fricatura. Item testacea spicata tiburtina sunt diligenter exigenda, ut ne habeant lacunas nec extantes tumulos, sed extenta et ad regulam perfricata. Super fricaturam, levigationibus et polituris cum fuerint perfecta, incernatur marmor, et supra loricae ex calce et harena inducantur.

¹ inductis *ed*: -tus *H*.

² pinsatione *G*: piscatione *H S*.

³ inrudus *H*.

⁴ nucleos *H*.

¹ *Decuriae* of labourers, usually of slaves, *Sen. Ep.* 47, 9.

² *Opus signinum* made of potsherds and lime, used at Pompeii for pavements.

After finishing the flooring, fern—if you have it—or else straw, is to be spread over, so that the wood may be protected against the injury caused by lime. 3. Next a layer of stones is to be spread, each of which is not less than a handful. After spreading the stones, the rubble, if it is fresh, is to be mixed, three parts to one of lime; if it is of old materials, five parts of rubble are to be mixed with two of lime. Let it then be laid on, and rammed down with repeated blows by gangs¹ of men using wooden stamps. When the stamping is finished, it must be not less than nine inches thick. Upon this, a hard coat of powdered pottery is to be laid, three parts to one of lime, forming a layer of six inches.² On the finishing coat, a pavement³ of marble slabs or of mosaic is to be laid to rule and level. 4. When it is laid, and the proper fall is adjusted, it is to be rubbed down; so that, if the pavement is of marble, no projecting edges may arise in the diamonds or triangles or squares or hexagons;⁴ but the adjustment of the joints is to be level one with another. If it is mosaic, the edges of the tesserae are all to be level. For when the edges are not even, the rubbing down will be imperfect. So also Tiburtine tiles⁵ laid herring-bone fashion, are to be carefully handled so that they do not present gaps or ridges, being spread out and rubbed to a level. After the rubbing down, when they are completely smoothed and finished, marble dust is sprinkled over, and over that coats of lime and sand are to be applied.

³ Caesar took with him on his campaigns the materials for paving his headquarters with mosaics and marble, *Suet. Vit.* 46.

⁴ *Opus sectile* in marble in geometric forms.

⁵ Philander, *ad loc.*, reports them in the villas of Vopiscus and Hadrian at Tivoli.

5 Subdiu vero maxime idonea faciunda sunt pavimenta, quod contignationes umore crescentes aut siccitate decrescentes seu pandationibus sidentes¹ movendo se faciunt vitia pavimentis; praeterea gelicidia et proinae² non patiuntur integra permanere. Itaque si necessitas coegerit, ut minime vitiosa fiant, sic erit faciundum. Cum coaxatum fuerit, super altera coaxatio transversa sternatur clavisque fixa duplicem praebet contignationi loricationem. Deinde ruderi novo tertia pars testae tunsae admisceatur, calcisque duae partes ad quinque mortarii mixtionibus praestent responsum.

6 Statuminatione facta rudus inducatur, idque pistum absolutum ne minus pede sit crassum.³ Tunc autem nucleo inducto, uti s. s. est, pavementum e tessera grandi circiter binum digitum caesa struatur fastigium habens in pedes denos digitos⁴ binos; quod si bene temperabitur et recte fricatum fuerit, ab omnibus vitiis erit tutum. Uti autem inter coagmenta materies ab gelicidiis ne laboret, fracibus⁵ quotannis⁶ ante hiemem saturetur; ita non patietur in se recipere gelicidii pruinam.

7 Sin autem curiosius videbitur fieri oportere, tegulae bipedales inter se coagmentatae supra rudus substrata materia conlocentur habentes singulis coagmentorum frontibus excelsos canaliculos digitales. Quibus iunctis inpletur calx ex oleo subacta, confricenturque inter se coagmenta compressa. Ita calx, quae erit haerens in canalibus, durescendo [contestateque solidescendo]⁷ non patietur aquam

¹ sedentes H.

² proinae H: vera lectio apud Kr. qui hic, ut alibi, Ro correxit.

³ grassum H.

⁵ fragibus H.

⁴ digitus H S.

⁶ quodannis H.

5. Such pavements are most suitable to be used in the open. For wood floors swell with damp, or shrink in dry weather, or sag and settle, and make faulty pavements by giving way. Besides, ice and hoar-frost hinder their durability. But if need compels, we must limit their failure as far as possible in the following manner. After laying the floor, a second floor is to be laid above cross-wise; being fixed with nails, it will furnish a double coating to the joists. Then a third part of broken pottery is to be mixed in the fresh rubble, and two parts of lime are to answer to five¹ when mixed in the mortar.

6. Let the ground be spread with this, and the rubble be laid over it and pounded thoroughly to a thickness of not less than a foot. Then the finishing coat is to be put on as already described, and the pavement is to be laid with tesserae about two inches thick, with a fall of two inches in ten feet. If this is well mixed and properly rubbed over, it will be safe against all damage. That the mortar between the joints may not be affected by the frost, let it be soaked every year with oil lees before the winter. In this way it will not take up the frost into itself.

7. But if special care seems to be needed, tiles two feet square jointed together are to be laid upon the pavement of mortar, with small channels an inch deep on each side. When these are joined, lime tempered with oil is to be filled in, and the joints are to be pressed together and rubbed down. Thus the lime which will remain in the channels will harden and prevent water or anything else from passing

¹ I.e. One part potsherds, two parts rubble, two parts lime.

⁷ contestateque solidescendo G. om. H S, del. G^o.

neque aliam rem per coagmenta transire. Cum ergo fuerit hoc ita perstratum, supra nucleus¹ inducatur et virgis caedendo subigatur. Supra autem sive ex tessera grandi sive ex spica² testacea struantur fastigiis, quibus est supra scriptum, et cum sic erunt facta, non cito vitiabuntur.

II

1 CUM a pavimentorum cura discessum fuerit, tunc de albariis operibus est explicandum. Id autem erit recte, si glaebae calcis optimae ante multo tempore, quam opus fuerit, macerabuntur, uti, si qua glaeba parum fuerit in fornace cocta, in maceratione diuturna liquore defervere coacta uno tenore³ conquatur. Namque cum non penitus macerata sed recens sumitur, cum fuerit inducta habens latentes crudos calculos, pustulas emittit. Qui calculi, in opere uno tenore cum permacerantur, dissolvunt et
2 dissipant tectorii politiones. Cum autem habita erit ratio macerationis et id curiosius opere praeparatum erit, sumatur ascia et, quemadmodum materia dolatur, sic calx in lacu macerata ascietur. Si ad eam offenderint calculi, non erit temperata; cumque siccum et purum ferrum educetur, indicabit eam evanidam et siticulosam; cum vero pinguis fuerit et recte macerata, circa id ferramentum uti glutinum haerens omni ratione probabit esse temperatam.

¹ nucleus H.

² expica H, om. G.

³ tenore Joc: tempore H.

through the joints. When this has so been laid, the first finishing coat is to be spread, beaten with staves and so kneaded. Upon this, are to be put the pavements of thick tesserae or of tiles laid herringbone, with the fall already described, and when this is done, damage will not quickly arise.

CHAPTER II

ON THE PREPARATION OF STUCCO

1. WE now pass from the preparation of pavements to plasterers'¹ work. It will be necessary to obtain lumps of the best lime and crush it long before it is required; so that if any lump be imperfectly burnt in the kiln, owing to the long crushing, it is forced by the moisture to lose its heat and is tempered to an even quality. For when it is applied fresh and not thoroughly slaked; if, without due care it is spread containing rough lumps, it causes blisters. And these lumps of lime, when they get a thorough slaking after the work is begun, break up and destroy the surface of the stucco. 2. Now when attention is given to the slaking and care is taken in preparing the work, a trowel² is to be taken and the lime which is being slaked in the pit is to be chopped as one chops wood. If lumps are met in the chopping, the lime is not slaked. When the trowel is drawn out dry and clean, it shows that the lime is poor and absorbent; when, however, the lime is rich and duly slaked, it clings round the tool like glue, and shows that it is properly mixed. Then

² Neuburger, 407.

¹ The Roman stucco-work is unusually fine, and has preserved the fresco-paintings in a remarkable manner.

Tunc autem machinis comparatis camerarum dispositiones in conclavibus expediuntur, nisi lacunariis ea fuerint ornata.

III

- 1 Cum ergo camerarum postulabitur ratio, sic erit faciunda. Asseres directi disponantur inter se ne plus spatium habentes pedes binos, et hi maxime cupressei,¹ quod abiegni ab carie et ab vetustate celeriter vitiantur. Hique asseres, cum ad formam circinationis² fuerint distributi, catenis dispositis ad contignationes, sive tecta erunt,³ crebriter⁴ clavis ferreis fixi religentur. Eaeque catenae ex ea materia comparentur, cui nec caries nec vetustas nec umor possit nocere, id est e buxo, iunipero, olea, robore, cupresso ceterisque similibus praeter quercum, cum ea se⁵ torquendo rimas faciat⁶ quibus inest operibus.
- 2 Asseribus dispositis tum tomice ex⁷ sparto hispanico harundines graecae tunsae ad eos, uti forma postulat, religentur. Item supra cameram materies ex calce et harena mixta subinde inducatur, ut, si quae stillae⁸ ex contignationibus aut tectis ceciderint, sustineantur. Sin autem harundinis graecae copia non erit, de paludibus tenues colligantur⁹ et mataxae tomice¹⁰ ad iustam longitudinem una crassi-

¹ cupraessi H.

² circinationes H S.

³ tecta erunt G: tecter H.

⁴ crebriter H.

⁵ ea se Joc: eas H.

⁶ faciat Joc: faciant H S.

⁷ tomice ex Joc: tomices H S G^e, tonices G.

⁸ qua est ille H.

⁹ colligantur G S^e: -gatur H S.

¹⁰ tomicae H.

¹ Cicero watched over the work at his brother Quintus' country houses. He approved the pavements but not all the

the scaffolding is to be made ready, and the curved ceilings of the apartments are to be executed, unless they have straight panelled ceilings.

CHAPTER III

ON STUCCO

1. WHEN, therefore, curved ceilings¹ are in question, we must proceed as follows. Parallel laths are to be put not more than two feet apart. They are to be of cypress wood; deal is soon affected by decay and by age. The laths being fixed to the shape of an arch, are to be secured by wooden ties² to the floor or roof above, and fastened with an abundance of iron nails. The ties are to be of timber unaffected by decay or age or damp, such as box-wood, juniper, olive, winter oak, cypress and the like, except the common oak, which warps and causes cracks where it is used.

2. When the ribs are in their place, Greek reeds are to be bruised and bound to the ribs with cords of Spanish broom as the shape of the curve requires. Further, on the upper surface of the arch, mortar, mixed with lime and sand, is to be spread, so that if any drippings fall from the floor or roof above, they may be held up. If there be no supply of Greek reed, thin reeds are to be collected from the marshes, and are to be made up in bundles with cords of rough thread³ to the right length and of equal

arched ceilings. One to which he gave the name *testudo* had a fine curve. Cf. *Q. Fr.* III. 1.

² *catena* = wooden tie, Cato, *R. R.* xviii. 9.

³ *Mataxa*, *Schol. Ar. Ran.* 586.

tudine alligationibus temperentur, dum ne plus inter duos¹ nodos alligationibus binos pedes distent, et religentur cultellique lignei in eas tomice² Cetera omnia, uti supra scriptum est, configantur. 3 Cameris dispositis et intextis imum caelum earum trullissetur, deinde harena derigatur, postea autem creca aut marmore poliatur.

Cum camerae politae fuerint, sub eas coronae sunt subiciendae, quam maxime tenues et subtilis oportere fieri videbitur; cum enim grandes sunt, pondere deducuntur nec possunt se sustinere. In hisque minime gypsum debet admisceri, sed excepto³ marmore uno tenore perduci, uti ne praecipiendo non patiatur uno tenore opus inarescere. Etiamque cavendae sunt in cameris priscorum dispositiones, quod earum planitiae coronarum gravi pondere⁴ inpendentes sunt periculosae. Coronarum autem sunt figurae aliae caelatae. Conclavibus autem, ubi ignis aut plura lumina sunt ponenda, pura⁴ fieri debent, ut ea⁵ facilius extergeantur; in aestivis et exhedris, ubi minime fumus est nec fuligo potest nocere, ibi caelatae sunt faciendae. Semper enim album opus propter superbiam candoris non modo ex propriis sed etiam alienis aedificiis concipit fumum. 5 Coronis explicatis parietes quam⁶ asperrime trullissentur, postea autem supra, trullissatione⁷ subarescente, deformentur derectiones harenati, uti longitudines ad regulam et ad lineam, altitudines ad perpendicularum, anguli ad normam respondententes

thickness, provided that not more than two feet separates the knots of the bundles. These then are to be fixed with cord to the ribs as already described, and wooden pins are to be driven through them. Everything else is to be done as already described. 3. When the arched surfaces are fixed and interwoven with the reeds, the under surface is to be rough cast; then sand is to be applied and afterwards finished with hair mortar or marble.

When the coved surfaces are finished, the cornices must be carried along the springing below them, and these must be made as light and slender as possible. For when they are large, they settle under their own weight and cannot keep their place. Gypsum should not be employed, but selected marble of uniform texture, lest the gypsum by setting too soon prevent the work from drying uniformly. Further, we must avoid in these arched ceilings the old arrangements, because, in them, the projecting surfaces of the cornices overhang dangerously with their heavy weight. 4. Now there are other and more elaborate forms of cornice. In apartments, however, where there is a fire and lamps, the cornices should be plain so that they may be the more easily dusted. They can be carved in summer rooms and exedrae where there is very little smoke and soot cannot do any damage. For plaster work, with its glittering whiteness, takes up the smoke that comes from other buildings as well as from the owner's.

5. When the cornices are finished, the walls are to be rough-cast as coarsely as possible, and when the rough-cast is nearly dry, the surface of sand must be shaped in such a way that the lengths are set out by the rule and square, the heights by the

¹ duos G: uos H, .ii.os S. ² tomice G: -cae H.
³ ex creto Joc: excepto H. ⁴ pura H G.
⁵ eo Bondam: ea H, neutrum generale = eae res.
⁶ quem H. ⁷ trullissatione S: -nē G, -nem H.

exigantur; namque sic emendata tectoriorum¹ in picturis erit species. Subarescente iterum et tertio inducatur; ita cum fundatior erit ex harenato² derectura, eo firmior erit ad vetustatem soliditas tectorii.

6 Cum ab harena praeter trullisationem non minus tribus coriis fuerit deformatum, tunc e marmore graneo³ derectiones sunt subigendae, dum ita materies temperetur, uti, cum subigatur, non haereat ad rutrum, sed purum ferrum e mortario⁴ liberetur. Grandi inducto et inarescente alterum corium mediocre dirigatur; id cum subactum fuerit et bene fricatum, subtilius inducatur. Ita cum tribus coriis harenae et item marmoris solidati parietes fuerint, neque rimas neque aliud vitium in se recipere poterunt.

7 Sed et liaculorum subactionibus fundata soliditate marmorisque candore⁵ firmo levigata,⁶ coloribus cum politionibus inductis nitidos⁷ expriment splendores. Colores autem, udo⁸ tectorio cum diligenter sunt inducti, ideo non remittunt sed sunt perpetuo permanentes, quod calx, in fornacibus excocto liquore facta raritatibus et evanida, ieiunitate coacta corripit in se quae res forte contigerunt, mixtionibusque ex aliis potestatibus conlatis seminibus seu principis una solidescendo, in quibuscumque membris est formata

¹ tectoriorum *Joc*: tectorum *H*.

² harenato *G*: -ta *H S*.

³ graneo (*granio Fav.*) *Kr*: grandio *H*.

⁴ murtario *H*.

⁵ candore *ed*: -rē *G S*, -rem *H*.

⁶ levigata *Ro*: -tae *G*, -te *H S*.

⁷ nitidus *H*.

⁸ udo *Joc*: nudo *H*.

plummet, the corners by the set-square. For in this way the designs of the fresco-paintings will not be interfered with. A second and third coat is to be applied, as the one underneath dries. Thus when the solidity of the plaster is the more established from the application of the coats of sand, it is the more stable and enduring.

6. When in addition to the rough-cast, not less than three coats of sand have been laid, then coats of powdered marble are to be worked up, and the mortar is to be so mixed, that when it is worked up it does not adhere to the trowel, but the iron comes clean from the mortar. When a thick layer has been spread and is drying, a second thin coat is to be spread. And when this has been worked up and rubbed over, a still finer coat is to be applied. When the walls have been made solid with three coats of sand and also of marble, they will not be subject to cracks or any other fault.

7. After they are rendered solid by the use of the plasterer's tools and polished to the whiteness of marble, they will show a glittering splendour when the colours¹ are laid on with the last coat. When the colours are carefully laid upon the wet plaster, they do not fail but are permanently durable, because the lime has its moisture removed in the kilns, and becoming attenuated and porous, is compelled by its dryness to seize upon whatever happens to present itself. It gathers seeds or elements by mixture with other potencies,² and becoming solid

¹ The colours employed in the 'incrustation style' at Pompeii, are such as might be found in marble: black, white, reddish-violet, warm wine-red, dirty yellow, dark bluish-green, no blue. Baumeister, *Denkmäler*, 1376.

² *Potestates herbarum*, Verg. *A.* xii. 396.

- cum fit arida, redigitur, uti sui generis proprias videatur¹ habere qualitates.
- 8 Itaque tectoria, quae recte sunt facta, neque vetustatibus fiunt horrida neque, cum extergentur, remittunt colores, nisi si parum diligenter et in arido fuerint inducti.² Cum ergo itaque in parietibus tectoria facta fuerint, uti supra scriptum est, et firmitatem et splendorem et ad vetustatem permanentem virtutem poterunt habere. Cum vero unum corium harenae et unum minuti marmoris erit inductum, tenuitas eius minus valendo faciliter rumpitur nec splendorem politionibus propter inbecillitatem crassitudinis proprium optinebit.
- 9 Quemadmodum enim speculum argenteum tenui lamella ductum incertas et³ sine viribus habet remissiores splendores, quod autem e solida temperatura fuerit factum, recipiens in se firmis viribus politionem fulgentes in aspectu certasque considerantibus imagines reddet, sic tectoria, quae ex tenui sunt ducta, non modo sunt rimosae, sed etiam celeriter evanescent, quae autem fundata harenationis et marmoris soliditate sunt crassitudine spissa, cum sunt politionibus⁴ crebris subacta, non modo sunt nitentia, sed etiam imagines expressas aspicientibus ex eo opere remittunt.
- 10 Graecorum vero tectores non solum his rationibus utendo faciunt opera firma, sed etiam mortario conlocato, calce et harena ibi confusa, decuria hominum inducta ligneis vectibus pisant materiam, et ita ad cisternam⁵ subacta tunc utuntur. Itaque veteribus parietibus nonnulli crustas excidentis pro

¹ videatur *Joc*: videtur *H*.² inducti *Joc*: -ta *H*.³ incertas et *G S*: incerta. sed *H*.⁴ politionibus *H*.⁵ cisternam *Gr*: certamen *H*.

with whatever parts it is formed, it dries together so that it seems to have the qualities proper to its kind.

8. Stucco, therefore, when it is well made, does not become rough in lapse of time, nor lose its colours when they are dusted, unless they have been laid on carelessly and on a dry surface. When, therefore, stucco has been executed on walls in accordance with these instructions, it will retain its firmness and brilliance and fine quality. But when only one coat of sand and one of sifted marble is applied, the thin stucco cannot resist damage and is easily broken, and it does not keep a finish of proper brilliance because of its inadequate thickness.

9. For just as a silvered mirror covered with a thin layer gives back confused and ineffective reflections, while one that is made with a solid layer takes by its firmness a good finish, and reflects images which shine to the view and are clear to the spectator, so stucco which is spread with thin mortar soon cracks and perishes, while that which is based upon solid sand and marble of a suitable thickness, and is worked up by repeated polishing, not only shines but reflects clear images¹ from the wall to the spectator.

10. The Greek² plasterers not only make their work firm by using these methods, but they make a mortar trough with lime and sand mixed, and a gang of men beat the mortar with wooden staves, and they use the mortar thus worked up in the pit. Therefore some cut out panels from old walls and

¹ The stucco serves in some places as a mirror.² Greek materials and technique were taken over and developed by Roman craftsmen.

abacis utuntur, ipsaque tectoria abacorum et speculorum divisionibus circa se prominentes habent expressiones.

- 11 Sin autem in craticis tectoria erunt facienda, quibus necesse est in arrectariis et transversariis recipiunt umorem, cum autem arescent, necessario in tectoriis faciunt rimas, id ut non fiat, haec erit ratio. Cum paries totus luto inquinatus fuerit, tunc in eo opere cannae clavis muscariis perpetuae figantur, deinde iterum luto inducto, si priores transversariis harundinibus¹ fixae sunt, secundae erectis figantur, et uti supra scriptum est, harenatum et marmor et omne tectorium inducatur. Ita cannarum duplex in parietibus harundinibus transversis fixa perpetuitas nec tegmina nec rimam ullam fieri patietur.

IV

- 1 QUIBUS rationibus siccis locis tectoria oporteat fieri, dixi; nunc, quemadmodum umidis locis politiones² expediuntur, ut permanere possint sine vitiis, exponam. Et primum conclavibus, quae plano pede fuerint, in imo pavimento alte circiter pedibus tribus pro harenato testa trullissetur³ et dirigatur, uti eae partes tectoriorum ab umore ne vitientur. Sin autem aliqui paries perpetuos habuerit umores, paululum ab eo recedatur et struatur alter tenuis

¹ harundinibus H.

² politiones H.

³ trullissetur H S.

¹ Pes = ground; cf. 'footing,' Seneca, *Tranq. An.* X. 4.

use them like easel pictures. For the plaster work itself being divided into panels and mirrors, furnishes images which seem to stand out from it.

11. But if plastering is required on timber partitions, owing to their uprights and cross-pieces, cracks are bound to appear in it. For when they are coated with clay they must take up moisture; and when dry they shrink and cause cracks in the plaster. Hence the following precautions must be taken. When the whole wall has been smeared with clay, reeds are to be fixed right along with broad-headed nails. When a second layer of clay is put on, if the first coat has been set with horizontal reeds, the second must be set with the reeds vertical; according to the previous instructions, coats of sand and marble and indeed the complete coat of stucco may then be laid on. The double unbroken rows of reeds fixed crosswise on the walls will prevent any flaking off and the occurrence of cracks.

CHAPTER IV

ON STUCCO IN DAMP PLACES

1. I HAVE described how plastering is to be done in dry places: I will now explain how stucco is executed in damp places so as to avoid blemishes. And first as to rooms on the level ground.¹ To the height of about three feet from the pavement, rough-cast made of powdered earthenware instead of sand, is to be laid on, so that this part of the plaster may not suffer from damp. But if any wall shows continued damp, we must go a little behind it, and build another wall, thin and distant from the first,

- distans ab eo, quantum res patietur, et inter duos parietes canalis ducatur inferior, quam libramentum conclavis fuerit, habens nares ad locum patentem. Item, cum in altitudinem perstrictus¹ fuerit, relinquantur spiramenta; si enim non per nares umor et in imo et in summo habuerit exitus, non minus in nova structura se dissipabit. His perfectis paries testa trullissetur et dirigatur et tunc tectorio poliatur.
- 2 Sin autem locus non patietur structuram fieri, canales fiant et nares exeant² ad locum patentem. Deinde tegulae bipedales ex una parte supra marginem canalis³ inponantur, ex altera parte besalibus pilae substruantur, in quibus duarum tegularum anguli sedere possint, et ita a pariete eae distent,⁴ ut ne plus pateant palmum. Deinde insuper erectae hamatae⁵ tegulae ab imo ad summum ad parietem figantur, quarum interiores partes curiosius picentur, ut ab se respuant liquorem; item in imo et in summo supra camaram habeant spiramenta.⁶
- 3 Tum autem calce ex aqua liquida dealbentur, uti trullissationem testaceam⁷ non respuant; namque propter ieiunitatem quae est a fornacibus excocta non possunt recipere nec sustinere, nisi calx subiecta utrasque res inter se conglutinet et cogat coire.⁸ Trullissione inducta pro harenato testa dirigatur, et cetera omnia, uti supra scripta sunt in tectorii⁹ rationibus, perficiantur.

- 4 Ipsi autem politionibus eorum ornatus proprios

¹ perstructus *S*: perstrictus *H G*.

² exeunt *H*. ³ canales *H*.

⁴ distent *G S*: distant *H S*.

⁵ hamatae *Gr*: amatae *H S*, ammate *G*.

⁶ spiramenta *Joc*: stramenta *H*.

⁷ testaceam *rec*: testae tam *H*.

⁸ cogat *G*: cogitat quoire *H*.

⁹ tectorii *S*: -rio *H*.

as far as the case admits. Between the two walls, a gutter must be laid lower than the level of the room, with outlets into the open. Further, when the wall is built to the top, ventilation holes are to be left. For unless the moisture has outlets, it will none the less diffuse itself over the new wall. When these precautions have been taken, let the wall be rough-cast with powdered pottery, brought to an even surface and finished with plaster.

2. But if the space is not enough for another wall, let gutters be made with outlets to the open. Then let two-foot tiles¹ be placed above the edge of the gutter on the one side; on the other side, piers² of eight-inch bricks are to be built up, to take the edges of two tiles, and let the piers be distant not more than one palm's length from the wall. Then let flanged³ tiles be fixed to the wall vertically from the bottom to the top. Their inner side is to be carefully covered with pitch so as to reject the moisture. Also let there be air-holes at the bottom, and at the top above the spring of the ceiling.

3. They are then to be whitened over with lime and water so that they do not reject the rough-cast of powdered brick; for from the dryness that comes in the kiln they can neither take nor keep this coating unless the lime that is applied, glues both together and causes their union. When the rough-cast is put on, broken pottery is to be used instead of sand and the remainder is to be finished as described above about plastering.

4. The craftsmen, again, in the stucco-work, must

¹ 18-inch tiles, *sesquipedales*, Book V. x. 2.

² Book V. x. 2.

³ Lit. 'hooked.'

debent habere ad decoris rationes, uti et ex locis aptas et generum discriminibus non alienas habeant dignitates. Tricliniis hibernis non est utilis compositio nec melographia¹ nec camerarum coronario opere subtilis ornatus, quod ea et ab ignis fumo et ab luminum crebris fuliginibus conrumpuntur. In his vero supra podia abaci ex atramento sunt subigendi et poliendi cuneis silaceis² seu miniaceis³ interpositis; explicatae camerae pure politae; etiam pavimentorum non erit displicens, si qui animadvertere voluerit Graecorum ad hibernaculorum usum. Minime sumptuosus est utilis apparatus. 5 Foditur enim intra⁴ libramentum triclini altitudo circiter pedum binum, et solo festucato inducitur aut rudus aut testaceum pavementum ita fastigatum, ut in canali habeat⁵ nares. Deinde congestis et spisse calcatis carbonibus inducitur et sabulone et calce et favilla mixta materies crassitudine semipedali. Ad regulam et libellam summo libramento cote despumato redditur species nigri pavimenti. Ita conviviis eorum et, quod poculis et pytismatis⁶ effundetur, simul cadit siccescitque, quique versantur ibi ministrantes, etsi nudis pedibus fuerint, non recipiunt fraces⁷ ab eius modi genere pavimenti.

¹ megalographia *Joc*: melographia *H*; cf. μελογραφειω *eccl.* vide *infra* v. 2.

² silaceis *Joc*: sileceis *H*.

⁴ intra = infra ut saepe.

⁵ habeat *ed*: habeant *H*.

⁶ pytismatis *Salm*: sputismatis *H*.

⁷ fraces *Gr*: fragus *H*.

¹ Book I. ii. 5.

keep the designs in accordance with 'decor,'¹ that they may have a character fitted to their place and adjusted to the differences of style. In winter dining-rooms, painting of detail² is not useful in the composition, nor fine mouldings in the cornice under the vault, because they are damaged by the smoke from the fire and the frequent soot from the lamps.³ In these rooms, immediately above the dado, panels of black are to be worked up and finished with strips of yellow ochre or vermilion intervening. The arched ceilings have a plain finish. As to the pavements, it will not be unsatisfactory if we observe the arrangement of Greek winter apartments. A useful construction is not at all expensive. 5. For inside the levelled surface of the triclinium a depth of about two feet is dug. The ground is well rammed and a pavement of rubble or pounded brick is laid with a fall towards the gutter and its outlets. Then charcoal is collected and crushed by treading, and a mixture six inches thick of ashes, sand and lime is laid. The top surface is then rubbed with stone to rule and level, and has the appearance of a black pavement. At banquets, therefore, the wine which is thrown from the cups⁴ or spit out after tasting⁵ dries as it falls. And although the servants who are employed there are barefooted, their feet are not stained by the wine-lees on this kind of pavement.

¹ *m.* = 'anatomical drawing,' hence 'detail.' See v. 2. Plato uses μέλος and μέρος interchangeably, e.g. *Plat. Phileb.* 14E.

³ *Supra*, c. iii. 4.

⁴ The throwing of wine from the cup, *libatio*, was done in honour of a deity, or, like a toast, in honour of a person.

⁵ Wine was distinguished in tasting as rough, *asperum*, or smooth, *lene*, *Ter. Haut.* 458.

1 CETERIS conclavibus, id est vernis, autumnalibus, aestivis, etiam atriis et peristylis, constitutae sunt ab antiquis ex¹ certis rebus certae² rationes picturarum. Namque pictura imago fit eius, quod est seu potest esse, uti homines, aedificia, naves, reliquarumque rerum, e quibus finitis³ certisque corporibus figurata similitudine sumuntur exempla. Ex eo antiqui, qui initia expolitionibus instituerunt, imitati sunt primum crustarum marmorearum varietates et conlocationes, deinde coronarum, filicularum,⁴ cuneorum inter se varias distributiones.

2 Postea ingressi sunt, ut etiam aedificiorum figuras, columnarum et fastigiorum⁵ eminentes proiectiones⁶ imitarentur, patentibus autem locis, uti exhedris, propter amplitudines parietum scaenarum frontes tragico more aut comico seu satyrico designarent, ambulationibus vero propter spatia longitudinis varietatibus topiorum ornarent a certis⁷ locorum proprietatibus imagines exprimentes; pinguntur enim portus, promunturia, litora, flumina, fontes, euripi,⁸ fana, luci, montes, pecora, pastores. Nonnulli locis item signorum melographiam habentes deorum simulacra seu fabularum dispositas explica-

¹ ex certis *Joc* : & certis *H*.

² certe rationes *G* : caeterationes *H*.

³ finitis *Mar* : finibus *H*.

⁴ filicularum *Gr* : silicularum *H*.

⁵ fastidiorum *H S*.

⁶ proiectiones *Gr* : prolecturas *H S*.

⁷ certis *e*, : adcertis *H*.

⁸ eurypi *H G*.

¹ *Exemplum* = Gk. *paradeigma*, Herod. II. 86.

² Incrustation style : (a) plain, (b) florid.

1. IN other apartments for use in spring, autumn or summer, and also in atria and cloisters, the ancients used definite methods of painting definite objects. For by painting an image is made of what is, or of what may be; for example, men, buildings, ships, and other objects; of these definite and circumscribed bodies, imitations¹ are taken and fashioned in their likeness. Hence the ancients who first used polished stucco, began² by imitating the variety and arrangement of festoons, ferns, coloured strips.

2. Then they proceeded to imitate the contours of buildings, the outstanding projections of columns and gables;³ in open spaces, like exedrae, they designed scenery⁴ on a large scale in tragic, comic, or satyric style; in covered promenades, because of the length of the walls, they used for ornament the varieties of landscape gardening,⁵ finding subjects in the characteristics of particular places; for they paint harbours, headlands, shores, rivers, springs, straits, temples, groves, hills, cattle, shepherds. In places, some have also the anatomy of statues, the images of the gods, or the representations of legends;

³ The latter was the transition to architectural style, Bm. 1377.

⁴ Book V. vi. 9. Vitruvius suggests that the incrustation style corresponds to the tragic scenery; the architectural, to comic; the third, the landscape style, to satyric.

⁵ Stuart Jones suggests 'landscape' as the name of the third style, *Companion*, 402. This precisely corresponds to *topeodi species*, *H. V. vi. 9*.

tiones, non minus troianas pugnas seu Ulixis errationes per topia, ceteraque, quae sunt eorum similibus rationibus ab rerum natura procreata.

3 Sed haec, quae ex veris¹ rebus exempla sumebantur, nunc iniquis moribus inprobantur. <Nam pinguntur>² tectoriis monstra potius quam ex rebus finitis imagines certae: pro columnis enim struuntur calami striati, pro fastigiis appagineculi cum crispis foliis et volutis, item candelabra aedicularum sustentia figuras, supra fastigia eorum surgentes ex radicibus cum volutis³ teneri plures habentes in se sine ratione sedentia sigilla, non minus coliculi dimidiata⁴ habentes sigilla alia humanis, alia bestiarum capitibus.

4 Haec autem nec sunt nec fieri possunt nec fuerunt. Ergo ita novi mores coegerunt, uti inertiae mali iudices convincerent artium virtutes: quemadmodum enim potest calamus vere sustinere tectum aut candelabrum ornamenta fastigii, seu coliculus⁵ tam tenuis et mollis sustinere sedens sigillum, aut de radicibus et coliculis ex parte flores dimidiataque sigilla procreari? At haec falsa videntes homines non reprehendunt sed delectantur, neque animadvertunt, si quid eorum fieri potest necne. Iudiciis autem infirmis obscuratae mentes non valent probare, quod potest esse cum auctoritate et ratione decoris. Neque enim picturae probari debent, quae non sunt similes veritati, nec, si factae sunt elegantes ab arte, ideo de his statim debet 'recte' iudicari, nisi

¹ veris *e*, : *v&eris H*, *veteris S*, *veteribus G*.

² nam pinguntur *G*: *om. H S*.

³ voluteis *H*.

⁴ dimidiata *Joc*: *dimidiati H*.

⁵ culiculus *H S*.

further, the battles of Troy and the wanderings of Ulysses over the countryside with other subjects taken in like manner from Nature.

3. But these which were imitations based upon reality are now disdained by the improper taste¹ of the present. On the stucco are monsters rather than definite representations taken from definite things. Instead of columns there rise up stalks; instead of gables, striped panels with curled leaves and volutes. Candelabra uphold pictured shrines and above the summits of these, clusters of thin stalks rise from their roots in tendrils with little figures seated upon them at random. Again, slender stalks with heads of men and of animals attached to half the body.

4. Such things neither are, nor can be, nor have been. On these lines the new fashions compel bad judges to condemn good craftsmanship for dullness. For how can a reed actually sustain a roof, or a candelabrum the ornaments of a gable? or a soft and slender stalk, a seated statue? or how can flowers and half-statues rise alternately from roots and stalks? Yet when people view these falsehoods, they approve rather than condemn, failing to consider whether any of them can really occur or not. Minds darkened by imperfect standards of taste cannot discern the combination of impressiveness with a reasoned scheme of decoration. For pictures cannot be approved which do not resemble reality. Even if they have a fine and craftsmanlike finish, they are only to receive commendation if they

¹ Vitruvius follows the Stoic insistence on reality, as distinguished from the fantastic compositions which transformed the 'architectural' style under Alexandrian influences.

argumentationes certas rationes habuerint sine offensionibus explicatas.

5 Etenim etiam Tralibus cum Apaturius Alabandus eleganti manu finxisset scaenam in minusculo theatro, quod ecclesiasterion¹ apud eos vocitatur, in eaque fecisset columnas, signa, centauros sustinentes epistylia, tholorum² rotunda tecta, fastigiorum prominentes versuras, coronasque capitibus leoninis ornatas, quae omnia stillicidiorum e tectis habent rationem, praeterea supra ea nihilominus episcenium, in qua tholi, pronai, semifastigia omnisque tecti variis picturis fuerat ornatus, itaque cum aspectus eius scaenae propter asperitatem eblandiretur omnium visus et iam id opus probare fuissent parati, tum Licymnius³ mathematicus prodiit et ait

6 'Alabandis satis acutos ad omnes res civiles haberi,⁴ sed propter non magnum vitium indecentiae insipientes eos esse iudicatos,⁵ quod in gymnasio⁶ eorum quae sunt statuæ omnes sunt causas⁷ agentes, foro discos tenentes aut currentes seu pila ludentes. Ita indecens inter locorum proprietates status signorum publice civitati⁸ vitium existimationis adiecit. Videamus item nunc, ne a picturis scaena efficiat et nos Alabandis⁹ aut Abderitas. Qui enim vestrum domos supra tegularum tecta potest habere aut columnas seu fastigiorum expolitionis?¹⁰ Haec enim supra contignationis ponuntur, non supra tegularum tecta. Si ergo, quae non possunt in

¹ ἐκκλησιαστήριον *Joc*: eglisinterion *H*.

² tholorum *Joc*: pholumorum *H S G*.

³ Licymnius *Sillig*: lichinus *H*.

⁴ haberi *G*: habere *H S*. ⁵ iudicatus *H S*.

⁶ gipnasio *H*. ⁷ causas *G*: causa *H S*.

⁸ civitati *Joc*: -tis *H*. ⁹ Alabandis *Kr*: alabandas *H*.

¹⁰ explitionis *H*: expolicionis *S*.

exhibit their proper subject without transgressing the rules of art.

5. At Tralles,¹ Apaturius of Alabanda had invented scenery of fine technique for the tiny theatre which they call the Small Assembly. In this he showed columns, statues, or centaurs supporting the architraves, the orbéd roofs of domes, the projecting angles of pediments, cornices having lions' heads which provided outlets for the rain from the roofs. Besides, the story above the scenery had domes, porticoes, half pediments, and every kind of roof, with varied pictorial ornament. When, therefore, the appearance of such a stage, by its high relief,² charmed the eyes of all, and they were already on the point of applauding it, Licymnius the mathematician came forward and said, that (6) 'the inhabitants were shrewd enough in politics, but they had the reputation of being stupid because of one not very great fault, inconsistency. In the gymnasium, the statues were all of politicians; in the public assembly, they were of quoit-throwers or runners or javelin-throwers. Thus the unsuitable disposition of the statues added a blemish to the city in public estimation. Let us see to it that our stage scenery with its pictures does not make us citizens of Alabanda or of Abdera!³ For who of you can have above your roof tiles, buildings with columns and elaborate gables? For the latter stand upon floors, not above the roof tiles. If therefore,

¹ VII. *pref.* 12.

² The effect of perspective is compared to repoussé work; cf. Verg. *A. v.* 267. *cymbia . . . aspera signis*.

³ Abdera, proverbially a city of fools; Alabanda, proverbial for its luxury, Strabo XIV. 661.

veritate rationem habere facti, in picturis probaverimus, accedimus et nos his civitatibus, propter haec vitia insipientes sunt iudicatae.' quae

7 Itaque Apaturius contra respondere non est ausus, sed sustulit scaenam et ad rationem veritatis commutatam postea correctam adprobavit.¹ Utinam dii immortales fecissent, uti Licymnius² revivisceret et corrigeret hanc amentiam tectoriorumque errantia instituta! Sed quare vincat veritatem ratio falsa, non erit alienum exponere. Quod enim antiqui insumentes laborem ad industriam probare contendebant artibus, id nunc coloribus et eorum alleganti³ specie consecuntur, et quam subtilitas artificis adiciebat operibus auctoritatem, nunc dominicus sumptus efficit, ne desideretur.

8 Quis enim antiquorum non uti medicamento minio parce videtur usus esse? At nunc passim plerumque toti parietes inducuntur. Accedit huc chrysocola, ostrum, armenium. Haec vero cum inducuntur, etsi non ab arte sunt posita, fulgentes oculorum reddunt visus, et ideo quod pretiosa sunt, legibus excipiuntur, ut ab domino, non a redemptore repraesententur.

Quae commune facere⁴ potui, ut ab errore discedatur in opere tectorio, satis exposui; nunc de apparitionibus, ut succurrere potuerit, dicam, et primum, quoniam de calce initio est dictum, nunc de marmore ponam.

¹ adprobabit *H S.* ² uti licinius *H G,* utlicinius *S.*

³ alleganti *Gr:* aliganti *H.*

⁴ cummonefacere *H = κοινωνεῖν N.T.*

we approve in pictures what cannot justify itself in reality, we are added to those cities which, because of such faults, are esteemed slow-witted.'

7. So Apaturius had not the courage to reply, and removed the scenery; and when this was altered to resemble reality, he obtained sanction for his correction. O that heaven would raise Licymnius to life, and amend this madness, and the roving fashions of the fresco-painters! Now it is not foreign to our purpose to explain why a false method overcomes the truth. The aims which the ancients sought to realise by their painstaking¹ craftsmanship, the present attains by coloured materials and their enticing appearance. The dignity which buildings used to gain by the subtle skill of the craftsman, is not even missed owing to the lavish expenditure of the client.

8. For who of the ancients is not found to use minium as sparingly as the apothecary? But at the present day whole walls are covered with it everywhere. To it is added malachite, purple, Armenian ultramarine. And when these are applied, apart from any question of skill, they affect the vision of the eyes with brilliance. Because of their costliness they are excluded in the specification, so that they are charged to the client and not to the contractor.

I have sufficiently set forth the advice I could give for avoiding mistakes in the plaster work. I will now deal with the necessary supplies, as it may occur to me; and first—since lime has been mentioned to begin with—I will now describe marble.

¹ ad industriam = de industria.

I MARMOR non eodem genere omnibus regionibus procreatur, sed quibusdam locis glaebae ut salis micas perlucidas habentes nascuntur, quae contusae et molitae praestant operibus utilitatem. Quibus autem locis eae copiae non sunt, caementa marmorea, sive assulae¹ dicuntur, quae marmorarii ex operibus deiciunt, contunduntur² et moluntur, subcretum in operibus utuntur. Aliis locis, ut inter Magnesiae et Ephesi fines, sunt loca, unde foditur <glaeba> parata, quam nec molere nec cernere opus est, sed sic est subtilis,³ quemadmodum si qua est manu contusa et subcreta.

Colores vero alii⁴ sunt, qui per se certis locis procreantur⁵ et inde fodiuntur, nonnulli ex aliis rebus tractationibus aut mixtionum⁶ temperaturis compositi perficiuntur, uti praestent in eandem operibus utilitatem.

¹ assilae *H.*

² contunduntur et molliuntur et is qui ex his etc. viii. 2.—*expolitus et aridus ix. 3 H. verum ordinem restituit Lorentzen.*

³ subtilis *ed. Fl: subtilius H.*

⁴ aliis *H.*

⁵ procreantur *H.*

⁶ mixtionum *Nohl: mixtionibus H.*

¹ At this point the next leaf of the archetype begins: *est subcretum*, and goes on to *interaescant, infra viii. 2.* The next leaf but one begins *et is qui ex his, viii. 2,* and goes on to *expolitus et aridus, ix. 3.* These two leaves were interchanged so that the second followed upon *contunduntur et molliuntur* in *H* and the first leaf followed upon the end of the second after *expolitus et aridus.* In the Escorial MS. *e*, there is the marginal note at *molliuntur (sic): Inversa sunt haec omnia eadem serie*

1. MARBLE is not found of the same kind in all regions. In some places, blocks occur with shining flakes, as of salt. And these being crushed and ground are of use. But where there are no such supplies, marble-rubble, or splinters as they are called, which the marble workers throw down from their benches, are crushed and ground.¹ This material when sifted the plasterers use in their work. Elsewhere, for example between the boundaries of Magnesia and Ephesus, there are places where it is dug up ready for use, and need not be ground nor sifted.² It is as fine as if it had been crushed by hand and sifted.

There are other coloured materials which occur in a natural state in certain places, and are dug up from mines. Yet others are composed of different substances and are treated and blended so as to serve the same³ purposes in buildings.

quae in Blandiniano c habetur. (c = codice.) The end of the second leaf is marked, but *est* is attached to *aridus.* *subcretum* is an accusative after *utuntur.* Jocundus, who first printed the text in the proper order, rewrote the Latin of the chapter on marble after *deiciunt*, down to *colores vero, etc.*, where he takes up the text again. His interpolation appeared in the Tauchnitz Latin text and was followed by Gwilt; it was detected by Schneider, who, however, thought that Jocundus took it from a MS.

¹ When a compound verb occurs, it is repeated in the simple form, e.g. *exposui* and *ponam*, VII. v. 8; here *subcretum, cernere.*

² *In eandem*: use of preposition before direct object, cf. Cyprian ad Donatum 1, *in arbores et in vites videmus.*

- 1 PRIMUM autem exponemus, quae per se nascentia fodiuntur, uti sil,¹ quod graece *ochra*² dicitur. Haec vero multis locis, ut etiam in Italia, invenitur; sed quae fuerat optima, attica, ideo nunc non habetur, quod Athenis argentifodinae cum habuerunt familias, tunc specus sub terra fodiebantur ad argentum inveniendum. Cum ibi vena forte inveniretur, nihilominus uti argentum persequebantur³; itaque antiqui egregia copia silis ad politionem operum sunt usi.
- 2 Item rubricae copiosae multis locis eximuntur, sed optimae paucis, uti Ponto Sinope, et Aegypto, in Hispania Balearibus, non minus etiam Lemno, cuius insulae vectigalia Atheniensibus senatus populusque Romanus concessit fruenda. Paraetonium vero ex ipsis locis, unde foditur, habet nomen. Eadem ratione melinum, quod eius metallum⁴ insula cycladi Melo dicitur esse. Creta viridis item pluribus locis nascitur, sed optima Zmyrnae; hanc autem Graeci *Theodoteion*⁵ vocant, quod Theodotus nomine fuerat, cuius in fundo id genus cretae primum est inventum. Auripigmentum, quod *arsenicon* graece dicitur, foditur Ponto. Sandaraca⁶ item pluribus locis, sed optima Ponto proxime flumen Hypanim habet metallum.

¹ sil Schn: si H.² ochras H.³ persequebatur H.⁴ metallum Ro: metalli insulae H.⁵ theodoteū H.⁶ pontos andarea H.

¹ "Yellow and scarlet appeal to the undamaged eye."—William Morris, *Life by Mackail*, I. 106.

² The ochres, yellow and red, are earths coloured by iron oxide.

³ At Laurium near Sunium.⁴ About 167 B.O.⁵ Calcium carbonate.

1. FIRST we will describe the colours¹ which are dug up in their natural state, such as the yellow¹ material which the Greeks call ochre.² This is found in many places, as also in Italy. What used to be the best, the Attic, is not available now, for the following reason. When the silver mines at Athens³ were worked, shafts were dug underground to find silver; but when a vein of ochre happened to be found, they worked it no less than silver. Hence the ancients used a large amount of yellow in their frescoes.
2. Abundant *red* ochre, also, is extracted in many places, but the best is only found in a few, such as Sinope in Pontus, and in Egypt, in Spain in the Balearic Isles, and also in Lemnos, where the Roman government⁴ handed over the revenues to the Athenians. 3. Paraetonium white⁵ has its name from the place⁶ where it is mined. In the same way Melian white has its name because a mine is said to occur in Melos, an island of the Cyclades. 4. Green chalk is found in many places, but the best is from Smyrna, which the Greeks call *Theodoteion*, because Theodotus was the name of the man on whose land it was first found. 5. Orpiment,⁷ which the Greeks call arsenic is mined in Pontus. Red arsenic⁸ also, in many places, but the best is mined in Pontus close to the river Hypanis.⁹

⁶ Paraetonium on the coast of Tripoli.⁷ Arsenious sulphide.⁸ Arsenic disulphide.⁹ River Boug, in S. Russia.

- 1 INGREDIAR nunc minii rationes explicare. Id autem agris Ephesiorum Cilbianis¹ primum esse memoratur inventum. Cuius et res et ratio satis magnas habet admirationes. Foditur enim glaeba quae dicitur, antequam tractationibus ad minium perveniant, vena uti ferrum,² magis subrufo colore, habens circa se rubrum pulverem. Cum id foditur, ex plagis ferramentorum crebras emittit laerimas argenti vivi, quae a fossoribus statim colliguntur.
- 2 Hae glaebae, cum collectae sunt in officinam, propter umoris plenitatem coiciuntur in fornacem, ut interarescant,³ et is qui ex his ab ignis vapore fumus suscitatur, cum resedit in solum furni, invenitur esse argentum vivum. Exemptis glaebis guttae eae, quae residebunt,⁴ propter brevitates non possunt colligi, sed in vas aquae⁵ converruntur et ibi inter se congruunt et una confunduntur. Id autem cum sint quattuor sextariorum mensurae, cum expenduntur, invenientur esse pondo centum.
- 3 Cum in aliquo⁶ vase est confusum,⁷ si supra id lapide⁸ centenarium pondus inponatur, natat in summo neque eum liquorem potest onere suo premere nec elidere nec dissipare. Centenario sublato si ibi auri scripulum ponatur, non natabit,

¹ Cilbianis *Phil*: cliuvianis *H*.

² ferrum *Ro*: ferro *H*.

³ interarescant fuerit ceram punicam *etc.* (ix. 3) *H*.

⁴ resedebunt *H*.

⁵ in vasa quae *H*.

⁶ alico *H*.

⁷ confusum *ed*: -sus *H*.

⁸ lapidē *H*.

ON VERMILION AND QUICKSILVER

1. I WILL now go on to describe the treatment of minium¹ or vermilion. It is said to have been discovered in the Cilbian Fields of Ephesus.² The material and its treatment is sufficiently wonderful. For what is called the ore is first extracted. Then, using certain processes, they find minium. In the veins the ore is like iron, of a more caroty colour, with a red dust round it. When it is mined, and is worked with iron tools, it exudes many drops of quicksilver, and these are at once collected by the miners.

2. When the ore has been collected in the workshop, because of the large amount of moisture, it is put in the furnace to dry. The vapour which is produced by the heat of the fire, when it condenses on the floor of the oven, is found to be quicksilver. When the ore is taken away, the drops which settle because of their minuteness cannot be gathered up, but are swept into a vessel of water: there they gather together and unite. Four sextarii of quicksilver when they are weighed come to 100 lbs.³

3. When quicksilver is poured into a vessel, and a stone weight of 100 lbs. is placed upon it, the stone floats upon the surface. For it is unable by its weight to press the liquid down and so squeeze it out and separate it. If the stone is taken away and a scruple⁴ of gold is placed upon the quicksilver, it

¹ Sulphide of mercury.

² A fuller account is given by Pliny, *N.H.* XXXIII. 113.

³ Sextarius = .96 pint; libra = .7 lb. ⁴ 17.5 gr.

sed ad imum per se deprimetur. Ita non amplitudine ponderis sed genere singularum rerum gravitatem esse non est negandum.

4 Id autem multis rebus est ad usum expeditum. Neque enim argentum neque aes sine eo potest recte inaurari. Cumque in vestem intextum est aurum eaque vestis contrita¹ propter vetustatem usum non habeat honestum, panni in fictilibus vasis inpositi supra ignem conburuntur. Is cinis coicitur² in aquam, et additur eo argentum vivum. Id autem omnis micas auri corripit in se et cogit secum coire. Aqua diffusa cum id in pannum infunditur et ibi manibus premitur, argentum per panni raritates propter liquorem extra labitur, aurum compressione coactum intra purum invenitur.

IX

1 REVERTAR nunc ad minii temperaturam. Ipsae enim glabrae, cum sunt aridae, contunduntur pilis ferreis, et lotionibus et cocturis crebris relictis stercoribus efficiuntur, ut adveniant, colores. Cum ergo emissae³ sint ex minio⁴ per argenti vivi relictionem quas in se naturales habuerat virtutes, efficitur tenera natura et viribus inbecillis. Itaque² cum est in expolitionibus conclavium tectis inductum, permanet sine vitiis suo colore; apertis vero, id est peristyliis aut exhedris aut ceteris eiusdem modi locis,⁵ quo sol et luna possit splendores et radios

¹ constricta H.

² coigitur H.

³ emissae sint (Schn) Ro: emissa esset H.

⁴ minio Schn: minii H.

⁵ post locis H paginam aversam folii 103, fortasse propter membranae tenuitatem, vacuum exhibet.

will not swim, but is pressed down to the bottom, of itself. We cannot deny, therefore, that the gravity of bodies depends on their species¹ and not on their volume.

4. Quicksilver is adapted for many uses. Without it neither silver nor brass can be properly gilt. When gold is embroidered in cloth, and the garment, being worn out by age, is no longer fit for use, the cloth is put in earthenware vessels and burnt over the fire. The ashes are thrown into water, and quicksilver is added. This collects all the particles of gold and combines with them. The water is then poured away and the remainder is placed on a cloth, and is pressed by hand. Under this pressure the quicksilver being liquid passes through the pores of the cloth, and the pure gold is retained within.

CHAPTER IX

ON THE PREPARATION OF MINIUM

1. I WILL now return to the preparation of vermilion. When the ore is dry, it is bruised with iron rammers, and by frequent washing and heating, the waste is removed and the colour is produced. When, therefore, the quicksilver has thus been removed, minium loses its natural virtues, and becomes soft and friable.² 2. And so when it is used in the finishing of enclosed apartments, it remains of its own colour without defects; but in open places like peristyles and exedrae and so forth, where the sun and moon can send their brightness and their rays,

¹ Principle of specific gravity stated.

² Neuburger, 193.

inmittere, cum ab his locus tangitur, vitiatur et amissa virtute coloris denigratur. Itaque cum et alii multi tum etiam Faberius scriba, cum in Aventino¹ voluisset habere domum eleganter expolitam, peristyliis parietes omnes induxit minio, qui post dies xxx facti sunt invenusto varioque colore. Itaque primo locavit inducendos alios colores.

3 At² si qui subtilior fuerit et voluerit expolitionem miniaciam suum colorem retinere, cum paries expolitus et aridus est,³ ceram punicam⁴ igni liquefactam paulo oleo temperatam saeta inducat; deinde postea carbonibus in ferreo vase compositis eam ceram a primo cum pariete calfaciundo sudare cogat fiatque, ut peraequetur; deinde tunc candela linteisque⁵ puris⁶ subigat, uti signa marmorea nuda⁴ curantur (haec autem *ganosis*⁷ graece dicitur): ita obstans cerae punicae⁸ lorica non patitur nec lunae splendorem nec solis radios lambendo⁹ eripere his politionibus colorem. Quae autem in Ephesiorum metallis fuerunt officinae, nunc traiectae sunt ideo Romam, quod id genus venae postea est inventum Hispaniae regionibus, quibus metallis glaebae portantur et per publicanos Romae curantur. Eae autem officinae sunt inter aedem Florae et Quirini.

5 Vitiatur minium¹⁰ admixta calce. Itaque si qui

¹ *aventino rec*: *adventino H.* ² *at EG*: *ad HS.*

³ *et aridus est subcretum etc. (supra c. vi. 1).*

⁴ *punicam e₂ Sulp*: *pumicam H.*

⁵ *linteis (Plin. N.H. XXXIII. 122)*: *cunctis H.*

⁶ *puris ed*: *pluris H.*

⁷ *γάνωσις Welcker*: *gnosis H.*

⁸ *pumicae HS.*

⁹ *lambendo ed*: *labendo H.*

¹⁰ *minimum H.*

¹ After being in Caesar's service, he forged documents for Antony. Cic. Att. XIV. 18. 1.

the part so affected is damaged and becomes black, when the colour loses its strength. Among the many instances of this is the case of the public official Faberius.¹ He wished to have his palace on the Aventine² elegantly finished, and had all the walls of the peristyle covered with vermilion. In a month the walls turned to an unpleasant and uneven colour; and so he was the first to let a contract for laying on other colours.

3. But if anyone proceeds in a less crude fashion, and wishes a vermilion surface to keep its colour after the finishing of the wall is dry, let him apply with a strong brush Punic wax melted in the fire and mixed with a little oil. Then putting charcoal in an iron vessel, and heating the wall with it, let the wax first be brought to melt, and let it be smoothed over, then let it be worked over with waxed cord and clean linen cloths, in the same way as naked marble statues; this process is called *ganōsis* in Greek. 4. Thus a protective coat of Punic wax does not allow the brilliance of the moon or the rays of the sun to remove the colour from these finished surfaces by playing on them. The workshops which were in the Ephesian mines are now removed to Rome, because this kind of vein has been discovered in parts of Spain. The ore from the Spanish mines is conveyed to Rome and dealt with by the farmers-general. The workshops³ are between the temples of Flora and Quirinus.⁴

5. Minium is adulterated by the admixture of

² This plebeian quarter became fashionable under the empire.

³ On the Quirinal. Platner, 371.

⁴ Book III. ii. 7.

velit experiri id sine vitio esse, sic erit faciendum. Ferrea lamina sumatur, eo minium inponatur, ad ignem conlocetur, donec lamina candescat. Cum e candore color mutatus fuerit eritque ater, tollatur lamina ab igni, et sic refrigeratum restituatur in pristinum colorem; sine vitio esse probabit; sin autem permanserit nigro colore, significabit se esse vitiatum.

6 Quae succurrere potuerunt mihi de minio, dixi. Chrysocolla adportatur a Macedonia; foditur autem ex is locis, qui sunt proximi aerariis metallis. Armenium¹ et indicum nominibus² ipsis indicatur, quibus in locis procreatur.

X

1 INGREDIAR nunc ad ea, quae ex aliis generibus tractationum temperaturis commutata recipiunt colorum proprietates. Et primum exponam de atramento, cuius usus in operibus magnas habet necessitates, ut sint notae, quemadmodum praeparentur certis rationibus artificiorum, ad id temperaturae.

2 Namque aedificatur locus uti laconicum et ex politur marmore subtiliter et levigatur. Ante id fit fornacula habens in laconicum nares, et eius praefurnium magna diligentia conprimitur, ne³ flamma extra dissipetur. In fornace resina conlocatur.⁴ Hanc autem ignis potestas urendo cogit

¹ armenium *Schn*: minium *H*.

² nominibus *E G*: inomnibus *H S*.

³ nec *H et a. ras. S*.

⁴ collocetur *H S*.

lime. If anyone wishes to test its purity, the method is as follows. Take an iron plate, put the minium on it and set it on the fire until the plate is red-hot. When the colour is changed by the heat and is black, take the plate from the fire, and let the minium, on cooling, regain its former colour: its purity will be demonstrated. But if it remains black, it shows adulteration.

6. I have said what seemed of practical use about minium. Malachite is imported from Macedonia; it is mined in places which adjoin the copper mines. Ultramarine (armenium¹) and indigo (indicum²) show by their names the places where they are found.

CHAPTER X

ON BLACK

1. I WILL now proceed to those materials which, by special processes, are changed substantially, and acquire the properties of colour. And first I will deal with black. The use of this in buildings is often necessary, so that we must know how the tempering of materials for the purpose is carried out by special craftsmanship.

2. A vaulted apartment is built like a sweating chamber,³ and is covered carefully with a marble facing and smoothed down. In front of it a small furnace is built with outlets into the chamber, and the mouth of the furnace is carefully enclosed so that the flame does not escape. Resin is placed in the furnace. Now the fiery potency burns it and compels

¹ Probably azurite; perhaps powdered lapis lazuli.

² Indian ink.

³ Book V. x. 5.

emittere per nares intra laconicum fuliginem, quae circa parietem et camerae curvaturam adhaerescit. Inde collecta partim componitur ex gummi subacta¹ ad usum atramenti librarii, reliquum tectores glutinum³ admiscentes in parietibus utuntur. Si autem hae copiae non fuerint paratae, ita necessitatibus erit administrandum, ne expectatione morae res retineatur. Sarmenta aut taedae schidiae comburantur; cum erunt carbones, extinguantur, deinde in mortario cum glutino² terantur; ita erit atramentum⁴ tectoribus non invenustum. Non minus si faex vini arefacta et cocta in fornace fuerit et ea contrita cum glutino in opere inducetur, super quam³ atramenti suavitatis efficiet colorem; et quo magis ex meliore vino parabitur, non modo atramenti, sed etiam indicii colorem dabit imitari.

XI

1 CAERULI temperationes Alexandriae primum sunt inventae, postea item Vestorius⁴ Puteolis instituit faciendum. Ratio autem eius, e quibus est inventa, satis habet admirationis. Harena enim cum nitri flore conteritur adeo subtiliter, ut efficiatur quemadmodum farina; et aes cyprum⁵ limis crassis uti scobis facta⁶ mixta conspargitur, ut conglomeretur; deinde pilae manibus versando efficiuntur et ita

¹ subacta *Schn*: subacto *x*.

² glutino *H*.

³ super quam *Ro*: superque *H*.

⁴ Vestorius *e*₂: Nestorius *e*₂ *schol*, *Sulp*.

⁵ cyprum *H*: cyprium *e*₂ *Sulp*. *Plin. N.H. XXXIV. 116*.

⁶ facta *Kr*: factam *H*.

it to emit soot through the outlets into the chamber. The soot clings round the walls and vaulting of the chamber. It is then collected and in part compounded with gum and worked up for the use of writing ink; the rest is mixed with size and used by fresco-painters for colouring walls. 3. But if this cannot be obtained, we must satisfy our requirements without holding back the works by the delay involved. Brushwood or pine-chips must be burnt, and when they are charred they are to be pounded in a mortar with size. Thus the fresco-painters will have a not unpleasant black colour. 4. Again, a black colour even more pleasant than this is produced if the dregs of wine are dried and burnt in a furnace, and applied to the walls after being ground with size. The use of the finer wines will allow us to imitate not only black but indigo.

CHAPTER XI

ON BLUE AND YELLOW

1. THE processes for making blue were first discovered at Alexandria; afterwards also Vestorius founded a factory at Puteoli.¹ His method and his ingredients are sufficiently noteworthy. Sand is ground with flowers of soda to such fineness that it becomes like flour. Cyprian copper is sprinkled from rough files like fine dust so that it combines with the mixture. Then, it is rolled by hand into

¹ Vestorius, a banker of Puteoli, was the friend of Cicero and Atticus. He advised Cicero about building, *Att. XIV. 9. 1*. He was not interested in philosophy but a sound accountant, *Att. XIV. 12. 3*.

conligantur, ut inarescant; aridae componuntur in urceo fictili, urcei in fornace: ita¹ aes et ea harena ab ignis vehementia confervescendo cum coaruerint, inter se dando et accipiendo sudores a proprietatibus discedunt suisque rebus per ignis vehementiam² confectis² caeruleo rediguntur colore. Usta vero, quae satis habet utilitatis in operibus tectoriis, sic temperatur. Glaeba silis³ boni coquitur,⁴ ut sit in igni candens; ea autem aceto extinguitur et efficitur purpureo colore.

XII

1 DE cerussa aerugineque, quam nostri aerucam vocitant, non est alienum, quemadmodum comparetur, dicere. Rhodo enim doleis sarmenta conlocantes aceto suffuso supra sarmenta conlocant plumbeas massas, deinde ea operculis obturant, ne spiramentum obturatum emittatur. Post certum tempus aperientes inveniunt e massis plumbeis cerussam. Eadem ratione lamellas aereas conlocantes² efficiunt aeruginem, quae aeruca appellatur. Cerussa vero, cum in fornace coquitur, mutato colore ad ignem incendi efficitur sandaraca—id autem incendio facto ex casu didicerunt homines—et ea multo meliorem usum praestat, quam quae de metallis per se nata foditur.

¹ ita Schn: sita ut H.

² silis rec: silix H.

² confectis Rode: -ti H.

⁴ quoquitur H.

¹ Artificial cinnabar discovered by Callias of Athens 315 B.C. Plin. N.H. XXXIII. 113.

² Lead acetate.

balls and they are put together to dry. When dry they are collected in an earthenware jar, and the jars are put in a furnace. In this way the copper and the sand burning together owing to the vehemence of the fire dry together, and, interchanging their vapours, lose their properties; and their own character being overcome by the vehemence of the fire, they acquire a blue colour. 2. Burnt 'cinnabar,'¹ which is very useful in plastering, is mixed as follows. Ore of good yellow ochre is roasted to a bright heat. It is quenched with vinegar and becomes of a purple colour.

CHAPTER XII

ON WHITE LEAD, VERDIGRIS, RED LEAD

1. It belongs to our subject to deal with the production of white lead and verdigris which our people call *aeruca*. At Rhodes they place a layer of chips in a large vessel, and pouring vinegar over them, they then put lumps of lead on the top. The vessel is covered with a lid lest the vapour which is enclosed should escape. It is opened after a certain time and the lead is found to be changed into *cerussa*.² In the same way, by using plates of copper they obtain verdigris or *aeruca*.³ 2. When white lead is roasted in a furnace, under the heat of the fire it changes its colour and becomes red lead or *sandaraca*.⁴ This fact was accidentally discovered in a conflagration. A much better result is obtained in this way than from the natural substance which is procured from the mines.

² Basic copper acetate; mixed with wine, the green of MSS.

⁴ Lead oxide.

¹ INCIPIAM nunc de ostro dicere, quod et carissimam et excellentissimam habet praeter hos colores aspectus suavitatem. Id autem excipitur e conchylio marino, e quo purpura ¹ efficitur, cuius non minores sunt quam ceterarum <rerum> ² naturae considerationibus admirationes, quod habet non in omnibus locis, quibus nascitur, unius generis colorem, sed ² solis cursu naturaliter temperatur. Itaque quod legitur Ponto et Gallia, quod hae regiones sunt proximae ad septentrionem, est atrum; progredientibus inter septentrionem et occidentem invenitur lividum; quod autem legitur ad aequinoctialem orientem et occidentem, invenitur violacio colore; quod vero meridianis regionibus excipitur, rubra procreatur potestate, et ideo hoc Rhodo etiam insula ³ imae sunt solis cursui. Ea conchyliis, cum sunt lecta, ferramentis circa scinduntur, e quibus plagis purpurea ³ sanies, uti lacrima profluens, excussa in mortariis terendo comparatur. Et quod ex concharum marinarum testis eximitur, ideo ostrum est vocitatum. Id autem propter salsuginem cito fit siticulosum, nisi mel habeat circa fustum.

XIV

¹ FIUNT etiam purpurei colores infecta creta rubiae ⁴ radice et hysgino, ⁵ non minus et ex floribus alii

¹ purpura H S.

² add. Joc.

³ purporea H S.

⁴ rubiae Joc: rubra H.

⁵ et hysgino Joc (Plin. N.H. XXXV. 45): et excygno H.

¹ Gk. *ostreon* = oyster.

CHAPTER XIII

ON PURPLE

1. WE now turn to purple, which of all is most prized and has a most delightful colour excellent above all these. It is obtained from sea shells which yield the purple dye, and inspires in students of nature as much wonder as any other material. For it does not yield the same colour everywhere, but is modified naturally by the course of the sun. 2. What is collected in Pontus and Gaul is black because these regions are nearest to the north. As we proceed between the north and west it becomes a leaden blue. What is gathered in the equinoctial regions, east and west, is of a violet colour. But in the southern regions it has a red character; for example, in Rhodes and other similar regions which are nearest the sun's course. 3. When the shells have been collected, they are broken up with iron tools. Owing to these beatings a purple ooze like a liquid teardrop is collected by bruising in a mortar. And because it is gathered from the fragments of sea shells it is called *ostrum*.¹ On account of its saltness it soon dries unless it is mixed with honey.²

CHAPTER XIV

ON ARTIFICIAL COLOURS

1. PURPLE colours are also made by dyeing chalk with madder and hysginum.³ Other colours also

² It is replaced in modern times by indigo derivatives.

³ Dye made from a parasite of *quercus coccifera*, a small oak-bush found in Spain and N. Africa.

colores. Itaque tectores, cum volunt sil atticum¹ imitari, violam aridam coicientes in vas cum aqua,² confervfaciunt ad ignem, deinde, cum est temperatum, coiciunt <in>³ linteum, et inde manibus exprimentes recipiunt in mortarium aquam ex violis coloratam, et eo cretam infundentes et eam terentes efficiunt silis atticum colorem.

2 Eadem ratione vaccinium temperantes et lacrem miscentes purpuram faciunt elegantem. Item qui non possunt chrysocolla propter caritatem uti, herba, quae luteum appellatur, caeruleum inficiunt, et utuntur viridissimum colorem; haec autem infectiva appellatur. Item propter inopiam coloris indici cretam selinusiam⁴ aut anulariam vitro,⁵ quod Graeci *isatin*⁶ appellant, inficientes imitationem faciunt indici coloris.

3 Quibus rationibus et rebus ad dispositionem firmitatis quibusque decoras oporteat fieri picturas, item quas habeant omnes colores in se potestates, ut mihi succurrere potuit, in hoc libro perscripsi. Itaque omnes aedificationum perfectiones, quam habere debeant opportunitatem ratiocinationis, septem voluminibus sunt finitae; insequenti autem de aqua, si quibus locis non fuerit, quemadmodum inveniatur et qua ratione ducatur quibusque rebus, si erit salubris et idonea, probetur, explicabo.

¹ sil atticum H.

² vas cum aqua E G: vas cum quā H.

³ add. ed.

⁴ selinusiam Joc (Plin. N.H. XXXV. 46): Sinysiam H.

⁵ vitro Schn: vitroque H.

⁶ isatin Turnebus: insallim H.

are obtained from flowers. When the stucco painters wish to imitate Attic ochre, they put dried yellow violets into a vessel with water and boil them. Then, when it is ready, it is poured on a cloth and squeezed by hand. They receive in a mortar the water coloured by the violets, and pouring chalk into it and rubbing it, they obtain the colour of Attic ochre.

2. In the same way they prepare whortleberries and mix them with milk, thus making a fine purple. Malachite is dear, and those who cannot afford it steep blue dye with the herb which is called weld¹ and obtain a brilliant green. This is called dyer's green. Also, because of the scarcity of indigo they make a dye of chalk from Selinus, or from broken beads, along with woad (which the Greeks call *isatis*), and obtain a substitute for indigo.

3. I have described in this book what suggested itself as of practical use, about the methods and materials required for stability, and how painting is employed in decoration, and, further, about the properties of colours. Thus in seven books I have defined the right methods of building and the due adjustment of the design. In the following book, which is about water, I will explain how it may be found where it is lacking, how it may be supplied and by what tests we may determine its wholesomeness and suitability for its purpose.

¹ A kind of mignonette yielding a yellow dye.

BOOK VIII

LIBER OCTAVUS

1 DE septem sapientibus Thales Milesius omnium rerum principium aquam est professus, Heraclitus ignem, Magorum sacerdotes aquam et ignem, Euripides, auditor Anaxagorae, quem philosophum Athenienses scaenicum appellaverunt, aera et terram, eamque e caelestium imbrium conceptionibus in-seminatam fetus gentium et omnium animalium in mundo procreavisse, et quae ex ea essent prognata, cum dissolverentur temporum necessitate¹ coacta in eandem² redire, quaeque de aere nascerentur,³ item in caeli regiones reverti neque interitiones recipere et dissolutione mutata in eam recidere, in qua ante fuerant,⁴ proprietatem. Pythagoras vero, Empedocles, Epicharmos alique physici et philosophi haec principia esse quattuor proposuerunt: aerem, ignem, terram, aquam, eorumque inter se cohaerentiam⁵ naturali figuratione e generum discrimini-bus efficere qualitates.

¹ necessitate S: -tē H G.

² eandem G: eadem H S.

³ de aere nascentur G, dehaere nascentur H, de hac renasce-
rentur S.

⁴ fuerant G: fuerat H.

⁵ cohaerentiam Gal: -tia H.

¹ In the preface to Book VII, the pre-Socratic philosophers are distinguished as 'physici'.

² The names are variously given, e.g. Plato, *Protag.* 343A.

BOOK VIII

PREFACE

1. THALES¹ of Miletus, one of the Seven Wise Men,² affirmed that the principle of all things is water; Heraclitus, fire; the priests of the Magi,³ water and fire; Euripides,⁴ the pupil of Anaxagoras, whom the Athenians named the philosopher on the stage, air and earth.⁵ 'The earth,' he said, 'impregnated by the seed contained in the rain from the sky, gives birth to mankind and all creatures living in the world; and whatever is born of earth, when it is dissolved by the necessary compulsion of time, returns to the same earth. What is born of the air returns to the regions of the sky and is not subject to destruction, but being changed by dissolution returns to that property of which it consisted before.' Pythagoras, Empedocles, Epicharmus,⁶ and other physicists and philosophers affirmed that there are four principles: air, fire, earth, water; and that their coherence taking shape according to kind produces attributes in accordance with the variation of species.

¹ In the *LXX Daniel* i. 20, φιλόσοφοι corresponds to μάγοι in Theodotion's version of *Daniel* which from an early date had replaced the *LXX Daniel*. Swete, *Introduction*, 47.

⁴ Plato, *Rep.* 568A.

⁵ Fr. 836 (Nauck).

⁶ Of Syracuse, comic dramatist and philosopher, met Aeschylus at the court of Hiero I.

2 Animadvertimus vero non solum nascentia ex his esse procreata, sed etiam res omnes non ali sine eorum potestate neque crescere nec tueri. Namque corpora sine spiritus¹ redundantia non possunt habere vitam, nisi aer influens cum incremento fecerit auctus et remissiones continenter. Caloris vero si non fuerit in corpore iusta comparatio, non erit spiritus animalis neque erectio firma, cibique vires non poterunt habere coctionis temperaturam. Item si non terrestri cibo membra corporis alantur, deficientur et ita a terreni principii mixtione erunt deserta.

3 Animalia vero si fuerint sine umoris potestate, exsanguinata et exsucata a principiorum liquore interarescent. Igitur divina mens, quae proprie necessaria essent gentibus, non constituit difficilia et cara, uti sunt margaritae, aurum, argentum ceteraque, quae neque corpus nec natura desiderat, sed sine quibus mortalium vita non potest esse tuta, effudit ad manum parata per omnem mundum. Itaque ex his, si quid forte deficit in corpore spiritus, ad restituendum aer adsignatus id praestat. Apparatus autem ad auxilia caloris solis impetus et ignis inventus tutiorem efficit vitam. Item terrenus fructus escarum praestans copiis supervacuis desiderationibus alit et nutrit animales pascendo continenter. Aqua vero non solum potus sed infinitas usu praebendo necessitates, gratas, quod est gratuita, praestat utilitates.

4 Ex eo etiam qui sacerdotia gerunt moribus Aegyptiorum, ostendunt omnes res e liquoris potestate consistere. Itaque cum hydria aqua² ad templum

¹ spiritus *Schn* : spiritu *H*.

² hydriâ aqua *Ro* : hydrio quem *H*.

2. We observe, however, that things are not only created of them at birth, but also are nourished, grow, and are preserved by their power. For apart from the flow of breath, bodies cannot have life unless the influx of air continually increases inspiration and respiration. If there is not in the body a due provision of heat, there will be neither breath of life nor firm and upright pose, and the properties of food will lack the effect of digestion. Again, if the members of the body are not nourished by the produce of the earth they will waste away, being deprived of the mixture of that element.

3. Animals which lack the water lose their blood and juices, and dry up their liquid part. Therefore the Divine Mind has not made those things which are specially necessary to mankind as inaccessible and expensive as are pearls, gold, silver and the like, which neither our body nor our nature requires, but has poured forth ready to hand through all the world what is necessary for the safety of our mortal life. Therefore, if of these elements there is a need of breath, the air appointed to supply it, does so. The heat of the sun and the invention of fire are ready to help us with warmth and to render our life more safe. Further, the fruit of the earth, surpassing our need of food by abundant supplies, feeds and nourishes animals by unfailing diet. Water, moreover, by furnishing not only drink but all our infinite necessities, provides its grateful utility as a gracious gift.

4. Hence also those who fill priesthoods of the Egyptian tradition¹ show that all things arise from the principle of water. Therefore, after carrying water

¹ Plutarch, *de Iside*, 59. Water is identified with Osiris. Thales is said to have been inspired by Egyptian priests.

aedemque casta religione refertur, tunc in terra procumbentes manibus ad caelum sublatis inventionis¹ gratias agunt divinae benignitati.

Cum ergo et a physicis et philosophis et ab sacerdotibus iudicetur ex² potestate aquae omnes res constare, putavi, quoniam in prioribus septem voluminibus rationes aedificiorum sunt expositae, in hoc oportere de inventionibus aquae, quasque habeat in locorum proprietatibus virtutes, quibusque rationibus ducatur, et quemadmodum ante³ probetur, scribere.

I

1 Est enim maxime necessaria et ad vitam et ad delectiones⁴ et ad usum cotidianum. Ea autem erit facilius, si erunt fontes aperti et fluentes. Sin autem non profluent, quaerenda sub terra sunt capita et colligenda. Quae sic erunt experienda, uti procumbatur in dentes, antequam sol exortus fuerit, in locis, quibus erit quaerendum, et in terra mento conlocato et fulto prospiciantur eae regiones; sic enim non errabit excelsius quam oporteat visus, cum erit in motum mentum, sed libratam altitudinem in regionibus certa finitione designabit. Tunc, in quibus locis videbuntur umores con crispantes et in aera surgentes, ibi fodiatur; non enim in sicco loco hoc potest signum fieri.

2 Item animadvertendum est quaerentibus aquam, quo genere sint loca; certa enim sunt, in quibus

¹ inventionis Ro: -nibus H.

² ante Ro: into H.

³ & potestate H.

⁴ delectiones H et a. c. G.

in a vessel to the precincts and temple with pure reverence, they fall upon the ground, raise their hands to heaven and return thanks to the divine goodwill for its invention.

Therefore, inasmuch as physicists philosophers and the clergy judge that everything consists of the principle of water, I thought fit that, having explained in the previous seven volumes the methods of building, I should write in the present volume about the discovery of water, the qualities of its special sources, the methods of water-supply and of testing water before using it.

CHAPTER I

ON FINDING WATER

1. WATER is very necessary for life, for delight, for daily use. Water will be more accessible if the springs flow in the open. But if they do not flow above ground, sources are to be sought and collected underground. The method of trial is to fall on one's face before sunrise in the place where the search is to take place, and placing and supporting one's chin on the ground, to look round the neighbourhood. For when the chin is fixed, the sight will not wander higher than it ought, but will mark the same level throughout the landscape, with a definitely limited height. Thereupon digging is to be carried out where moisture seems to curl upwards and rise into the air; for this indication cannot arise on dry ground.

2. Those who look out for water must also observe the nature of the ground; for there are certain

nascitur. In creta tenuis et exilis et non alta est copia; ea erit non optimo sapore. Item sabulone soluto tenuis, sed inferioris loci invenietur; ea erit limosa et insuavis. Terra autem nigra sudoris et stillae exiles inveniuntur, quae ex hibernis tempestatibus collectae in spissis et solidis locis subsident; haec habent optimum saporem. Glarea vero mediocres et non certae¹ venae reperiuntur; hae quoque sunt egregia suavitate. Item sabulone masculo harenaque carbunculo certiores [et stabiliores]² sunt copiae; eaeque³ sunt bono sapore. Rubro saxo et copiosae et bonae, si non per intervenia dilabantur et liquescant. Sub radicibus autem montium et in saxis silicibus uberiores et affluentiores; eaeque⁴ frigidiores sunt et salubriores. Campestribus autem fontibus salsae, graves, tepidae, non suaves,⁵ nisi quae ex montibus sub terra submanantes erumpunt in medios campos ibique⁶ arborum umbris contectae praestant montanorum fontium suavitatem.

³ Signa autem, quibus terrarum generibus supra scriptum est, ea invenientur nascentia: tenuis iuncus, salix erratica, alnus, vitex, harundo, hederæ aliaque, quae eiusmodi sunt, quae non possunt nasci per se sine umore. Solent autem eadem in lacunis nata esse, quae sidentes⁷ praeter reliquum agrum excipiunt ex imbribus et agris per hiemem propterque capacitatem diutius conservant umorem. Quibus non est

¹ non certae *Joc (Fav., Plin.)*: non incertae *H.*

² et stabiliores *G*: *om. H S.*

⁴ aequae *H.* ⁵ suavis *H.*

⁶ medio campo sibique *H S.*

³ eaeque *G*: aequae *H.*

⁷ sedentes *H.*

¹ *Creta* = clay from which bricks, etc. are made, Book II. viii. 19.

places where it rises. In clay¹ the supply is thin and scanty and near the surface; this will be not of the best flavour. In loose gravel the supply is scanty but it is found lower down; this water will be muddy and unpleasant. In black earth, moisture and small drops are found; when these gather after the winter rains and settle in hard solid receptacles, they have an excellent flavour. But in gravel small and uncertain currents are found; these also are of unusual sweetness. In coarse gravel, common sand and red sand,² the supply is more certain, and this is of good flavour. The waters from red rock are copious and good, if they do not disperse through the interstices and melt away. At the foot of mountains³ and in flinty rocks water flows more copiously; and this is more cool and wholesome. Springs on level ground are salt, coarse, lukewarm and unpleasant, unless they flow from the mountains underground, and break out in the middle of the fields, and there under the shadows of the trees they furnish the sweetness of mountain springs.

³ The following growths will be found to show where the kinds of soil already described are found; the slender bulrush, the wild willow, the alder, the agnus castus, reeds, ivy and the like which cannot grow without moisture. These plants usually grow in marshy places; for these, settling below the level of the rest of the ground, receive water from the rains and from the rest of the land in winter, and because of their capacity retain the moisture. We must

² The pebble beds and the New Red Sandstone of the Triassic series supply abundant water.

³ Cretaceous formations containing water are found all along the Apennines.

credendum, sed quibus regionibus et terris, non lacunis, ea signa nascuntur, non sata, sed naturaliter per se procreata, ibi est quaerenda.

- 4 In quibus si eae significabuntur inventiones, sic erunt experiundae. Fodiatur quoquoersus locus latus ne minus pedes <tres, altus pedes>¹ quinque, in eoque conlocetur circiter solis occasum scaphium aereum aut plumbeum aut pelvis. Ex his quod erit paratum, id² intrinsecus oleo ungetur ponaturque inversum, et summa fossura operiatur harundinibus aut fronde, supra terra obruatur; tum postero die aperiat, et si in vaso stillae sudorisque erunt, is locus habebit aquam.
- 5 Item si vasum ex creta factum non coctum in ea fossione eadem ratione opertum positum fuerit, si is locus aquam habuerit, cum apertum fuerit,³ vas umidum erit et iam dissolvetur ab umore. Vellusque lanae si conlocatum erit in ea fossura, insequenti autem die de eo aqua expressa erit, significabit eum locum habere copiam. Non minus si lucerna concinnata oleique plena et accensa in eo loco operta fuerit conlocata et postero die non erit exusta, sed habuerit reliquias olei et enlychni⁴ ipsaque umida invenietur, indicabit eum locum habere aquam, ideo quod omnis tepor ad se ducit umores. Item in eo loco ignis factus si fuerit et percalfacta terra et adusta vaporem nebulosum ex se suscitaverit, is⁶ locus habebit aquam. Cum haec ita erunt pertemp-
tata et, quae supra scripta sunt, signa inventa, tum deprimendus est puteus in eo loco, et si erit caput

not rely upon these places, but water is to be sought in those regions and soils other than marshes in which such trees are found naturally, and not artificially planted.

4. When such a discovery is indicated, we must make trials in the following way. A hole is to be dug not less than three feet square and five feet deep, and about sunset a bronze or lead vessel, or a basin, is to be placed there. Whichever it is, must be smeared inside with oil and put upside down, and the top of the hole covered with rushes or leaves; and earth must be thrown above. On the next day it is to be opened, and if there are drops of water and moisture in the vessel, water will be found.

5. Further, if a vessel made of clay, but not burnt, be covered in the same way and put in the pit, if there is water in the place, the vessel will be moist when opened and soon be destroyed by the moisture. Or if a fleece of wool is placed in the hole, and next day water can be squeezed from it, it will show that water is abundant there. Similarly let a lamp be trimmed and filled with oil and lit. If it is covered and put in that place and on the following day it is not burnt out, but has traces of the oil and wick and is itself found moist, it will show that water is found there, because all heat draws moisture to itself. Again, if a fire is made there and the soil which is heated and burnt raises a misty vapour from itself, the place will supply water. 6. When these experiments have been made and the above mentioned signs of water found, a well is to be sunk. If a head of

¹ *add. Phil (ex Fav.).* ² *id S: idque H G.*

³ *cum apertum fuerit om. S (del. G^o).*

⁴ *enlychm Gr: inlychni H S, ≡ lychni G^o.*

aquae inventum, plures circa sunt fodiendi et per specus¹ in unum locum omnes conducendi.

Haec autem maxime in montibus et regionibus septentrionalibus sunt quaerenda, eo quod in his et suaviora et salubriora et copiosiora inveniuntur. Aversi enim sunt solis cursui, et in his locis primum crebrae sunt arbores et silvosae, ipsique montes suas habent umbras obstantes et radii solis non directi perveniunt ad terram nec possunt umores exurere.

7 Intervallaque montium maxime recipiunt imbres et propter silvarum crebritatem nives ab umbris arborum et montium ibi diutius conservantur, deinde liquatae per terrae venas percolantur et ita perveniunt ad infimas montium radices, ex quibus profluentes fontium erumpunt fructus.² Campestribus autem locis contrario non possunt habere copias. Nam quaecumque sunt, non possunt habere salubritatem, quod solis vehemens impetus propter nullam obstantiam umbrarum eripit exhauriendo fervens ex planitie camporum umorem, et si quae sunt aquae apparentes,³ ex his, quod est levissimum tenuissimumque et subtili salubritate, aer avocans dissipat in impetum caeli, quaeque⁴ gravissimae duraeque et insuaves sunt partes, eae in fontibus⁵ campestribus relinquuntur.

II

1 ITAQUE, quae ex imbris aqua colligitur, salubriores habet virtutes, quod eligitur ex omnibus fontibus

¹ per specus *ed*: perspicuus *H S*, ppsicus *G*.

² fructus *H (i. marg. G°)*: ructus *G*.

³ apparantes *H*.

⁴ quaque *H*.

⁵ frontibus *H*.

water is found, several wells are to be sunk round it, and all are to be brought together by underground channels into one place.

Water, however, is to be most sought in mountains and northern regions, because in these parts it is found of sweeter quality, more wholesome and abundant. For such places are turned away from the sun's course, and in these especially are many forest trees; and the mountains themselves have intervening shadows, nor do the sun's rays reach the earth directly and cause the moisture to evaporate.

7. Valleys between mountains are subject to much rain, and because of the dense forests, snow stands there longer under the shadow of the trees and the hills. Then it melts and percolates through the interstices of the earth and so reaches to the lowest spurs of the mountains, from which the product of the springs flows and bursts forth. But on the plains one cannot get supplies of water. And what there is, cannot be wholesome, because, in the absence of shadow, the violent power of the sun catches and drains, by its heat, the moisture from the level fields. And if any water is visible, the air calls out the lightest, thinnest and most subtly wholesome part and dissipates it towards the sky; but the heaviest, the harsh and unpleasant parts, are left in the field springs.

CHAPTER II

ON RAIN-WATER

1. THEREFORE rain-water has more wholesome qualities, because it comes from the lightest and

levissimis subtilibusque tenuitatibus, deinde per aeris exercitationem percolata tempestatibus liquescendo pervenit ad terram. Etiamque non crebriter in campis confluunt imbres, sed in montibus aut ad ipsos montes, ideo quod umores ex terra matutino solis ortu moti cum sunt egressi, in quamcumque partem caeli sunt proclinati, trudent aera; deinde, cum sunt moti, propter vacuitatem loci post se
 2 recipiunt aeris ruentis¹ undas. Aer autem, qui ruit, trudens quocumque umorem per vim spiritus impetus et undas crescentes facit ventorum. A ventis autem quocumque feruntur² umores conglobati ex fontibus, ex fluminibus et paludibus et pelago, cum tempore solis colligunt et exhauriunt et ita tollunt in altitudinem nubes. Deinde cum aeris unda nitentes, cum perventum ad montes, ab eorum offensa et procellis propter plenitatem et gravitatem liquescendo disparguntur³ et ita diffunditur in terras.

3 Vaporem autem et nebulas et umores ex terra nasci haec videtur efficere ratio, quod ea habet in se et calores fervidos et spiritus immanes refrigerationesque et aquarum magnam multitudinem. Ex eo, cum refrigeratum noctu sol oriens impetu tangit orbem terrae et ventorum flatus oriuntur per tenebras, ab umidis locis egrediuntur in altitudinem nubes. Aer autem cum a sole percalefactus⁴ cum rationibus tollit ex terra umores, licet ex balineis
 4 exemplum capere. Nullae enim camerae, quae sunt

¹ ruentis Ro: ruentes H.

² feruntur H^o: feruntur HG.

³ dispargunt H. ⁴ percalefactus H.

¹ cum tempore is doubtful; cf. *nec vernus melius floret cum tempore ramus*, ps. Cypr. de resurrectione 224.

most finely tenuous of all sources; then filtering through moving air, it liquefies in storms and so reaches the earth. Further, it is not often that rain showers gather in the plains, but rather on the mountains or near them. For moisture rising from the earth being moved by the rising sun at dawn, thrusts the air into whatever part of the sky it tends. Thereupon the moisture thus moved, because of the vacuum, receives behind it the waves of rushing air. 2. Now the air which rushes on, thrusting the moisture in whatever direction, by the violence of the blast causes the rising force and undulations of the winds. Whithersoever the wind carries the massed moisture from springs, from rivers and marshes and the sea, the moisture under the sun's influence¹ is collected and drawn forth, and the clouds are raised on high. Then the clouds, supported on the wave of air, meet the resistance of the mountains and, becoming liquid in rain-storms, by their fullness and weight, break and their water is poured over the fields.

3. Now vapour and clouds and moisture seem to rise from the earth, for this reason that the earth contains both fervid heat and huge blasts of air, coldness and a large amount of water. Hence when the world is cooled by night, and the rising sun touches it by its force, and gusts of wind rise up through the darkness, the clouds rise on high from the damp places. In that the air warmed by the sun through its effect raises moisture from the earth, we can find a parallel in the baths. 4. For the vaulted chambers² which enclose a hot bath cannot

² Book V. x. 3.

caldariorum, supra se possunt habere fontes, sed caelum, quod est ibi¹ ex praefurniis ab ignis vapore percalefactum, corripit ex pavimentis aquam et aufert secum in camararum curvaturas et sustinet, ideo quod semper vapor calidus in altitudinem se trudit. Et primo non remittit propter brevitatem, simul autem plus umoris habet congestum, non potest sustinere propter gravitatem, sed stillat supra lavantium capita. Item² eadem ratione caelestis aer, cum ab sole percepit calorem, ex omnibus locis hauriendo tollit umores et congregat ad nubes. Ita enim terra fervore tacta eicit umores, etiam corpus hominis ex calore emittit³ sudores.

5 Indices autem sunt eius rei venti, ex quibus qui a frigidissimis partibus veniunt procreati, septentrio et aquilo, extenuatos⁴ siccitatibus in aere flatus spirant; auster vero et reliqui, qui a solis cursu impetum faciunt, sunt umidissimi et semper adportant⁵ imbres, quod percalefacti ab regionibus fervidis adveniunt, ex omnibus⁶ terris labentes eripiunt umores et ita eos profundunt ad septentrionales regiones.

6 Haec autem sic fieri testimonio possunt esse capita fluminum, quae orbe terrarum chorographiis picta itemque scripta plurima maximaque inveniuntur egressa ad septentrionem. Primumque in India Ganges et Indus ab Caucasio monte oriuntur; Syria Tigris et Euphrates; Asiae item,⁷ Ponto Borysthenes, Hypanis, Tanais; Colchis⁸ Phasis; Gallia Rhodanus;

¹ ibi *ed*: ubi *H*.

² item *S*: idem *H*.

³ emittit *h*: emit ut *H*.

⁴ & tenuatos *H*.

⁵ adportent *H*.

⁶ omnis *H*.

⁷ item *S G*: idem *H G*.

⁸ conchis *H S*: colchys *G*.

have springs above them, but the ceiling which is there heated with hot air from the furnace, takes up water from the pavement, and carrying it up to the curved surface of the vaulting, supports it, because warm vapour always thrusts upward. At first, owing to the slight amount, the ceiling does not drip, but as soon as it has collected more moisture, it cannot keep the water up because of its weight, but sprinkles it on the heads of the bathers. In the same way the air of the sky, receiving heat from the sun, draws moisture from all directions, lifts it and assembles it into clouds. For the earth when it is touched by heat casts forth moisture,—the human body also sweats from warmth.

5. This is proved by the winds. For those which originate and blow from the coldest quarters, the north and north-east, bring currents of air which are rarefied by their dryness; but the south wind and the rest, which attack us from the south, are very moist and always bring rains, because they come warmed from the hot regions; and as they fall, they take up the moisture everywhere and so pour it forth towards the north.

6. A proof of this is found in the sources of rivers, as they are painted on maps of the world,¹ and as they are described.² The most numerous and the largest are found to issue in the north. First of all in India, the Ganges and Indus rise in the Caucasus; in Syria, the Tigris and Euphrates; in Asian Pontus, the Dnieper, the Boug and the Don; in Colchis, the Phasis; in Gaul, the Rhone; in Celtic territory, the

¹ An allusion to the map of Agrippa in the Porticus Vipsania. *Plin. N.H. III. 17.*

² An allusion to the geographical work of Agrippa.

Celtica Rhenus; citra Alpis Timavos et Padus; Italia Tiberis; Maurusia, quam nostri Mauretanium appellant, ex monte Atlante Dyris,¹ qui ortus ex septentrionali regione progreditur per occidentem ad lacum Eptagonum et mutato nomine dicitur Agger, deinde ex lacu Eptabolo sub montes desertos subterfluens per meridiana loca manat et influit in Paludem quae appellatur, circumcingit Meroen, quod est Aethiopum meridianorum regnum, ab hisque paludibus se circumagens per flumina Astansobam² et Astoboam³ et alia plura pervenit per montes ad cataractam ab eoque se praecipitans per septentrionalem pervenit inter Elephantida et Syenen⁴ Thebaicosque in Aegyptum campos et ibi Nilus appellatur.

7 Ex Mauretania autem caput Nili profluere ex eo maxime cognoscitur, quod ex altera parte montis Atlantis alia capita item profluentia ad occidentem Oceanum, ibique nascuntur ichneumones, crocodili, aliae similes bestiarum pisciumque naturae praeter hippopotamos.

8 Ergo cum omnia flumina magnitudinibus in orbis terrarum descriptionibus a septentrione⁵ videantur profluere Afrique campi, qui sunt in meridianis partibus subiecti solis cursui, latentes penitus habent umores nec fontes crebros amnesque raros, relinquuntur,

¹ dryis H.

² hastansoban H, -bā S.

³ astoboam G^o: adstoboam H. ⁴ suenen H.

⁵ aseptentrionē H.

¹ Addiris, Plin. *N.H.* V. 13. Dyris = the name of Mt. Atlas, Strabo, 825.

² The course of the Nile is now described.

Rhine; south of the Alps, the Timavo and Po; in Italy, the Tiber; in Morocco, which we call Mauretania, the Dyris¹ comes from Mount Atlas. This river² rises in the north, turns to the west to Lake Eptagonus³ and there, changing its name, it is called Agger.⁴ Thence it flows from Lake Eptabolos⁵ under mountains of the desert through the south and flows into the Marsh⁶ so-called. It then winds round Meroe, which is the Southern Ethiopian kingdom, and turning from these marshes through the rivers Astansobas and Astoboas⁷ and many others, it arrives through the mountains at the Cataract. Thence rushing northwards it passes into Egypt, between Elephantis and Syene and the Theban plain, and is there called the Nile.

7. What shows more than anything else that the source of the Nile rises in Mauretania, is, that on the other side of Mount Atlas there are other springs flowing to the Western Ocean, and in them are found the ichneumon, the crocodile and other animals and fishes of a like nature, but not the hippopotamus.⁸

8. Since then all rivers of magnitude seem according to the descriptions of the world to flow from the north, and the plains of Africa, which are on the south subject to the sun's course, have their moisture deeply hidden and few fountains or rivers,

³ Probably the Albert Nyanza.

⁴ Ger, Plin. *N.H.* V. 14. *Gir* in Berber signifies 'running water.'

⁵ Probably the Victoria Nyanza.

⁶ Probably the sudd of the White Nile.

⁷ Atbara. These descriptions were probably due to traders journeying from Zanzibar.

⁸ The hippopotamus is found in the Niger as well as in the upper waters of the Nile.

uti multo meliora inveniuntur capita fontium, quae ad septentrionem aut aquilonem spectant, nisi si incidant in sulphureum locum aut aluminosum seu bituminosum. Tunc enim permutantur *<et>*¹ aut calidae aquae aut frigidae odore malo et sapore profundunt fontes. Neque enim calidae aquae est ulla proprietas, sed frigida aqua, cum incidit percurrens in ardentem locum, effervescit et percalefacta egreditur per venas extra terram. Ideo diutius non potest permanere, sed brevi spatio fit frigida. Namque si naturaliter esset calida, non refrigeraretur calor eius.² Sapor autem et odor et color³ eius non restituitur, quod intinctus et commixtus est propter naturae raritatem.

III

1 SUNT autem etiam nonnulli fontes calidi, ex quibus profluit aqua sapore optimo, quae in potione ita est suavis, uti nec fontalis ab Camenis nec Marcia saliens desideretur. Haec autem ab natura perficiuntur his rationibus. Cum in imo per alumen aut bitumen seu sulphur ignis excitatur, ardore percandefacit terram, quae est supra se; autem⁴ fervidum emittit in superiora loca vaporem, et ita, si qui in his locis, qui sunt supra, fontes dulcis aquae nascuntur, offensi eo vapore effervescunt inter venas et ita profluunt incorrupto sapore.

¹ *add. Joc.*

² *calcoleius H.*

³ *color e₂ Sulp: calor H.*

⁴ *fortasse soloecismus: cf. autem non habuit, Quint. I. 5. 39.*

¹ Lucretian phrase; cf. *textura praedita rara*, iv. 196. Vitruvius has *rara proprietas*, Book II. iii. 4.

it remains that much better sources are found to the north and north-east, unless they come upon sulphur, alum or bitumen. For then they are changed; and either hot or cold, they send forth springs of a bad flavour or odour. 9. For there is no special character attaching to hot water, but when cold water, as it runs, comes upon hot ground, it seethes and comes out warm through the cracks above ground. Therefore it cannot retain its heat, but soon becomes cold. For if it were naturally warm, its warmth would not be subject to chill. But taste and smell and colour are not surrendered, because it is steeped and blended with these qualities owing to its rarefied texture.¹

CHAPTER III

ON THE NATURE OF DIFFERENT WATERS

1. THERE are some hot springs from which water flows of excellent flavour and so pleasant to drink that we miss neither the Fountain of the Camenae² nor the conduit of the Marcian Aqueduct.³ Hot springs arise naturally in the following way. Fire arises underground owing to alum or bitumen or sulphur, and by its heat makes the soil above it to glow. It further sends a warm vapour to the surface of the ground, and whatever springs of sweet water rise in such places, meeting this vapour they surge forth between the cracks and flow without damage to their flavour.

² On the south side of the Caelian Hill, Platner, 89. Frontin. *Aquaed.* 4.

³ 'Finest of all water,' Plin. *N.H.* XXXI. 41.

2 Sunt etiam odore et sapore non bono frigidi fontes, qui ab inferioribus locis penitus orti per loca ardentia transeunt et ab eo per longum spatium terrae percurrentes refrigerati perveniunt supra terram sapore odore coloreque corrupto, uti in Tiburtina via flumen Albula et in Ardeatino fontes frigidi eodem odore, qui sulphurati dicuntur, et reliquis locis similibus. Hi autem, cum sunt frigidi, ideo videntur aspectu fervere, quod, cum in ardentem locum alte penitus inciderunt, umore et igni inter se congruentibus offensa vehementi fragore validos recipiunt in se spiritus, et¹ ita inflati vi venti coacti bullientes crebre per fontes egrediuntur. Ex his autem qui non sunt aperti, sed a² saxis continentur, per angustas venas vehementia spiritus extruduntur ad summos grumorum tumulos.

3 Itaque qui putant³ se altitudine, qua sunt grumi, capita fontium posse⁴ habere, cum aperiunt fossuras latius, decipiuntur. Namque uti aeneum vas non in summis labris plenum sed aquae mensurae suae capacitatis habens tribus duas partes operculumque⁵ in eo conlocatum, cum ignis vehementi fervore tangatur, percalefieri cogit aquam, ea autem propter naturalem raritatem in se recipiens fervoris validam inflationem non modo implet vas, sed spiritibus extollens operculum et crescens abundat, sublato autem operculo emissis inflationibus in aere patenti rursus ad suum locum residit:⁶ ad eundem modum ea capita fontium cum sunt angustiis con-

¹ et ed: ut H.

² a Schn: aut H.

³ qui putant rec: quitant H.

⁴ posse Joc: fosse H.

⁵ operculum ed: opertum H.

⁶ resedit H.

¹ Sulphur baths still used.

2. There are also cold springs not of pleasant smell or taste, which, rising far below, pass through hot soil, and thereupon running a long distance are chilled and reach the surface with damage to their flavour, their smell and colour; such as the river Albula¹ on the Via Tiburtina,² and the cold springs near Ardea, with the same smell, and called sulphur springs, and in other like places. Now these springs, being cold, have the appearance of bubbling, because when, deep down, they come upon a hot place, the fire and water meet; and because of the collision, the springs take up with a loud noise the violent currents of air. They are thus forced by the power of the wind driven into them, to issue with much bubbling through the fountains. But those which have no outlet and are contained by rocks, are driven forth through narrow passages by the vehemence of the air-currents to the tops of hillocks.

3. Hence those who think that they can have fountain-heads of the same height as the hills find their mistake when they open out their trenches. For instance, let a bronze vessel be filled not to the brim but holding two-thirds, by measure, of its capacity of water; and let a lid be placed upon it. When it is subjected to the vehement heat of the fire, it makes the water boil. Yet, owing to its natural penetrability, it takes up a strong inflation of the heat, and not only fills the vessel but, raising the lid with the currents of air, it expands and boils over. When, however, the lid is removed, the steam passes into the open and the water settles down into its own place again. In the same way when fountain-heads are forced along narrow channels, the

² Road to Tivoli 16 miles north-east of Rome.

pressa, ruunt ¹ in summo spiritus aquae bullitus, simul autem sunt latius aperti, exanimati per raritates liquidae potestatis residunt et restituntur in libramenti proprietate.

4 Omnis autem aqua calida ideo [quod] ² est medicamentosa, quod in pravis rebus percocta aliam virtutem recipit ad usum. Namque sulphurosi fontes nervorum labores reficiunt percalefaciendo exurendoque caloribus e corporibus umores vitiosos. Aluminosi autem, cum dissoluta membra corporum paralyti aut aliqua vi morbi receperunt, fovendo per patentes venas refrigerationem ³ contraria caloris ⁴ vi reficiunt, et hoc continenter restituntur in antiquam membrorum curationem. Bituminosi autem interioris corporis vitia potionibus purgando solent mederi.

5 Est autem aquae frigidae genus nitrosum, uti Pinnae Vestinae, Cutiliis aliisque locis similibus, quae potionibus depurgat per alvumque transeundo etiam strumarum minuit tumores. Ubi vero aurum, argentum, ferrum, aes, plumbum reliquaeque res earum similes fodiuntur, fontes inveniuntur copiosi, sed hi maxime sunt vitiosi. Habent enim vitia aquae calidae sulphur alumen bitumen, eademque, ⁵ per potiones cum in corpus iniit et per venas permanendo nervos attingit et artus, eos durat inflando. Igitur nervi inflatione turgentes e longitudine contrahuntur et ita aut nervicos aut podagricos efficiunt homines,

¹ compressa ruunt *G*: conpraesserunt *H*.

² *del. rec.* ³ refrigerationem *ed*: -ne *H*.

⁴ caloris vi *Joc*: calore sui *H*.

⁵ eademque *Gr*: eademque *H S*.

¹ Favourite phrase of Lucretius: *plumbi potestas*, v. 1242.

² Hippocrates, *de aere aquis locis*, is followed in some places by Vitruvius.

currents of air rush in bubbles through the water on the top; as soon as the channels are opened out wider, the springs part with the air through the pores of the liquid potency, ¹ and, settling down, they regain their proper level.

4. As to the curative ² power of warm springs, the reason is that the water being thoroughly heated in vitiated soils, takes up an additional and useful quality. For sulphur springs refresh muscular weakness by heating and burning poisonous humours from the body. Alum springs affect parts of the body which are dissolved ³ by paralysis or some stroke of disease; they warm through the open pores and overcome the cold by the opposing power of the heat, and thus forthwith the diseased parts are restored to their ancient health. Bitumen ⁴ springs furnish draughts which purge and heal interior defects.

5. There is an alkaline sort of cold spring, as at Penne and Cutili ⁵ and other like places, which, when taken, purges, and passing through the intestines, also lessens scrofulous tumours. But when gold, silver, iron, copper, lead and the like are mined, abundant springs are found, but mostly impure. They have the impurities of hot springs, sulphur, alum, bitumen; and when the water is taken into the body and, flowing through the vessels, reaches the muscles and joints, it hardens them by expansion. Therefore the muscles swelling with expansion are contracted in length. In this way men suffer from cramp or gout,

¹ *Vulg. II. Cor. v. 1, si terrestri domus . . . dissolvatur.*

² Berkeley, *Siris*, deals with curative virtues of tar, a form of bitumen.

⁵ *Towus* in the Abruzzi.

ideo quod ex durissimis et spissioribus¹ frigidissimisque rebus intinctas habent venarum raritates.

6 Aquae autem species est, quae cum habeat non satis perlucidas et ipsa uti flos natat in summo, colore similis vitri purpurei. Haec maxime considerantur Athenis. Ibi enim ex eiusmodi locis et fontibus in asty et ad portum Piraeum ducti sunt salientes, e quibus bibit nemo propter eam causam, sed lavationibus² et reliquis rebus utuntur, bibunt autem ex puteis et ita vitant eorum vitia. Troezeni non potest id vitari, quod omnino aliud genus aquae non reperitur, nisi quod *cibdeli* habeant; itaque in ea civitate aut omnes aut maxima parte sunt pedibus vitiosi. Cilicia vero civitate³ Tarso flumen est nomine Cydnos, in quo podagrivi crura macerantes levantur dolore.

7 Sunt autem et alia multa genera, quae habent suas proprietates, ut in Sicilia flumen est Himeras, quod, a fonte cum est progressum, dividitur in duas partes; quae pars profluit contra Etruriam, quod per terrae dulcem sucum percurrit, est infinita dulcedine, quae altera parte per eam terram currit, unde sal foditur, salsum habet saporem. Item Paraetonio et quod est iter ad Ammonem et Casio⁴ ad Aegyptum lacus sunt palustres, qui ita sunt salsi, ut habeant insuper se salem congelatum. Sunt autem et aliis pluribus locis et fontes et flumina <et>⁵ lacus, qui per salifodinas percurrentes necessario salsi perficiuntur.

8 Alii autem per pingues terrae venas profluentes uncti oleo fontes erumpunt, uti Solis, quod oppidum

¹ spissioribus *e*₂ *ed*: spissionibus *H*.

² labationibus *H*.

³ civitate *Joc*: civitas *H*.

⁴ cassio *H S*.

⁵ *add. ed.*

because they have the pores of the vessels saturated with hard, thick and cold particles.

6. There is a kind of water which has pores insufficiently clear; a foam floats on the top, in colour like blue glass. This is especially seen at Athens where conduits¹ from such places and fountains are taken to the city and the Piraeus. No one drinks from it because of the reason given, but they use it for baths and so forth. They drink from wells and thus avoid its ill effect. This cannot be avoided at Troezen, because no other water is found there at all, except what is furnished by polluted springs; therefore in that city either all or the greatest part suffer from their feet. In the Cilician city Tarsus there is a river, Cydnus by name, in which gouty persons bathe their legs to relieve the pain.

7. There are many other kinds of water which have their properties. In Sicily, the river Himeras,² on leaving its source, divides into two branches: one flows towards the coast which faces Etruria and is of infinite sweetness, because it runs through the sweet juices of the soil; the other stream which runs through the other part where there are salt mines has a salt flavour. At Paraetonium and on the road to the oracle of Ammon, and at Mt. Casius in Egypt, there are marshy lakes which contain so much salt that it cakes over them. In many other places there are springs and rivers and lakes which run through salt mines and necessarily are made salt.

8. Other fountains flow through rich veins of soil and spring up with an oily surface. At Soli, a town

¹ Esp. the Enneacrunos, *J.H.S.* XIII. 141.

² Northern branch, the Fiume Grande; the southern, the Fiume Salso.

est Ciliciae, flumen nomine Liparis, in quo natantes aut lavantes ab ipsa aqua unguuntur. Similiter Aethiopiae lacus est, qui unctos homines efficit, qui in eo nataverint,¹ et India, qui sereno caelo emittit olei magnam multitudinem, item Carthagini fons, in quo natat insuper oleum, odore uti scobe citreo; quo² oleo etiam pecora solent ungui.³ Zacyntho⁴ et circa Dyrrachium⁵ et Apolloniam fontes sunt, qui picis magnam multitudinem cum aqua evomunt. Babylone⁶ lacus amplissima magnitudine, qui *limne asphaltitis*⁷ appellatur, habet supra natans liquidum bitumen; quo⁸ bitumine et latere testaceo⁹ structum murum Sameramis circumdedit Babylonem. Item Iope¹⁰ in Syria Arabiaque Numidarum¹¹ lacus sunt inmani magnitudine, qui emittunt bituminis maximas moles, quas diripiunt qui habitant circa.

9 Id autem non est mirandum; nam crebrae sunt ibi lapidicinae bituminis duri. Cum ergo per bituminosam terram vis erumpit aquae, secum extrahit et, cum sit egressa extra terram, discernitur et ita reicit ab se bitumen. Etiamque est in Cappadocia in itinere, quod est inter Mazaca et Tyana,¹² lacus amplus, in quem lacum pars sive harundinis sive alii generis si dimissa fuerit et postero die exempta, ea pars, quae fuerit exempta, invenietur lapidea, quae autem pars extra aquam manserit, permanet in sua proprietate.

10 Ad eundem modum Hierapoli Phrygiae effervet aquae calidae multitudo, e quibus circum hortos et

¹ nataverit *H.*

² ungui *S*: ungeri *H.*

³ dirrachium *H.*

⁴ limnea spartacis *H* (*corr. Schott*).

⁵ quo *S*: quod *H.*

⁶ Iope *e*₂ (*schol*): tope *H.*

⁷ quod *H.*

⁸ zachinto *H.*

⁹ babilone *H.*

¹⁰ testaceo *e*₂: testatio *H.*

of Cilicia, there is a river named Liparis, and those who swim or wash in it are oiled by the water. There is also a lake of Ethiopia which anoints men who swim in it, and another in India which in clear weather produces a great amount of oil. There is also a spring at Carthage¹ on which there floats an oil with the perfume of cedar-shavings, and with this oil, sheep are usually dressed. In Zacynthus and round Dyrrachium and Apollonia² are springs which discharge with the water a great amount of pitch. At Babylon there is a lake of wide extent which is called the Asphalt Lake, with liquid bitumen floating on it. Semiramis built a wall round Babylon of this bitumen and burnt-brick. At Joppa in Syria, also, and in Nomad³ Arabia are lakes of immense size producing much bitumen which is gathered by the neighbouring tribes.

9. This is not surprising, because there are many quarries of hard bitumen there. When, therefore, a spring of water rushes through the bituminous land, it draws the bitumen with it, and passing outside, the water separates and deposits the bitumen. Again, in Cappadocia, on the road between Mazaca⁴ and Tyana, there is a great lake; if part of a reed or any other substance is let fall into it and taken out the next day, it is turned to stone, and the part which remains outside the water stays as it is.

10. In the same way at Hierapolis in Phrygia⁵ abundance of hot water boils up, from which a supply

¹ Arist. *Mirab.* 113.

² *Ibid.* 127.

³ Cf. Luc. iv. 677: *Numidaeque vagi.*

⁴ Strabo, 629.

⁵ Received the name Caesarea A.D. 18.

¹¹ numidarum *H*: cf. *Paulus s.v. numidas dicimus quos Graeci nomadas.*

¹² tuana *H.*

vineas fossis ductis inmittitur; haec autem efficitur post annum crusta lapidea. Ita quotannis dextra ac sinistra margines ex terra faciundo inducunt eam et efficiunt in his¹ crustis in agris saepta. Hoc autem ita videtur naturaliter fieri, quod in is locis et ea terra, quibus is nascitur, sucus subest coaguli naturae similis; deinde cum commixta vis egreditur per fontes extra terram, a solis et aeris calore² cogitur
 11 congelari, ut etiam in areis salinarum videtur. Item sunt ex amaro suco terrae fontes exeuntes vehementer amari, ut in Ponto est flumen Hypanis.³ A capite profluit circiter milia XL sapore dulcissimo; deinde, cum pervenit ad locum, qui est ab ostio ad milia CLX, admiscetur ei fonticulus⁴ oppido quam parvolus. Is cum in eum influit, tunc tanta magnitudine fluminis facit amaram, ideo quod per id genus terrae et venas, unde sandaracam fodiunt,⁵ ea⁶ aqua manando perficitur amara.

12 Haec autem dissimilibus saporibus a terrae proprietate perficiuntur, uti etiam in fructibus videtur. Si enim radices arborum aut vitium aut reliquorum seminum non ex terrae proprietatibus sucum capiendo ederent fructus, uno genere essent in omnibus locis et regionibus omnium sapes. Sed animadvertimus insulam Lesbos vinum protropum,⁷ Maeoniam⁸ Catacecaumeniten,⁹ Lydiam Tmoliten,¹⁰

¹ in his *H*: *Sem. cf. in gladio Luc. XXII. 49.*

² calor *H*.

³ Hypanis *Joc*: hipanis *H S*, Hispanis *e*, *Sulp.*

⁴ fonticulos *H*.

⁵ fodiunt *Müller-Str.*: fodiuntur *H*.

⁶ ea *Joc*: & *H*. ⁷ protropum *Joc*: protyrum

⁸ Maeoniam *Phil*: maloniam *H*.

⁹ catacecaumeniten *Joc*: catacaecaumen. item *H*.

¹⁰ Tmoliten *Phil*: moliton *H*.

is taken by channels round the orchards and vineyards. After a year the water leaves a stony crust. So every year they make banks of soil to the right and left, let in the water, and with the incrustations build enclosures in the fields. The cause of this seems to be natural, in that in these places and in the soil where this happens there is a fluid like the nature of rennet; thereupon when this potency is blended and comes above ground in the springs, it is solidified by the heat of the sun and air, as appears in salt pits. 11. There are also sources arising from the bitter juice of the soil and exceedingly bitter, like those of the Boug. This river flows about 40 miles from its source with very sweet water. Then, when it reaches a spot 160 miles from its mouth, it is joined by a quite small spring. On flowing into the river it makes the broad stream bitter; and this is because the water is made bitter by flowing through the kind of soil and the veins of earth from which they mine red lead.¹

12. These also acquire different flavours from the properties of the soil, as we observe in the case of fruits. For if the roots of trees or vines or other plants² did not produce their fruits by absorbing their juice from the properties of the soil, the flavour of each species would be the same in every district and region.³ But we observe the island of Lesbos and the Protropos⁴ (a sweet wine); Maeonia and the Catacecaumenite,⁵ Lydia and the Tmolite,⁶ Sicily and

¹ Book VII. xii. 2.

² *Semen* in Hebrew sense = 'planting,' *Vulg. Isa. XVII. 11 al.*

³ Vitruvius sees a relation between flora and fauna and climate.

⁴ Athen. 45E.

⁵ Praised by Strabo, 628.

⁶ Plin. *N.H.* XIV. 74.

Siciliam Mamertinum, Campaniam Falernum, in Terracinam et Fundis Caecubum¹ reliquisque locis pluribus innumerabili multitudine genera vini virtutesque procreari. Quae non aliter possunt fieri, nisi, cum terrenus umor suis proprietatibus saporis² in radicibus sit infusus, enutrit materiam, per quam egrediens ad cacumen profundat proprium loci et generis sui fructus saporem.

13 Quodsi terra generibus umorum non esset dissimilis et disparata, non tantum in Syria et Arabia in harundinibus et iuncis³ herbisque omnibus essent odores, neque arbores turiferae, neque piperis darent bacas, nec murræ glaebulae, nec Cyrenis in ferulis laser nasceretur, sed in omni terra regionibus eodem genere⁴ omnia procrearentur. Has autem varietates regionibus et locis inclinatio mundi et solis impetus propius⁵ aut⁶ longius cursum faciendo tales efficit terrae umorisque qualitates nec solum in his rebus, sed etiam in pecoribus et armentis haec non ita similiter efficerentur, nisi proprietates singularum terrarum in generibus⁷ ad solis potestatem temperarentur.⁸

14 Sunt enim Boeotiae⁹ flumina Cephisos et Melas, Lucanis Crathis,¹⁰ Troia Xanthus inque agris Clazomeniorum et Erythraeorum et Laodicensium fontes. Ad flumina cum pecora suis temporibus anni parantur ad conceptionem partus, per id tempus adiguntur¹¹ eo cotidie potum, ex eoque, quamvis¹² sint alba,

¹ Caecubum *ed*: caesibum *H*.

² saporis *rec*: -res *H*.

³ iuncis *Joc*: uineis *H*.

⁴ eodem genera *H*, eadem genera *S*.

⁵ propius *H*.

⁶ aut *E*: ut *H G S*.

⁷ ingeneribus *H S*: inregionibus *E G*.

⁸ temperarentur *S^c*: perarentur *H*.

⁹ boeotiae *H*.

¹⁰ Crathis *ed*: aeraris *H*.

¹¹ adiguntur *E*: adicuntur *H G*, adiciuntur *S*.

¹² qua vis *H*.

the Mamertine,¹ Campania and the Falernian, at Terracina and Fundi the Caecuban, and in many other places kinds and flavours of wine are produced in a countless multitude.² This would not happen unless the juices of the soil, being infused with their characteristic flavour into the roots, fed the tree, and rising to the top, produced the flavour proper to the kind of vine and the locality.

13. For unless the soil were unlike and disparate in its juices, not only in Syria and Arabia would there be perfumes in the reeds, rushes, and all herbs, nor incense-bearing trees; nor would they yield pepper berries, nor would there grow flakes of myrrh; nor in Cyrene would the assafetida grow in the stalks of silphium. But in every land and region everything would be produced of the same kind. On the other hand, these varieties are produced in regions and localities by the climate and the nearer or more distant course of the sun, and are made such by the qualities of the juices of the soil. To go beyond these, the like differences would not arise in flocks and herds unless the properties of the several soils in their own kinds were acquired according to the sun's power.

14. For in Boeotia are the rivers Cephisos and Melas; among the Lucanians, the Crathis; in Troy, the Xanthus; in the territories of Clazomenae, Erythrae and of Laodicea, there are springs. When the cattle in their own season are about to bring forth, they are taken daily during that time of the year to the river to drink. Thereby, although they are maybe white, they bring forth young in some

¹ If kept, lost its flavour, *Mart.* XIII. 117.

² For Roman wines, *Plin. N.H.* XIV. 59 ff.

procreant aliis locis leucophaea, aliis locis pulla, aliis coracino colore. Ita proprietas liquoris, cum inſit in corpus, proſeminat intinctam ſui cuiusque generis qualitatem. Igitur quod in campis Troianis proxime flumen armenta rufa et pecora leucophaea nascuntur, ideo id flumen Ilienses¹ Xanthum appellavisse dicuntur.

15 Etiamque inveniuntur aquae genera mortifera, quae per maleficum sucum terrae percurrentia recipiunt in se vim venenatam, uti fuisse dicitur Terracinae² fons, qui vocabatur Neptunius, ex quo qui biberant imprudentes, vita privabantur; quapropter antiqui eum obstruxisse dicuntur. Et Chrobsi Thracia³ lacus, ex quo non solum qui biberint, moriuntur, sed etiam qui laverint.⁴ Item in Thessalia fons est profluens, ex quo fonte nec pecus ullum gustat nec bestiarum genus ullum propius⁵ accedit; ad quem fontem proxime est arbor florens purpureo colore.

16 Non minus in Macedonia quod loci sepultus est Euripides, dextra ac sinistra monumenti advenientes duo rivi concurrunt. In unum, viatores pransitare⁶ solent propter aquae bonitatem, ad rivum autem, qui est ex altera parte monumenti, nemo accedit, quod mortiferam aquam dicitur habere. Item est in Arcadia Nonacris⁷ nominata terrae regio, quae habet in montibus ex saxo stillantes frigidissimos umores. Haec autem aqua⁸ *Stygos Hydor* nominatur, quam neque argentum neque aeneum nec ferreum vas potest sustinere, sed dissilit

¹ nilienses *H S.*

² terrae cinae *H.*

³ thratia *H S.*

⁴ laberint *H.*

⁵ propius *H.*

⁶ pransitare *Joc*: transitare *H.*

⁷ non agris *H.*

⁸ aquas tyglos hydor *H*: (*corr. ed.*).

places of a dun colour, in other places of dark grey, in others raven-black. Thus the property of the liquid when it enters the body produces the kind of quality with which it is tintured. Therefore the Trojans are said to have given the name Xanthus¹ or Chestnut to the river which flows in the plains of Troy, because in its neighbourhood the cattle are red and the sheep of a light brown colour.

15. Kinds of water are also found which cause death; these run through dangerous juices of the soil and acquire a poisonous property. Such is said to have been the spring at Terracina which was called Neptune's; people who drank of it unwittingly lost their lives. For this reason, the ancients are said to have stopped it up. At Chrobs² in Thrace there is a lake which brings death not only to those who drink of it, but to those who bathe in it. There is also, in Thessaly,³ a running spring of which sheep do not taste, nor do wild animals approach it; near the spring is a tree bearing a purple flower.

16. Again, at the tomb of Euripides in Macedonia, two streams flowing to the right and the left of the monument come together. At the one stream, travellers recline and take their lunch because of the goodness of the water; but no one approaches the stream on the other side of the monument, because it is said to have poisonous water. There is also in Arcadia a district called Nonacris,⁴ where among the hills icy-cold water drips from the rock. This is called the Water of Styx. Neither vessels of silver, nor of bronze, nor of iron can contain it, but it bursts

¹ *Ξανθαὶ Ἴπποι* = chestnut mares, Hom.

² Arist. *Mirab.* 121.

³ At Tempe, Plin. *N.H.* XXXI. 28.

⁴ Paus. VIII. 18. 4.

et dissipatur. Conservare autem eam et continere nihil aliud potest nisi mulina ungula, quae etiam memoratur ab Antipatro in provinciam¹ ubi erat Alexander, per Iollam filium perlata² esse et ab eo ea aqua regem esse necatum.

17 Item Alpibus in Cotti³ regno est aqua; qui gustant, statim concidunt. Agro autem Falisco via Campana in campo Corneto est lucus, in quo fons oritur; ubique avium et lacertarum reliquarumque serpentium ossa iacentia apparent.

Item sunt nonnullae acidae venae fontium, uti Lyncesto et in Italia Velino,⁴ Campania Teano aliisque locis pluribus, quae hanc habent virtutem, uti calculos, in vesicis qui nascuntur in corporibus hominum, potionibus discutiant. Fieri autem hoc naturaliter ideo videtur, quod acer et acidus sucus subest in ea terra, per quam egredientes venae intinguntur acritudine, et ita, cum in corpus inierunt, dissipant quae ex aquarum subsidentia in corporibus et concrecentia offenderunt. Quare autem discutiantur ex acidis eae res, sic possumus animadvertere. Ovum in aceto si diutius positum fuerit, cortex eius mollescit⁵ et dissolvitur. Item plumbum, quod est lentissimum et gravissimum, si in vase conlocatum fuerit et in eo acetum suffusum, id autem opertum et oblitum erit, efficietur, uti plumbum dissolvatur, et fiet cerussa.

19 Eisdem rationibus aes, quod etiam solidiore est

¹ provinciam ed: -cia H. ² perlata Laet: -tum H.

³ Cotti Joc: crobi H.

⁴ Velino Budaevs (Plin. XXXI. 9): vienna H.

⁵ mollescit H S.

¹ Plut. Alex. 74.

the vessels and is lost. Nothing but the hoof of a mule can contain and keep it. In this way it is said to have been conveyed by Antipater,¹ through his son Iollas, to the province where Alexander was, and the king was killed by Antipater² with this water.

17. There is a spring in the Alps in the kingdom of Cottius,³ and those who taste of it, at once fall dead. On the Via Campana in the Falerian district in the neighbourhood of Cornetum there is a spring in a grove; everywhere the skeletons of birds, lizards and other snakes are seen lying.

There are also some acid springs, as in Lyncestis,⁴ and in Italy⁵ at Velia, at Teanum in Campania and many other places, which have this property that, when they are drunk, they dissolve the stones which form in the human bladder. 18. This seems to happen by nature, because a sharp and acid juice is present in the soil, and when currents of water pass out of it, they are tinged with acridity. Hence when they enter the body, they disperse what they meet as the water settles and solidifies in the body. We can observe the reason why these are dissolved by acid. If an egg is put in vinegar for some time, the shell will become soft and dissolve. When lead also, which is very pliant and heavy, is placed in a vessel and vinegar is poured in, and the vessel is covered over and sealed, the lead will be dissolved and it will become white lead.⁶

19. In the same way, brass, which is still more

² Aristotle was credited with the scheme, Plin. N.H. XXX. 149.

³ Cottius erected the arch of Augustus at Susa W. of Turin, 8 B.C.

⁴ In Macedonia.

⁵ Plin. N.H. XXXI. 9.

⁶ Book VII. xii. 1.

natura, similiter curatum si fuerit, dissipabitur et fiet aerugo. Item margarita. Non minus saxa silicea, quae neque ferrum neque ignis potest per se dissolvere, cum ab igni sunt percalecta, aceto sparso dissiliunt et dissolvuntur. Ergo cum has res ante oculos ita fieri videamus, ratiocinemur isdem rationibus ex acidis propter acritudinem suci etiam calculosos e natura rerum similiter posse curari.

20 Sunt autem etiam fontes uti vino mixti, quemadmodum est unus Paphlagoniae, ex quo eam sine vino potantes fiunt temulenti. Aequiculis autem in Italia et in Alpibus natione Medullorum est genus aquae, quam qui bibunt, efficiuntur turgidis gutturibus. 21 Arcadia vero civitas est non ignota Clitor,¹ in cuius agris est spelunca profluens aqua, e qua qui² biberint, fiunt abstemii. Ad eum autem fontem epigramma est in lapide inscriptum: haec sententiae versibus graecis: eam non esse idoneam ad lavandum, sed etiam inimicam vitibus, quod apud eum fontem Melampus sacrificiis purgavisset rabiem Proeti filiarum restituissetque earum virginum mentes in pristinam sanitatem. Epigramma autem est id, quod est subscriptum:

ἀγρότα,³ ἐν ποίμναις τὸ μεσημβρινὸν ἦν σε βαρύνῃ⁴
δίψος ἀν' ἐχάτιας Κλείτορος⁵ ἐρχόμενον,

¹ Clitori H.

² aquae qui H.

³ Epigrammata quae sequuntur eadem graece extant in Eclogis Florentinis (de mirabilibus) quae sub ficto Sotionis nomine (ex cod. Laur. LVI, I) edidit H. Stephanus. H litterarum formis utitur graecis et latinis mixtis, praecipue c, ut in papyris pro σ. ΑΓΡΑΤΑ H.

⁴ ΗΝΘΕΒΑΡΥΗΝ H.

⁵ ΚΑΙΤΟΡΟΣ H.

solid, if it is treated in like manner, will be dissolved and changed into verdigris. So also pearls; and flints, which neither iron nor fire can dissolve of itself, when they are heated in the fire and sprinkled with acid, fly asunder and are dissolved.¹ Therefore, since we see these processes before our eyes, we shall conclude by the same arguments that persons suffering from stone can be cured naturally in like manner by acids owing to their pungency.

20. There are also springs, as it were, mixed with wine, such as one in Paphlagonia, and persons drinking it without wine become drunk. Among the Aquiculi in Italy and among the tribe of the Medulli in the Alps, there is a kind of water which causes goitre² among those who drink it. 21. In Arcadia there is the city of Clitor, not unknown,³ in the lands of which there is a cave with running water, and those who drink of it become abstemious.⁴ Against the spring there is an inscription engraved on the stone. This is the meaning of the Greek verses: that the water is not fit for washing and is also harmful to vines, because at this spring Melampus with sacrifices cleansed the madness of the daughters of Proetus and restored the minds of the girls to their former sanity. This is the inscription⁵ written below:

Shepherd, if at noon thirst oppress thee as thou comest with thy flocks to the bounds of Clitor,

¹ Vinegar acetum is credited with an exaggerated capacity to dissolve pearls.

² quis tumidum guttur miratur in Alpibus? Juv. XIII. 162.

³ Cf. Acts, non ignotae civitatis, Vg. XXI. 39; οὐκ ἄσημος Ἐλλήνων πόλις (Athens), Eur. Ion, 8.

⁴ Ovid, Met. XV. 322.

⁵ Anth. Pal. App. IV. 20. These three epigrams are found in ps. Sotion de mirabilibus.

τᾶς μὲν ἀπὸ κρήνης ἄρυνται¹ πόμα καὶ παρὰ νύμφαι
 ὑδρεάειν ἐτήσον πᾶν τὸ σὸν αἰπόλιον.
 νάμααι μὴτ' ἐπὶ λουτρὰ βάλῃς χροί, μὴ σε καὶ αὔρη²
 πη<νή>νη <τερπνῆς> ἐντὸς³ ἔοντα μέθης.
 φεῦγε δὲ τὴν πηγὴν μεικάμπελον, ἔνθα Μελάμπουε
 λυκάμενος λύσσης⁴ Προϊτίδας ἀρτεμέας⁵
 πάντα καθαρμὸν ἔκοψεν ἀπόκρυφον,⁶ <εὗτ' ἄρ' ἀπ'
 Ἄργουε
 οὔρεα τρηχείης ἤλυθεν Ἀρκαδίας>.

22 Item est in insula Cia⁷ fons, e quo qui imprudentes biberint, fiunt insipientes, et ibi est epigramma insculptum ea sententia: iucundam eam esse potionem fontis eius, sed qui biberit, saxeos habiturum sensos.⁸ Sunt autem versus hi:

ἡδέ' ἀπὸ ψυχροῦ πόματος λιβάς, ἃ γ' ἀναβαίνει
 <πηγή, ἀλλὰ νόω> πέτροε ὁ τήνδε πίων.⁹

23 Susis¹⁰ autem, in qua civitate est regnum Persarum, fonticulus est, ex quo qui biberint, amittunt dentes. Item in eo est scriptum epigramma, quod significat¹¹ hanc sententiam: egregiam esse aquam ad lavandum, sed ea si bibatur, excutere e radicibus dentes. Et huius epigrammatis sunt versus graece:

¹ ΚΡΗΝΗΚΑΡΥΣΑΙ Η.

² ΙΑΟΥΤΡΑΒΑΤΙΤΕΧΡΑΜΗΣΗΚΑΙΔΥΡΗ Η.

³ ΠΗ<ΜΗ>ΝΗ <ΤΕΡΠΝΗΣ> ΕΝΤΟΣ ΡΣ. ΣΟΤ.: ΠΗΝΗΣΝΤΥΣ Η.

⁴ ΛΥΣΑΜΕΝΟΣ ΛΥΣΣΗΣ ΡΣ. ΣΟΤ.: ΑΥΣΑΜΕΝΟ|ΣΑΥΣΘΗΣ Η.

⁵ ΠΡΟΙΤΙΑΑΣΑΡΤΕΜΕΙΑΕ Η.

⁶ ΚΛΘΑΡΜΟΝΕΚΟΨΕΝΕΠΑΧΡΥΨΟΝ (hoc verbo finitur epigr. in H, reliqua ex Ecl. Flor. addiderunt edd.).

⁷ chia Η (cea Plin.).

⁸ Cf. motos Η (X. iii. 9).

⁹ ΗΑΕΛΠΟΨΥΧΡΟΥΠΟΜΑΤΟΣΑΙΒΑΣΑΑΝΑΒΑΙΝΣΙΠΕΠ ΡΟΣΟΤΗΝΑΕΠΙΩΝ Η. ἃ γ' ἀναβαίνει Rouse: ἀναβάλλει cod. Laur. ἀναβαίνει Η: πηγὴ, ἀλλὰ νόω cod. Laur. (om. Η).

Draw water from this fountain, and, near the water nymphs, give rest to all thy goats.

But cast not water for the bath on thy skin, lest the vapour harm thee when thou art plunged in the joys of wine.

Shun my vine-hating spring; here Melampus restored to sense the daughters of Proetus from their frenzy,¹

He smote the scapegoat deep and out of sight, when from Argos he came to the mountains of wild Arcadia.

22. There is also a spring in the island of Chios,² and those who drink of it unawares become stupid. There is an inscription³ carved there to this effect: that a draught of the spring is pleasant, but anyone who drinks will have fossilised notions. The verses follow.

Sweet is the flow of cooling drink, which rises in a fountain, but he who drinks of it is turned to stone in his mind.

23. At Susa also, which is the capital city of Persia, there is a small spring, and those who drink from it lose their teeth. On it there is written an inscription⁴ which bears this meaning: that the water is good for bathing, but whatever is drunk, shakes out the teeth from their roots. Of this inscription the verses run as follows in Greek.

¹ Paus. VIII. 18. 7.

² Pliny says Ceos, N.H. XXXI. 15.

³ Anth. Pal. App. III. 94.

⁴ Anth. Pal. App. III. 101.

¹⁰ suesis Η.

¹¹ -cant Η.

ὑδατα κρανάεντα βλέπεις, ξένε, τῶν ἀπο χερσίν¹
 λουτρὰ μὲν ἀνθρώποις ἀβλαβῆ ἔστιν ἔχειν.²
 ἣν δὲ λάβης κοίλου βοτανήδεος ἀγλαὸν ὕδωρ³
 ἄκρα μόνον δολιχοῦ χεῖλεος ἀψάμενος,⁴
 αὐτῆμαρ πριστηῆρες ἐκ πὶ χθονὶ δαιτὸς ὀδόντες⁵
 πείπτουσιν, γειύων ὀρφανὰ θέντες ἔδη.⁶

24 Sunt etiam nonnullis locis fontium proprietates, quae procreant qui ibi nascuntur egregiis vocibus ad cantandum, uti Tarso,⁵ Magnesia, aliis eiusmodi regionibus. Etiamque Zama est civitas Afrorum, cuius moenia rex Iuba duplici muro saepsit ibique regiam domum sibi constituit. Ab ea milia passus xx est oppidum Ismuc, cuius agrorum regiones incredibili finitae⁶ sunt terminatione. Cum esset enim Africa parens et nutrix ferarum bestiarum, maxime serpentium, in eius agris oppidi nulla nascitur, et si quando adlata ibi ponatur, statim moritur; neque id solum, sed etiam terra ex his locis si alio translata fuerit, et ibi. Id genus terrae etiam Balearibus dicitur esse. Sed aliam mirabiliorem virtutem ea habet terra, quam ego sic accepi.

25 Gaius Iulius Masinissae filius, cuius erant totius oppidi agrorum possessiones, cum patre⁷ Caesare militavit. Is hospitio meo est usus. Ita cotidiano convictu necesse fuerat de philologia disputare. Interim cum esset inter nos de aquae potestate et

¹ ὙΔΑΤΑ ΚΡΑΝΑΕΝΤΑ ΒΛΕΠΕΙΣ ΞΕΝΩΝ ΑΠΟ ΧΕΡΣΙΝ Η.

² οπ. Η.

³ ΛΟΥΤΡΑ ΜΕΝ ΑΝΤΡΟΠΟΙΗΝΑΕΜ ΒΗΟΚΟ | ΙΔΟΥ ΒΟΤΑΝ ΗΛΕΘΟΑΤ ΜΟΝΥΔΩΡ Η.

⁴ ΑΥΤΗΜΕΡ ΠΡΙΣ | ΤΗΡΕΣΘΕ ΠΕΙΠΤΟΥΣΙΝ ΤΩΝ ΥΩΝ ΟΡΦΑΝΑ ΘΕΝΤΕΣ ΕΔΗ Η. πείπτουσιν hanc orthographiam ubique in evv. habent codices NT. Vat. et Bezae: cf. μείσαμπελον supra.

⁵ uti tharso Η.

⁶ finitae ed: -ti Η.

⁷ patres Η.

Waters from the rock you see, stranger, from which it is safe for men to take to wash their hands; But if you take of the fair water of the leafy cave, and touch it but with the tip of your lips, Forthwith those banquet grinders, your teeth, fall on the ground, and leave empty the sockets in your jaw.

24. There are in some places springs which have the property of causing those who are born there to have fine voices for singing; such as at Tarsus, in Magnesia, and elsewhere. Further, there is in Africa the city of Zama¹ the ramparts of which King Juba² enclosed with a double wall, and built his palace there. Twenty miles away is the town of Ismuc. The area of the lands of this city is marked by an incredible barrier. Africa is the mother and nurse of wild creatures, especially snakes, but they do not grow in the neighbourhood of Zama; and if at any time a snake is brought and put there, it dies on the spot. Not only so, but even if soil is taken from these places elsewhere the same thing happens there. (The soil of the Balearic Isles is said to be of that kind.) It has, however, a still more remarkable quality which I learnt in the following way.

25. Gaius Julius, the son of Masinissa, who held possession of the whole lands of the city, fought on the side of the late emperor. He sometimes stayed with me, and in our daily intercourse we were often driven to talk about scholarship. Once the question arose between us about the potency of water and its

¹ Probably from Varro, Plin. N.H. XXXI. 15.

² Juba, the father of the historian, fought against Caesar. Bell. Afric. 91.

eius virtutibus sermo, exposuit esse in ea terra eiusmodi fontes, ut, qui ibi procrearentur, voces ad transmarinos catlastros emere formonsos¹ et puellas maturas eosque coniungere, ut, qui nascerentur ex his, non solum voce egregia sed etiam forma essent non invenusta.

26 Cum haec tanta varietas sit disparibus rebus natura distributa quod humanum corpus est ex aliqua parte terrenum, in eo autem multa genera sunt umorum,² uti sanguinis, lactis, sudoris, urinae, lacrimarum: ergo si in parva particula terreni tanta discrepantia invenitur saporum, non est mirandum, si tam in magnitudine terrae innumerabilis suorum reperientur varietates, per quarum venas aquae³ vis percurrens tincta pervenit ad fontium egressus, et ita ex eo dispares variique perficiuntur in propriis generibus fontes propter locorum discrepantiam et regionum qualitates terrarumque dissimiles proprietates.

27 Ex his autem rebus sunt nonnulla, quae ego per me perspexi, cetera in libris graecis scripta inveni, quorum scriptorum hi sunt auctores: Theophrastos, Timaeus, Posidonios, Hegesias, Herodotus, Aristides, Metrodorus, qui magna vigilantia et infinito studio locorum proprietates, aquarum virtutes ab inclinatione caelique regionum qualitates ita esse distributas scriptis dedicaverunt. Quorum secutus ingressus in

¹ formonsos *H*: formonsam *Verg. E.* i. 5.

² morum *H*.

³ aquae *rec*: quae *H*.

¹ Book VI. *pref.* 2.

² Of Tauromenium; historian of Sicily, fl. 300 B.C.

³ Of Apamea; philosopher, taught at Rhodes, d. 48 B.C.

virtues. He informed me that, in his country, there were springs such that those who were born in the neighbourhood had fine singing voices, and that they bought from time to time across the sea handsome youths and grown-up girls and mated them so that their children might have fine voices and good looks as well.

26. Since, therefore, such variety is produced by nature among diverse things, in that the human body is in part earthy, and at the same time contains humours of many kinds, blood, milk, sweat, urine, tears; if, therefore, in a small particle of the earthy there is found such a discrepancy of flavours, we need not wonder if in the expanse of earth there shall be found such innumerable varieties of juices. The watery energy passing along their channels is tinted with them when it reaches the outflow of the springs. Thus for this reason springs are rendered disparate and various in their several kinds, because of the divergence of localities and the qualities of regions and the unlike qualities of soils.

27. Of these facts there are some which I have observed myself; others I have found recorded in Greek works of which I name the authors: Theophrastus,¹ Timaeus,² Posidonios,³ Hegesias,⁴ Herodotus,⁵ Aristides,⁶ Metrodorus.⁷ These writers, with close attention and unlimited pains, have declared the properties of localities, the virtues of different waters, and by reference to climate, the distribution of regional qualities. Following in their footsteps, I

⁴ Of Magnesia nr. Sipylus; historian, fl. 280 B.C.

⁵ Of Lycia; Athen. 75.

⁶ Of Miletus; historian, Plin. *N.H.* IV.

⁷ Of Scepsis; historian, d. 70 B.C.

hoc libro perscripsi quae satis esse putavi de aquae varietatibus, quo facilius ex his praescriptionibus eligant homines aquae fontes, quibus ad usum salientes possint ad civitates municipiaque perducere.

28 Nulla enim ex omnibus rebus tantas habere videtur ad usum necessitates, quantas aqua, ideo quod omnium animalium natura, si frumenti fructu privata fuerit, arbustivo aut carne aut piscatu aut etiam qualibet ex his reliquis rebus escarum utendo poterit tueri vitam, sine aqua vero nec corpus animalium nec ulla cibi¹ virtus potest nasci nec tueri nec parari. Quare magna diligentia industriaque quaerendi sunt et eligendi fontes ad humanae vitae salubritatem.

IV

1 EXPERTIONES autem et probationes eorum sic sunt providendae. Si erunt profluentes et aperti, antequam duci incipiantur, aspiciantur animoque advertantur, qua membratura sint qui circa eos fontes habitant homines; et si erunt corporibus valentibus, coloribus nitidis, cruribus non vitiosis, non lippis oculis, erunt probatissimi. Item si fons novus fossus fuerit, et in vas corinthium sive alterius generis, quod erit ex aere bono, ea aqua sparsa maculam non fecerit, optima est. Itemque in aeneo si ea aqua defervefacta et postea requieta et defusa fuerit, neque in eius aenei fundo harena aut limus invenietur, ea aqua erit

2 item probata. Item si legumina in vas cum ea aqua coiecta ad ignem posita celeriter percocta fuerint,

¹ cuius H.

¹ Alloy of gold, silver and copper.

have recorded in this book what I thought enough about the different kinds of water, so that from these instructions springs of water might be chosen from which conduits could be taken for the supply of cantons and towns.

28. For of all things, not one seems to be so necessary for use as water, since the nature of all animals, though it be deprived of the use of corn, can maintain life from shrubs or meat or fish or some other provender. But without water, neither the animal frame nor any virtue of food can originate, be maintained, or provided. Hence great diligence and industry must be used in seeking and choosing springs to serve the health of man.

CHAPTER IV

ON TESTING WATER

1. THE discovery and testing of springs is to be pursued in the following manner. When they are abundant and in the open, we are to observe and consider, before we begin to lay the water on, what is the physique of those who live in the neighbourhood. If they are strong, of clear complexion, free from distortion and from inflamed eyes, the water will pass. Again, if a fresh spring be dug, and the water, being sprinkled over a vessel of Corinthian,¹ or any other good bronze, leave no trace, the water is very good. Or if water is boiled in a copper vessel and is allowed to stand and then poured off, it will also pass the test, if no sand or mud is found in the bottom of the copper vessel. 2. Again, if vegetables being put in the vessel with water and boiled, are soon

indicabunt aquam esse bonam et salubrem. Non etiam minus ipsa aqua, quae erit in fonte, si fuerit limpida et perlucida, quoque pervenerit aut fluxerit,¹ muscus non nascetur neque iuncus,² pro-inquinatus ab aliquo inquinamento is locus³ neque sed puram habuerit speciem, innuitur⁴ his fuerit, esse tenuis et in summa salubritate.

V

1 NUNC de perductionibus ad habitationes moeniaque, ut fieri oporteat, explicabo. Cuius ratio est prima perlibratio. Libratur autem dioptris⁵ aut libris aquariis aut chorobate, sed diligentius efficitur per chorobaten, quod dioptrae libraeque fallunt. Chorobates autem est regula longa circiter pedum viginti. Ea habet ancones in capitibus extremis aequali modo perfectos inque regulae capitibus ad normam coagmentatos,⁶ et inter regulam et ancones a cardinibus compacta⁷ transversaria, quae habent lineas ad perpendicularum recte descriptas pendentiaque ex regula perpendiculara in singulis partibus singula, quae, cum regula est conlocata, ea quae tangent⁸ aequae ac pariter lineas descriptionis, indicant libratae conlocationem.

2 Sin autem ventus interpellaverit et motionibus lineae non potuerint certam significationem facere, tunc habeat in superiore parte canalem longum pedes v, latum digitum, altum sesquidigitum, eoque aqua infundatur, et si aequaliter aqua canalibus summa labra⁹

¹ limpida — profluxerit bis ponit H.

² iuncus ed: iuncum H. ³ his locus H.

⁴ innuitur e₂ ed.: inbuitur H. ⁵ dioptris H.

⁶ coagmentatus H. ⁷ compactat H.

⁸ tangent ed: tangentur H. ⁹ labra rec: libra H.

cooked, they will show that the water is good and wholesome. Likewise, if the water itself in the spring is limpid and transparent and if wherever it comes or passes, neither moss nor reeds grow nor is the place defiled by any filth, but maintains a clear appearance, the water is indicated by these signs to be light and most wholesome.

CHAPTER V

ON THE METHOD OF LEVELLING

1. I WILL now explain the supply of water to country houses and to towns. The first stage is to fix levels. This is done by dioptrae, or water levels, or the chorobates.¹ But the more accurate method is by the chorobates because the dioptrae and the water levels mislead. The chorobates is a straight plank about twenty feet long. At the extreme ends it has legs made to correspond, and fastened at right angles to the ends of the plank, and, between the plank and the legs, cross-pieces joined by tenons. These have lines accurately drawn to a perpendicular, and plummets hanging severally over the lines from the plank. When the plank is in position, the perpendiculars which touch equally and of like measure the lines marked, indicate the level position of the instrument.

2. But if the wind disturbs and, owing to their movements, the lines cannot give a certain indication, a channel is to be put on the top side of the plank, five feet long, an inch wide and an inch and a half deep. Let water be poured in. If the water evenly touches the lips of the channel, we shall know that

¹ Neuburger, *op. cit.* gives a drawing, 394.

tanget, scietur esse libratum. Ita eo chorobate cum perlibratum ita fuerit, scietur, quantum habuerit fastigii.

3 Fortasse, qui Archimedis libros legit, dicet non posse fieri veram ex aqua librationem, quod ei placet aquam non esse libratam, sed sphaeroides¹ habere schema sed ibi habere centrum, quo loci habet orbis terrarum. Hoc autem, sive plana est aqua seu sphaeroides, necesse est: <ad>² extrema capita regulae sit³ pariter sustinere regulam aquam; sin autem proclinatorum erit ex una parte, quae erit altior, non habuerit regulae canal⁴ in summis labris aquam. Necesse⁵ est enim, quocumque aqua sit infusa, in medio inflationem curvaturamque habere, sed capita dextra ac sinistra inter se librata esse. Exemplar autem chorobati erit in extremo volumine descriptum. Et si⁶ erit fastigium magnum, facilius erit decursus aquae; sin autem intervalla erunt lacunosa, substructionibus erit succurrendum.

VI

1 Ductus autem aquae fiunt generibus tribus: rivis per canales structiles, aut fistulis plumbeis, seu tubulis fictilibus. Quorum hae sunt rationes. Si canalibus, ut structura fiat quam solidissima, solumque rivi libramenta habeat fastigata ne minus in centenos pedes semipede eaeque⁷ structurae

¹ phaeroides *H.*

² add. *Ro.*

³ regulae sit *Gr*: regula erit *H.*

⁴ canal^{is} *Joc*: canalem *H.*

⁵ nenesse *H.*

⁶ et si *G*: et sic *H.*

⁷ aequae *H*, eque *G.*

the levelling is successful. Further, when we have levelled with the chorobates, we shall know the amount of the fall.

3. Perhaps the student of the works of Archimedes may say that true levelling cannot be made by means of water, because his theory is that the surface of water is not level, but is that of a sphere of which the centre is that of the earth. But whether the surface of the water is plane or spherical, it is necessary that the extreme ends of the plank should uphold the water evenly. But if there be a fall at one end, the end which is higher will not have water up to the lips of the channel. For while it is necessary that where water is poured along, there should be an inflation and curvature in the middle, it is also necessary that the ends, right and left, should be level one with another. A drawing of the chorobates is furnished at the end of the book. If the fall is considerable, the flow of the water will be made easier. If there are marshy intervals, the assistance of substructures must be sought.

CHAPTER VI

ON AQUEDUCTS, LEADEN AND EARTHEN PIPES

1. THE supply of water¹ is made by three methods: by conduits along artificial channels, or by lead pipes, or by earthenware tubes. And they are arranged as follows. In the case of channels, the structure must be on a very solid foundation; the bed of the current must be levelled with a fall of not less than 6 inches in 100 feet. The channels are to be arched over to

¹ Neuburger, *op. cit.* 425 ff. describes in detail the water-supply of the Romans.

conformicentur, ut minime sol aquam tangat. Cumque venerit ad moenia, efficiatur castellum et castellosarium, conlocenturque in castello triplex inmissaequaliter divisae intra receptacula coniuncta, uti, cum abundaverit ab extremis, in medium receptaculum redundet.

- 2 Ita in medio ponentur fistulae in omnes lacus et salientes, ex altero in balneas vectigal quotannis populo praestent, ex quibus tertio in domus privatas, ne desit in publico; non enim poterint avertere, cum habuerint a capitibus proprias ductiones. Haec autem quare divisa constituerim, hae sunt causae, uti qui privatim ducent in domos vectigalibus tueantur per publicanos aquarum ductus. Sin autem medii montes erunt inter moenia et caput fontis, sic erit faciendum, uti specus fodiantur¹ sub terra librenturque ad fastigium, quod supra scriptum est. Et si tofus erit aut saxum, in suo sibi canalis excidatur, sin autem terrenum aut harenosum erit, solum et parietes cum camara² in specu struantur et ita perducatur. Puteique ita sint facti, uti inter duos sit actus.
- 4 Sin autem fistulis plumbeis ducetur, primum castellum ad caput struatur, deinde ad copiam³ aquae lumen fistularum constituatur, eaeque⁴ fistulae castello⁵ conlocentur ad castellum, quod erit in moenibus. Fistulae ne minus longae pedum denum fundantur. Quae si centenariae erunt, pondus habeant in singulas pondo MCC; si octogenariae,

¹ fodientur *H.*

² camera *H.*

³ ad copiam aquae *e, ed*: ad copia quae *H.*

⁴ eaeque: aeq; *H,* eque *G.*

⁵ *abl. sine prep.*

protect the water from the sun. When they come to the city walls, a reservoir is to be made. To this a triple receptacle is to be joined, to receive the water; and three pipes of equal size are to be put in the reservoir, leading to the adjoining receptacles, so that when there is an overflow from the two outer receptacles, it may deliver into the middle receptacle.

2. From the middle receptacle pipes will be taken to all pools and fountains; from the second receptacle to the baths, in order to furnish a public revenue; to avoid a deficiency in the public supply, private houses are to be supplied from the third: for private persons will not be able to draw off the water, since they have their own limited supply from their receptacle. The reason why I have made this division, is in order that those who take private supplies into their houses may contribute by the water rate to the maintenance of the aqueducts. 3. If there are hills between the city and the fountain head, we must proceed as follows. Tunnels are to be dug underground and levelled to the fall already described. If the formation of the earth is of tufa or stone, the channel may be cut in its own bed; but if it is of soil or sand the bed and the walls with the vaulting are to be constructed in the tunnel through which the water is to be brought. Air shafts are to be at the distance of one actus (120 feet) apart.

4. But if the supply is to be by lead pipes, first of all a reservoir is to be built at the fountain head. Then the section of the pipe is to be determined for the supply of water, and the pipes are to be laid from the reservoir to a reservoir in the city. The pipes are to be cast in lengths of not less than 10 feet. If the lead is 100 inches wide, they are to weigh 1200 lbs.

pondo dccccclx; si quinquagenariae, pondo dc; quadragenariae pondo cccclxxx; tricenariae pondo ccclx; vicenariae pondo ccxl; quinûm denûm pondo clxxx; denûm pondo cxx;¹ octonûm pondo c; quinquaginta pondo lx. E latitudine autem lamnarum, quot digitos habuerint, antequam in rotundationem flectantur, magnitudinum ita nomina concipiunt fistulae. Namque quae lamna fuerit digitorum quinquaginta, cum fistula perficietur ex ea lamna, vocatur quinquagenaria similiterque reliqua.

5 Ea autem ductio, quae per fistulas plumbeas est futura, hanc habebit expeditionem. Quodsi caput habeat libramenta ad moenia montesque medii non fuerint altiores, ut possint interpellare, sed intervalla, necesse est substruere ad libramenta, quemadmodum in rivis et canalibus. Sin autem non longa erit circumitio, circumductionibus, sin autem valles erunt perpetuae, in declinato loco cursus dirigentur. Cum venerint ad imum, non alte substruitur, ut sit libratum quam longissimum; hoc autem erit venter, quod Graeci appellant *coelian*. Deinde cum venerit adversus clivum, ex longo spatio ventris leniter tumescit; exprimatur in altitudinem summi clivi.²

6 Quodsi non venter in vallibus factus fuerit nec substructum ad libram factum, sed geniculus erit, erumpet et dissolvit fistularum commissuras.³ Etiam in ventre colluvaria⁴ sunt facienda, per quae vis spiritus relaxetur. Ita per fistulas plumbeas aquam qui ducent, his rationibus bellissime poterunt efficere,

¹ cxx G: ccxx H.

² clevis H.

³ commissuras rec: commixturas H.

⁴ colluvaria e, ed: collivaria H.

¹ The reservoirs or water-towers are represented by the Roman 'Fountains.'

each; if 80 inches, 960 lbs.; if 50 inches, 600 lbs.; if 40 inches, 480 lbs.; if 30 inches, 360 lbs.; if 20 inches, 240 lbs.; if 15 inches, 180 lbs.; if 10 inches, 120 lbs.; if 8 inches, 100 lbs.; if 5 inches, 60 lbs.¹ The pipes receive the names of the sizes from the width of the sheets of lead in inches, before they are bent round into pipes. For when a pipe is made of a sheet of lead 50 inches wide, it is called a fifty-inch pipe, and similarly the rest.²

5. When, however, an aqueduct is made with lead pipes it is to have the following arrangement. If from the fountain head there is a fall to the city, and the intervening hills are not so high as to interrupt the supply, and if there are valleys, we must build up the pipes to a level as in the case of open channels. If the way round the hills is not long, a circuit is to be used; if the valleys are wide-spreading, the course will be down the hill, and when it reaches the bottom, it is carried on a low substructure so that it may be levelled as far as possible. This will form a U-shaped bend which the Greeks call *koilia*. When the bend comes uphill after a gentle swelling spread over the long space of the bend, the water is to be forced to the height of the top of the hill.

6. But if the bend is not made use of in the valleys, or if the pipe is not brought up to a level, and there is an elbow,³ the water will burst through and break the joints of the pipes. Further, stand-pipes are to be made in the bend, by which the force of the air may be relaxed. In this way the supply of water by lead pipes may be carried out in the best manner, because

¹ Plin. N.H. XXXI. 58 seems to quote this passage.

² Where two pipes meet at an angle.

quod et decursus et circumductiones et ventres et expressus¹ hac ratione possunt fieri, cum habebunt a capitibus ad moenia ad² fastigii libramenta.

7 Item inter actus ducentos non est inutile castella conlocari, ut, si quando vitium aliqui locus fecerit, non totum onus neque³ opus contundatur et, in quibus locis sit factum, facilius inveniatur; sed ea castella neque in decursu neque in ventris planitia neque in expressionibus neque omnino in vallibus, sed in perpetua aequalitate.

8 Sin autem minore sumptu voluerimus, sic est faciendum. Tubuli crasso corio ne minus duorum digitorum fiant, sed uti hi tubuli ex una parte sint lingulati, ut alius in alium inire convenireque possint. Coagmenta autem eorum calce viva ex oleo subacta sunt inlinienda, et in declinationibus libramenti ventris lapis est ex saxo rubro in ipso geniculo conlocandus isque perterebratus, uti ex decursu tubulus novissimus in lapide coagmentetur et primus ex librati ventris;⁴ ad eundem modum adversum clivum et novissimus⁵ librati ventris in cavo saxi rubri haereat et primus expressionis ad eundem modum coagmentetur.

9 Ita librata planitia tubulorum ad⁶ decursus et expressionis⁷ non extolletur. Namque vehemens spiritus in aquae ductione solet⁸ nasci, ita ut etiam saxa perrumpat, nisi primum leniter et parce a capite aqua immittatur et in geniculis aut versuris alligationibus aut pondere saburra contineatur.

¹ expressus *ed*: -sis *H.*

² adfastigii libramenta (ad *acc. Sem.*) *H.*

³ onus neque *e*₂: omneque *H.*

⁴ *gen. Graec. ?*

⁵ novissimus *e*₂ *Joc*: -um *H.*

⁶ ad *Mar*: aut *H.*

⁷ *exp*ressionis *H.*

the descent, the circuit, the bend, the compression of the air, can be thus managed when there is a regular fall from the fountain head to the city.

7. Again, it is not without advantage to put reservoirs at intervals of 200 actus (24,000 feet), so that if a fault arises anywhere, neither the whole load of water nor the whole structure may be disturbed, but it may be more easily found where the fault is. But these reservoirs are to be neither in the descent nor on the level portion of the bend, nor on the rise, nor generally in valleys, but on unbroken level ground.

8. But if we wish to employ a less expensive method, we must proceed as follows. Earthenware pipes are to be made not less than two inches thick, and so tongued that they may enter into and fit one another. The joints are to be coated with quicklime worked up with oil. At the descents to the bend, a block of red stone is to be placed at the actual elbow, and pierced so that the last pipe¹ on the incline, and the first from the level of the bend, may be jointed in the stone. In the same way uphill: the last from the level of the bend, and the first of the ascent, are to be jointed in the same way in the hollow of the red stone.

9. Thus, by adjusting the level of the tubes, the work will not be forced out of its place at the downward inclines and the ascents. For a strong current of air usually arises in the passage of water, so that it even breaks through rocks, unless, to begin with, the water is evenly and sparingly admitted from the fountain head, and controlled at the elbows and turns by bonding joints or a weight of ballast. Every-

¹ *ex librati ventri* can hardly be right.

⁸ solet *e*₂ *Sulp*: solent *H.*

Reliqua omnia uti fistulis plumbeis ita sunt conlocanda. Item cum primo aqua a capite inmittitur, ante favilla inmittetur, uti coagmenta, si qua sunt non satis oblita, favilla oblinantur.¹

10 Habent autem tubulorum ductiones ea commoda. Primum in opere quod si quod vitium factum fuerit, quilibet id potest reficere. Etiamque multo salubrior est ex tubulis aqua quam per fistulas, quod per plumbum videtur esse ideo vitiosum,² quod ex eo cerussa nascitur; haec autem dicitur esse nocens corporibus humanis. Ita quod ex eo procreatur, <si>³ id est vitiosum, non est dubium, quin⁴ ipsum quoque non sit salubre.

11 Exemplar autem ab artificibus plumbariis possumus accipere, quod palloribus occupatos habent corporis colores. Namque cum fundendo plumbum flatur, vapor ex eo insidens corporis artus et inde⁵ exurens eripit ex membris eorum sanguinis virtutes. Itaque minime fistulis plumbeis aqua duci videtur, si volumus eam habere salubrem. Saporemque meliorem ex tubulis esse cotidianus potest indicare victus, quod omnes, et⁶ structas cum habeant vasorum argenteorum mensas, tamen propter saporis integritatem fictilibus utuntur.

12 Sin autem fontes, unde ductiones aquarum, faciamus, necesse est puteos fodere. In puteorum autem fossionibus⁷ non est contemnenda ratio, sed acuminibus sollertiaque magna naturales rerum rationes considerandae, quod habet multa variaque

¹ oblinantur *ed*: -nentur *H*.

³ si *add. Joc* (post ita).

⁵ inde *h*: indie *H*.

⁶ et structas *Kr.*: exstructas *H*.

⁷ fossionibus *h*: possessionibus *H*.

thing else is to be fixed as for lead pipes. Further, when the water is first sent from the fountain head, ashes are to be put in first, so that if any joints are not sufficiently coated, they may be grouted with the ashes.

10. Water-supply by earthenware pipes has these advantages. First, if any fault occurs in the work, anybody can repair it. Again, water is much more wholesome from earthenware pipes than from lead pipes. For it seems to be made injurious by lead, because white lead is produced by it; and this is said to be harmful to the human body.¹ Thus if what is produced by anything is injurious, it is not doubtful but that the thing is not wholesome in itself.

11. We can take example by the workers in lead who have complexions affected by pallor. For when, in casting, the lead receives the current of air, the fumes from it occupy the members of the body, and burning them thereupon, rob the limbs of the virtues of the blood. Therefore it seems that water should not be brought in lead pipes if we desire to have it wholesome. Our daily table may show that the flavour from earthenware pipes is better, because everybody, even when they pile up their tables with silver vessels,² for all that, uses earthenware to preserve the flavour of water.

12. But if we are to create fountains from which come the water-supplies, we must dig wells. But in digging wells we must not make light of science. The methods of nature must be considered closely in the light of intelligence and experience, because the

¹ Poisoning from lead pipes occasionally occurs in modern times; Neuburger, *op. cit.* 434.

² A silver table set from the House of Menander at Pompeii, is now in the Naples Museum.

terra in se genera. Est enim uti reliquae res ex quattuor principiis composita. Et primum est ipsa terrena; habetque ex umore aquae fontes; item calores, unde etiam sulphur, alumen, bitumen nascitur; aerisque spiritus inmanes, qui, cum graves per intervenia fistulosa terrae perveniunt ad fossionem puteorum et ibi homines offendunt fodientes, ut naturali vaporis obturant¹ eorum naribus spiritus animales; ita, qui non celerius inde effugiunt, ibi interimuntur.²

13 Hoc autem quibus rationibus caveatur, sic erit faciendum. Lucerna accensa demittatur; quae si permanserit ardens, sine periculo descendetur. Sin autem eripietur lumen a vi vaporis, tunc secundum puteum dextra ac sinistra defodiantur aestuaria;³ ita quemadmodum per nares spiritus ex aestu(ariis)⁴ dissipabuntur. Cum haec sic explicata fuerint et ad aquam erit perventum, tunc saepiatur a structura,⁵ nec obturentur venae.⁶

14 Sin autem loca dura erunt aut nimium venae penitus fuerint, tunc signinis⁷ operibus ex tectis⁸ aut superioribus locis excipiendae sunt copiae. In signinis autem operibus haec sunt facienda. Uti harena primum purissima asperrimaque paretur, caementum de silice frangatur ne gravius quam librarium, calx quam vehementissima mortario mixta, ita ut quinque partes harenae ad duos respondeant. Eorum fossa ad libramentum altitudinis, quod est

¹ obturant *Joc*: obturante *H*.

² interemuntur *H G*.

³ defodiantur aestuaria *ed*: defodianturq aestuaria *H S*.

⁴ aestuariis *Joc*: aestu *H*.

⁵ saepiatur a structura *e₂*: saepiatur a structura *H*.

⁶ venae *e₂* *ed*: venas *H*. ⁷ signinis *G*: signis *H*.

⁸ tectis *Joc*: testis *H*.

soil contains many various elements. For, like other things, it is composed of four principles. First, it is itself earthy; from the liquid, it has springs of water; there are various heats from which sulphur, alum and bitumen arise; and mighty currents of air. When these are heavy and come through the porous intervals of the soil to the wells which are being dug, they affect the excavators, in so far as the nature¹ of the exhalation chokes the animal spirits in their nostrils. Hence those who fail to escape at once, die there.

13. The precautions against this are to be carried out as follows.² Let a lighted lamp³ be lowered. If it remains alight, the descent will be accomplished without danger. If, however, the light is extinguished by the power of the exhalation, then air-shafts⁴ are to be dug right and left adjoining the well. In this way the vapours from the air will be dissipated, as the air is through the nostrils. When this has been arranged and we come to the water, then let it be enclosed by walling without blocking up the veins.

14. But if the locality is stony, or if the veins of water lie too deep, then supplies are to be collected from the roofs or higher ground in cement cisterns. We must proceed thus in making the cement. First let the purest and roughest sand be provided; then rubble is to be made of broken flint, no piece weighing more than a pound; the strongest lime is to be mixed in a trough, five parts of sand to two of lime. The trench is to be rammed down to the level of the depth

¹ *naturali* substantive.

² The more humane treatment of labour under the Empire is noteworthy.

³ *Plin. N.H. XXXI. 49.*

⁴ *Palladius, IX. 9, quotes from this passage.*

15 futurum, calcetur vectibus ligneis ferratis. Parietibus calcatis, in medio quod erit terrenum, exinaniatur ad libramentum infimum parietum. Hoc exaequato solum calcetur ad crassitudinem, quae exaequato fuerit. Ea autem si duplicia aut triplicia facta fuerint, uti percolationibus transmutari possint, multo salubriorem [et suaviorem]¹ aquae usum efficient; limus enim cum habuerit, quo subsidat, limpidior fiet et sine odoribus conservabit saporem. Si non, salem addi necesse erit et extenuari.

Quae potui de aquae virtute et varietate, quasque habeat utilitates quibusque rationibus ducatur et probetur, in hoc volumine posui; de gnomonicis² vero rebus horologiorum rationibus insequenti perscribam.

¹ et suaviorum *E G*: *om. H S*.

² gnomonicis *H G S*.

desired with wooden rams shod with iron. 15. After shaping the walls, the soil in the middle is to be emptied to the lowest level of the walls; when this is made even, the bottom is to be covered to the thickness which has been determined. If the cisterns are double or treble, so that they can be changed by percolation, they will make the supply of water much more wholesome. For when the sediment has a place to settle in, the water will be more limpid and will keep a flavour unaccompanied by smell. If not, salt must be added to purify it.

I have laid down in this volume what I could about the virtues and varieties of water, its uses, and how it is supplied and tested; in the next book I will deal with the making of dials and the theory of time-pieces.

BOOK IX

LIBER NONUS

1 NOBILIBUS athleticis, qui Olympia, Isthmia, Nemea vicissent, Graecorum maiores ita magnos honores constituerunt, uti non modo in conventu stantes cum palma et corona ferant¹ laudes, sed etiam, cum revertantur in suas civitates cum victoria, triumphantes quadrigis in moenia et in patrias invehantur e reque publica perpetua vita constitutis vectigalibus fruuntur. Cum ergo id animadvertam, admiror, quid ita non scribtoribus eidem honores etiamque maiores sint tributi, qui infinitas utilitates aevo perpetuo omnibus gentibus praestant. Id enim magis erat institui dignum, quod athletae² sua corpora exercitationibus efficiunt fortiora, scriptores non solum suos sensus, sed etiam omnium, <cum>³ libris ad discendum et animos exacuendos praeparant praecepta.

2 Quid enim Milo Crotoniates, quod fuit invictus, prodest hominibus aut ceteri, qui eo genere fuerunt victores, nisi quod, dum vixerunt ipsi, inter suos⁴ cives habuerunt nobilitatem. Pythagorae vero praecepta, Democriti, Platonis, Aristotelis ceterorumque sapientum cotidiana perpetuis industriis culta non solum suis civibus, sed etiam omnibus gentibus

¹ ferant *ed*: ferrent *e*₂, fuerant *H*.

² athla&e *H*, adhlete *S*. ³ *add. Ro.*

⁴ inter uos *H*.

BOOK IX

PREFACE

1. FAMOUS sportsmen who win victories at Olympia, Corinth and Nemea,¹ have been assigned such great distinctions by the ancestors of the Greeks that they not only receive praise publicly at the games, as they stand with palm and crown, but also when they go back victorious to their own people they ride triumphant with their four-horse chariots into their native cities, and enjoy a pension for life from the State. When I observe this, I am surprised that similar or even greater distinctions are not assigned to those authors who confer infinite benefits on mankind throughout the ages. For this is the more worthy of enactment, in that while sportsmen make their own bodies stronger, authors not only cultivate their own perceptions, but by the information in their books prepare the minds of all to acquire knowledge and thus to stimulate their talents.

2. For in what respect could Milo of Croton advantage mankind because he was unconquered, or others who won victories in the same kind, except that in their lifetime they enjoyed distinction among their fellow-citizens? But the daily teachings of Pythagoras, Democritus, Plato, Aristotle, and other thinkers, elaborated as they were by unbroken application, furnish ever-fresh and flowering² harvests,

² *florida prata*, Lucr. v. 785.

¹ There is no need with *G* to supply a reference to Delphi.

recentes et floridos edunt fructus. E quibus qui a teneris aetatibus doctrinarum abundantia satiantur, tibus humanitatis mores, aequa iura, leges, quibus
 3 absentibus nulla potest esse civitas incolumis. Cum ergo tanta munera ab scriptorum prudentia privatim publiceque fuerint hominibus praeparata, non solum arbitror palmas et coronas his tribui oportere, sed etiam decerni triumphos et inter deorum sedes eos dedicandos iudicari.

Eorum autem cogitata utiliter hominibus ad vitam explicandam e pluribus singula paucorum uti exempla ponam, quae recognoscentes necessario his tribui
 4 honores oportere homines confitebuntur. Et primum Platonis e multis ratiocinationibus utilissimis unam, quemadmodum ab eo explicata sit, ponam. Locus aut ager paribus lateribus si erit quadratus eumque oportuerit duplicare, quod opus fuerit genere numeri, quod multiplicationibus non invenitur, eo descriptionibus linearum emendatis reperitur. Est autem eius rei haec demonstratio. Quadratus locus, qui erit longus et latus pedes denos, efficit areae pedes c. Si ergo opus fuerit eum duplicare, pedum cc, item e paribus lateribus facere, quaerendum erit, quam magnum latus eius quadrati fiat, ut ex eo cc pedes duplicationibus areae respondeant. Id autem numero nemo potest invenire. Namque si XIII constituentur, erunt multiplicati pedes cxcvi, si xv, pedes ccxxv.

not only to their fellow-citizens but also to all mankind. Those who from tender years are satisfied thence with abundance of knowledge, acquire the best habits of thought, institute civilised manners, equal rights, laws without which no state can be secure. 3. Since, therefore, such boons have been conferred on individuals and communities by wise writers, not only do I think that palms and crowns should be awarded to them, but that triumphs also should be decreed and that they should be canonised in the mansions of the gods.

I will propose, as examples taken from a great number, several conceptions of a few thinkers which have helped the furnishing of human life, in order that the consideration of these may lead mankind to confess that honours should be conferred upon their inventors. 4. And first, out of the many and most useful theorems of Plato,¹ I will set out one with its demonstration. If there is a square area, or field with equal sides, and it is necessary to double it, there will be required some number which cannot be found by multiplication; this is determined by a perfect geometrical figure. Here is the demonstration. A square space which is ten feet long and wide makes 100 feet. If then it is necessary that it should be made double—of 200 feet—and also to make it of equal sides, we must inquire how long the side of that square is to be made, so that it may produce 200 feet, corresponding to the doubling of the area. No one can discover this by arithmetic. For if the side be 14 feet, then the multiplication gives 196 feet; if 15, then 225 feet.

¹ The Paris MS. 7227 contains an illustration indented into the text.

5 Ergo quoniam id non explicatur numero, in eo quadrato, longo et lato pedes x quod fuerit, linea ab angulo ad angulum diagonios¹ perducatur, uti dividantur duo trigona aequa magnitudine, singula areae pedum quinquagenum, ad eiusque lineae diagonalis longitudinem locus quadratus paribus lateribus describatur. Ita quam magna duo trigona in minore quadrato quinquagenum pedum linea diagonio fuerint designata,² eadem magnitudine et eodem pedum numero quattuor in maiore³ erunt effecta. Hac ratione duplicatio grammicis rationibus ab Platone, uti schema⁴ subscriptum est, explicata est in ima pagina.

6 Item Pythagoras normam sine artificis fabricationibus inventam ostendit, et quam magno labore fabri normam facientes vix ad verum perducere possunt, id rationibus et methodis emendatum ex eius praeceptis explicatur. Namque si sumantur regulae tres, e quibus una sit pedes III, altera pedes IIII, tertia⁵ pedes V, eaeque regulae inter se compositae tangant alia aliam suis cacuminibus extremis schema habentes trigoni, deformabunt normam emendatam. Ad eas autem regularum singularum longitudes si singula quadrata paribus lateribus describantur, cum erit trium latus, areae habebit pedes VIII, quod IIII, XVI, quod V erit, XXV.

7 Ita quantum areae pedum numerum duo quadrata ex tribus pedibus longitudinis⁶ laterum et quattuor efficiunt, aequae tantum numerum reddidit unum ex quinque descriptum. Id Pythagoras cum invenisset,

¹ diagonios *Joc* : diagonis *H*.

² designata *ed* : -tae *H*.

³ quattuori | maiore *H*.

⁵ tertia : terua *H*.

⁴ scema *H*.

⁶ longitudes *H*.

5. Since arithmetic does not furnish a solution, let a diagonal line be drawn from angle to angle in the square which was 10 feet long and wide, so that two triangles of equal magnitude, each of the area of 50 feet, are described. On the length of the diagonal let a square be described with equal sides. Therefore two triangles of 50 feet in area will be drawn upon the diagonal line in the lesser square; four triangles of the same magnitude and the same number of feet will be described in the larger square. In this manner the duplication is demonstrated geometrically by Plato in accordance with the figure subjoined at the bottom of the page.¹

6. Again, Pythagoras² demonstrated how to make a set-square without the help of a craftsman. And whereas the craftsman with great labour making a set-square can scarcely carry it out accurately, the exact process is explained in accordance with Pythagoras' instructions. For if three straight rods be taken, of which one is 3 feet long, the second 4 feet, the third 5 feet, and let these rods, being jointed together, touch one another at their extremities in the form of a triangle, they will make a perfect set-square.³ Moreover, if single squares with equal sides be described along the several rods, when the side is 3 feet, it will have 9 feet in area; the 4 feet side, 16; the 5 feet side, 25.

7. Thus the square which is described on 5 feet contains an area measured in feet equal to the area produced by the two squares, one with a side of 3 feet, and one with a side of 4. When Pythagoras

¹ Vitruvius paraphrases Plato, *Meno*, 82 ff.

² Pythagoras himself has left no writings; we do not know what belonged to him as distinguished from his school.

³ This proportion was known empirically to the Egyptians.

non dubitans a Musis se in¹ ea inventione monitum, maximas gratias agens hostias dicitur his immolare. Ea autem ratio, quemadmodum in multis rebus et mensuris est utilis, etiam in multis graduum aedificationibus, uti temperatas habeant

8 Si enim altitudo contignationis ab summa coaxatione² ad imum libramentum divisa fuerit in partes tres, erit earum quinque in scalis scaporum iusta longitudine inclinatio. Quam magnae fuerint inter contignationem et imum libramentum altitudinis partes tres, quattuor a perpendiculo recedant et ibi conlocentur inferiores³ calces scaporum. Ita sic erunt temperatae; et graduum ipsarum scalarum erunt conlocationes. Item eius rei erit subscripta forma.

9 Archimedis vero cum multa miranda inventa et varia fuerint, ex omnibus etiam infinita sollertia id, quod exponam, videtur esse expressum. Nimium Hiero enim Syracusis auctus regia potestate, rebus bene gestis cum auream coronam votivam diis immortalibus in quodam fano constituisset ponendam, manupretio locavit faciendam et aurum ad sacomam adpendit redemptori. Is ad tempus opus manu factum subtiliter regi adprobavit et ad sacomam

10 pondus coronae visus est praestitisse. Posteaquam indicium est factum dempto auro tantundem argenti in id coronarium opus admixtum esse, indignatus Hiero se contemptum esse neque inveniens, qua

¹ amusise in *H.* ² coaxatione *S G.*: coaxitione *H G.*

³ inferiores *Gal*: interiores *H.*

¹ Vitruvius himself regarded scientific discoveries as inspired.
² Archimedes thus founded hydrostatics; Mach, *Science of Mechanics*, tr. 86.
³ Hiero II, 270–216 B.C.

discovered this, in the belief that the Muses had advised¹ him in the discovery, he is said to have thanked them and sacrificed victims to them. The same calculation, as it is useful in many things and measurements, so it applies to buildings in the construction of staircases, for the adjustment of the steps.

8. For if the height of a story from the flooring above to the level below is divided into three parts, five such parts will give the inclined string of the staircase in its exact length. Taking the height between the floor above and the level below as three parts, let four parts be set off from the perpendicular and let the foot of the string be placed there. This will be so adjusted; so also will be the plotting out of the several steps of the staircase itself. The drawing of this, also, is subjoined.

9. Archimedes made many and various wonderful discoveries. Of all these the one which I will explain² seems to be worked out with infinite skill. Hiero³ was greatly exalted in the regal power at Syracuse, and after his victories he determined to set up in a certain temple a crown vowed to the immortal gods. He let out the execution as far as the craftsman's wages⁴ were concerned, and weighed the gold out to the contractor to an exact amount.⁵ At the appointed time the man presented the work finely wrought for the king's acceptance, and appeared to have furnished the weight of the crown to scale.

10. However, information was laid that gold had been withdrawn, and that the same amount of silver had been added in the making of the crown. Hiero was indignant that he had been made light of, and

⁴ Plin. *N.H.* XXXIV. 37.

⁵ There was a guild of *sacomarii* makers of weights at Rome.

ratione id furtum reprehenderet, rogavit Archimeden, uti in se sumeret sibi de eo cogitationem. Tunc is,¹ cum haberet eius rei curam, casu venit in balineum, ibique cum in solium descenderet, animadvertit, quantum corporis² sui in eo insideret, tantum aquae extra solium effluere. Itaque cum eius rei rationem explicationis ostendisset, non est moratus, sed exiit gaudio motus de solio et nudus vadens domum verius significabat clara voce invenisse, quod quaereret; nam currens identidem graece clamabat *εὕρηκα εὕρηκα*.

11 Tum vero ex eo inventionis ingressu duas fecisse dicitur massas aequo pondere, quo etiam fuerat corona, unam ex auro et alteram ex argento. Cum ita fecisset, vas amplum ad summa labra³ implevit aquae, in quo dimisit argenteam massam. Cuius quanta magnitudo in vasum depressa est, tantum aquae effluxit. Ita exempta massa quanto minus factum fuerat, refudit sextario mensus,⁴ ut eodem modo, quo prius fuerat, ad labra aequaretur. Ita ex eo invenit, quantum ad certum pondus argenti ad certam aquae mensuram responderet.

12 Cum id expertus esset, tum auream massam similiter pleno vaso demisit et ea exempta, eadem ratione mensura addita invenit ex aquae numero non tantum esse:⁵ minore quanto minus magno corpore eodem pondere auri massa esset quam argenti. Postea vero repleto vaso in eadem aqua ipsa corona demissa

¹ is S: his H.

² in *del. ed*: incorporis H.

³ libra H.

⁴ mensus *Joc*: mensus est H.

⁵ non tantum esse *Gr*: non tantum se H.

failing to find a method by which he might detect the theft, asked Archimedes to undertake the investigation. While Archimedes was considering the matter, he happened to go to the baths. When he went down into the bathing pool he observed that the amount of water which flowed outside the pool was equal to the amount of his body that was immersed. Since this fact indicated the method of explaining the case, he did not linger, but moved with delight he leapt out of the pool, and going home naked, cried aloud that he had found exactly what he was seeking. For as he ran he shouted in Greek: *heurēka heurēka*.¹

11. Then, following up his discovery, he is said to have taken two masses of the same weight as the crown, one of gold and the other of silver. When he had done this, he filled a large vessel to the brim with water, into which he dropped the mass of silver. The amount of this when let down into the water corresponded to the overflow of water. So he removed the metal and filled in by measure the amount by which the water was diminished, so that it was level with the brim as before. In this way he discovered what weight of silver corresponded to a given measure of water.

12. After this experiment he then dropped a mass of gold in like manner into the full vessel and removed it. Again he added water by measure, and discovered that there was not so much water; and this corresponded to the lessened quantity of the same weight of gold compared with the same weight of silver. He then let down the crown itself into the vase after filling the vase with water,

¹ 'I have found.'

invenit plus aquae defluxisse in coronam quam in auream eodem pondere massam, et ita ex eo, quod fuerit plus aquae in corona quam in massa, ratiocinatus reprehendit argenti in auro mittionem¹ et manifestum furtum redemptoris.

13 Transferatur mens ad Archytæ Tarentini et Eratosthenis Cyrenæi cogitata; hi enim multa et grata a mathematicis rebus hominibus invenerunt. Itaque cum in ceteris inventionibus fuerint grati, in eius rei concitationibus maxime sunt suspecti. Alius enim alia ratione explicaverunt,² quod Delo imperaverat³ responsis Apollo, uti arae eius, quantum haberent pedum quadratorum, id duplicarentur, et ita fore uti,⁴ qui essent in ea insula, tunc religione liberarentur.

14 Itaque Archytas cylindrorum descriptionibus, Eratosthenes organica mesolabi ratione idem explicaverunt. Cum haec sint tam magnis doctrinarum iucunditatibus animadversa et cogamur naturaliter inventionibus singularum rerum considerantes effectus moveri, multas res attendens admiror etiam Democriti de rerum natura volumina et eius com-

¹ mittionem *H*: v.l. mittix pro miscix *Petr.* 46. 5.

² explicaverunt *rec*: explicarentur *H*.

³ impetraverat *H*.

⁴ fore uti *Ro*: forenti *H S*.

¹ The Delian problem, the duplication of the cube is solved by finding two mean proportionals. If $a : x :: x : y$, and $x : y :: y : b$, then $x^2 = ay$ and $y^2 = xb$. Hence $y^4 = x^2b^2 = ayb^2$; or $y^3 = ab^2$. Therefore if $a = 2b$, $y^3 = 2b^3$; and y is

and found that more water flowed into the space left by the crown than into the space left by a mass of gold of the same weight. And so from the fact that there was more water in the case of the crown than in the mass of gold, he calculated and detected the mixture of the silver with the gold, and the fraud of the contractor.

13. Let us turn our attention to the theorems of Archytas of Tarentum, and of Eratosthenes of Cyrene. For they made for mankind many welcome discoveries by means of mathematics. While, therefore, they were made welcome by their other inventions, they were most admired for their mathematical inspirations. For they satisfied, each by his own method, the demand which Apollo had imposed upon Delos:¹ namely, that the number of cubic feet in his altar should be doubled, and that thereby the residents in the island should be freed from a religious scruple.

14. Archytas² solved the problem by a diagram with cylinders; Eratosthenes by means of an instrument the *mesolabium*.³ These theorems are apprehended with the great pleasure which such methods can give. For we are compelled, when we consider the effects of individual causes, to feel a natural emotion in the presence of inventions. After a wide survey, I admire especially Democritus' treatises on the Nature of Things, and in them the commentary in which there is figured the cutting of

the side of the cube which shall be twice the cube of which b is the length of the side.

² Hippocrates of Chios formulated the problem in the terms of the previous note. Archytas gave a geometrical solution.

³ Eratosthenes' mechanical contrivance is illustrated on Plate K.

mentarium, quo scribitur¹ *cheirotometon*;² in quo etiam utebatur anulo signaturam optice³ est expertus.

15 Ergo eorum virorum cogitata non solum ad mores corrigendos, sed etiam ad omnium utilitatem perpetuo sunt praeparata, athletarum autem nobilitates brevi spatio cum suis corporibus senescunt; [itaque neque cum maxime sunt]⁴ florentes neque posteritati hi, quemadmodum sapientium cogitata hominum vitae, prodesse possunt.

16 Cum vero neque moribus neque institutis scriptorum praestantibus tribuantur honores, ipsae autem per se mentes aeris altiora prospicientes memoriarum gradibus ad caelum elatae⁵ aevo immortali⁶ non modo sententias sed etiam figuras eorum posteris cogunt esse notas. Itaque, qui litterarum iucunditatibus instinctas habent mentes, non possunt non in suis pectoribus dedicatum⁷ habere, sicuti deorum, sic Enni poetae simulacrum; Acci autem carminibus qui studiose delectantur, non modo verborum virtutes sed etiam figuram eius videntur secum habere praesentem esse.⁸

¹ quo scribitur *Gr*: quod scribitur *H*.

² ΧΕΙΡΟΤΟΜΗΤΟΝ *H*.

³ signaturam optice *Gr*: signaretur amolcie *H*.

⁴ itaque neque cum maxime sunt *E G*: om. *H S*: interpolationem ineptam quae contentionem senescunt; florentes perdit.

⁵ elatae *Joc*: -ti *H*.

⁶ aevo immortali *E G*: aeuum immortalitati *H*.

⁷ dedicatum *Joc*: -tas *H*. ⁸ locutio usitata apud *Vitr.*

¹ The influence of gem-cutting may perhaps be traced in the atomic philosophy. It is possible that the hardness of the diamond and corundum (with its allies), which is twice the hardness of iron, along with their crystalline shape, suggested the properties ascribed to atoms: the *ordo positura figurae* as Lucretius puts it.

² Democritus' application of his theory of projection to

gems.¹ With the help of optics,² he investigated the impression of the seal in the ring which he used.

15. So then the imaginations of these men were directed throughout not only to the improvement of conduct, but to the service of mankind. The distinctions of sportsmen soon pass along with their physique, nor in their prime can they advantage posterity, as the devices of thinkers advantage human life.

16. Thus although honour is given neither to the character nor to the excellent principles of authors, yet their minds of themselves look upon the upper air and rise to heaven by the staircase of human remembrance;³ throughout endless time they make not only their ideas but even their portraits familiar to posterity. Hence those whose minds are stirred by the delights of literature cannot but have the image of Ennius, as of a god, in the chapel of their breast. Those who take studious delight in the poems of Accius⁴ seem to keep at their side, not only his mighty words, but his very present portrait.

perspective was probably contained in his *actinographie*, (Ionic for *actinographia*) Diels, *Fragmente der Vorsokratiker*, II. 64. In that case the *cheirotometon* (Plate K) would be an illustration of an expedient comparable to the *mesolabium*, as an invention following upon a theory of causes. The current mistranslation of this passage arose from rendering *scribitur* as 'write.' In technical language it often means 'draw,' as in Cic. *Tusc.* V. 113, *lineam scribere*. Vitruvius' account of geometrical figures drawn on the shore at Rhodes, along with this passage, suggests that Jesus did not 'write,' but 'drew,' *John* viii. 6.

³ Vitruvius probably does not go beyond the idea of survival contained in Ennius' *volito vivos per ora virum*, 'I live and fly from lip to lip.'

⁴ Accius, the greatest tragic dramatist of Rome, was born 170 B.C.

17 Item plures post nostram memoriam nascentes cum Lucretio videbuntur velut coram de rerum natura disputare, de arte vero rhetorica cum Cicerone, multi posteriorum cum Varrone conferent sermonem de lingua latina, non minus etiam plures philologi cum Graecorum sapientibus multa deliberantes secretos cum his videbuntur habere sermones, et ad summam sapientium scriptorum sententiae corporibus absentibus vetustate florentes cum insunt inter consilia et disputationes, maiores habent, quam praesentium sunt, auctoritates omnes.

18 Itaque, Caesar, his auctoribus fretus sensibus eorum adhibitis et consiliis ea volumina conscripsi, et prioribus septem de aedificiis, octavo de aquis, in hoc de gnomonicis rationibus, quemadmodum de radiis solis in mundo sunt per umbras gnomonis inventae quibusque rationibus dilatentur aut contrahantur, explicabo.

I

1 EA autem sunt divina mente comparata habentque admirationem magnam considerantibus, quod umbra gnomonis aequinoctialis alia magnitudine est Athenis,

¹ Traces of Lucretius' influence occur in the astronomical references of Vitruvius.

² Cicero, *de Oratore*, I. 62, ascribes the eloquence displayed sometimes by architects, not to their calling, but to the art of rhetoric; cf. Book I. i. 18.

17. Many also, born in time to come, will seem with Lucretius to investigate *The Nature of Things*, as it were, face to face,¹ or with Cicero, *The Art of the Orator*; ² many of our posterity will hold converse with Varro ³ *On the Latin Language*; not less, also, many scholars deliberating much with the thinkers of Greece, will seem to hold secret converse with them. In a word, the ideas of scientific writers who are absent in the body, old and yet ever new, come to our counsels and investigations; and all have greater weight than if they were present with us.

18. Therefore, your Highness, I have relied on these authors, and bringing their minds and advice to bear, I have composed these volumes, dealing with buildings in the first seven, and with water in the eighth. In the present volume I will expound the methods of Dialling; how they were discovered from the rays of the sun in the universe, by the shadows of the gnomon, and in what proportions these lengthen or diminish.

CHAPTER I

ON THE UNIVERSE AND THE PLANETS

1. It is ordained by the divine spirit ⁴ and inspires great wonder ⁵ in those who consider it, that the shadow of the gnomon at the equinox is of one magni-

³ Vitruvius drew also upon Varro's *de Re Rustica*; but his references to philosophers came, not from Varro, but from Greek sources.

⁴ *hoc opus immensi constructum corpore mundi . . . vis animae divina regit.* Man. i. 247-9.

⁵ *mundi et astrorum magnificentia*, Book II. i. 2.

alia Alexandriae, alia Romae, non eadem Placentiae ceterisque orbis terrarum locis. Itaque longe aliter distant descriptionis horologiorum locorum mutationibus. Umbrarum enim aequinoctialium magnitudinibus designantur¹ analemmatorum formae, e quibus perficiuntur ad rationem locorum² et umbrae gnomonum³ horarum descriptiones. *Analemma* est ratio conquisita solis cursu et umbrae crescentis ad brumam⁴ observatione inventa, e qua per rationes architectonicas circinique descriptiones est inventus effectus in mundo.

2 Mundus autem est omnium naturae rerum conceptio summa caelumque sideribus conformatum.⁵ Id volvitur continenter circum terram atque mare per axis cardines extremos. Namque in his locis naturalis potestas ita architectata⁶ est conlocavitque cardines tamquam centra, unum a terra inmane⁷ in summo mundo ac post ipsas stellas septentrionum, alterum trans contra sub terra in meridianis partibus, ibique circum eos cardines orbiculos circum centra uti in torno perfecit, qui graece *apsides*⁸ nominantur, per quos pervolitat sempiterno caelum. Ita media terra cum mari centri loco naturaliter est conlocata.

3 His natura dispositis ita, uti septentrionali parte a terra excelsius habeat altitudinem centrum, in meridiana autem parte in inferioribus locis subiectum

¹ designantur *G* : desidesignantur *H*, si designantur *S G*.

² locorum *rec* : longorum *H G S*.

³ gnomoniū *H S*.

⁴ ad brumam *Ro* : abrumae *H*.

⁵ conformatum *G* : -tus *H*.

⁶ architecta *H S* (cf. naturae architectae vis, *Plin. N. H. X.* 196, *Hard.*).

⁷ inmane *Gr* : inmani *H*.

⁸ *apsides Gr* : *pasde H*.

tude at Athens, another at Alexandria, another at Rome, is different at Piacenza and in other parts of the world. Therefore the designs of dials vary widely with change of place. For the length of the shadows at the equinox determines the design of the *analemma*¹ by which the hours are marked in accordance with the locality and the shadow of the gnomon. The *analemma* is an exact contrivance invented by observing the course of the sun and the lengthening of the shadow towards the winter, by means of which through architectural² calculations and the use of the compass, the action of the sun in the universe is discovered.

2. The universe is the total conception of the whole system, and the firmament with its ordered constellations. It rolls continually round the earth and sea, on the furthest poles³ of its axis. For there the power of nature like an architect, has contrived and placed the poles like centres, one at a vast distance from the earth at the top of the universe and behind the very stars of the Great Bear, and the other opposite, under the earth in the regions of the south; and there has constructed rims of wheels (which the Greeks call *apsides*) round centres as in a lathe, about which the firmament for ever rolls. Thus the middle of the earth and sea is set by nature in the central place.

3. The arrangement of nature is such that on the north the higher centre is exalted above the earth, while in the southern part the centre lying under the lower

¹ Plate L. The *analemma* is a geometrical figure with the help of which dials are drawn.

² Architecture includes engineering.

³ Lit. 'hinges.'

a terra obscuretur, tunc etiam per medium transversa et inclinata in meridiem circuli delata zona XII signis XII partibus peraequatis exprimit depictam ab reliquisque sideribus ornata¹ circum terram mareque pervolantia cursus perficiunt ad caeli rotunditatem.

4 Omnia autem visitata et invisitata temporum necessitate sunt constituta. Ex quis sex signa numero supra terram cum caelo pervagantur, cetera sub terram subeuntia ab eius² umbra obscurantur. Sex autem ex his semper supra terram nituntur. Quanta pars enim novissimi signi depressione coacta versatione subiacens³ sub terram occultatur, tantundem eius contraria e conversationis necessitate suppressa rotatione⁴ circumacta trans locis patentibus ex⁵ obscuris egreditur ad lucem; namque vis una et necessitas utrimque simul orientem et occidentem perficit.

5 Ea autem signa cum sint numero XII partesque duodecimas singula possideant mundi versenturque ab oriente ad occidentem continenter, tunc per ea signa contrario cursu luna, stella Mercuri, Veneris, ipse sol itemque Martis et Iovis et Saturni ut per graduum ascensionem⁶ percurrentes alius alia circuitio- nis magnitudine ab occidenti ad orientem in mundo pervagantur. Luna die octavo et vicesimo

¹ ornatū H.

² ab eis H G^c.

³ subiacens Gr: subiciens H (*Iren. C.H. II. 28. 3*).

⁴ rotatione Joc: notatione H.

⁵ ex Ro: & H.

⁶ ascensione H.

¹ The Zodiac: an imaginary belt extending about eight degrees on either side of the ecliptic.

regions is hidden. Then, moreover, along the middle a transverse and oblique belt,¹ sinking towards the south of the equator, is figured with the twelve signs. (This figure of theirs with stars set in order reveals in twelve equal parts the pattern depicted by nature.)² These, as they shine in their array, along with the heavens and the other constellations, roll round the earth and sea and complete their courses with the revolution of the sky.

4. Now all the signs seen or unseen are constituted by the necessity of the seasons. While six of these revolve above the earth along with the sky, the others going under the earth are obscured by its shadow. Six, however, are always placed above the earth. For whatever part of the last sign driven by its revolution passes under the earth and is concealed by its depression, to that extent the contrary sign forced upwards by the necessity of the revolution is carried round in rotation and from darkness comes to light in the visible heavens. For a single power and compulsion controls simultaneously on both sides the rising and the setting.

5. Now while these twelve signs possess each the twelfth part of the firmament, and continually turn from east to west, through these same signs in the opposite direction the stars³ of the moon, Mercury, Venus, the Sun himself and also Mars, Jupiter and Saturn as though they revolved upon a rising staircase of degrees, each with an orbit of its own, wander in the firmament from west to east. The moon runs

² Nature as the artificer.

³ stella in Manilius often = 'planet,' Housman, *ad Man. i. 15, adversos stellarum noscere cursus*.

et amplius circiter hora caeli circuitiōnem percurrens, ex quo signo coeperit ire, ad id signum revertendo perficit lunarem mensem.

6 Sol autem signi spatium, quod est duodecima pars mundi, mense vertente vadens transit; ita XII mensibus XII signorum intervalla pervagando cum vertentis anni. Ex eo, quem circulum luna terdecies in XII mensibus percurrit, eum sol eisdem¹ mensibus semel permetitur. Mercuri autem et Veneris stellae circa solis radios uti per centrum eum² itineribus coronantes regressus retrorsus et retardatione faciunt, etiam stationibus propter eam circinationem morantur in spatiis signorum.

7 Id autem ita esse maxime cognoscitur ex Veneris stella, quod ea, cum solem sequatur, post occasum eius apparens in caelo clarissimeque lucens vespere vocitatur, aliis autem temporibus eum antecurrens et oriens ante lucem lucifer appellatur. Ex eoque nonnumquam plures dies in signo comorantur, alias celerius ingrediuntur in alterum signum. Itaque quod non aequè peragunt numerum dierum in singulis signis, quantum sunt moratae prius, transiliendo celerioribus itineribus perficiunt [iustum cursum. Ita efficitur,]³ uti, quod demorentur in nonnullis signis, nihilominus, cum eripiant se ab necessitate morae, celeriter consequantur iustam circuitiōnem.

8 Iter autem in mundo Mercuri stella ita pervolat, uti trecentesimo et sexagesimo die per signorum

¹ cum sole isdem *H.* ² eum *rec*: cum *H.*
³ iustum—efficitur *EG*: *om. HS*: interpolator quid significet vox perficiunt cum uti coniuncta, nescire videtur.

through its orbit from the sign in which it began, on the twenty-eighth day and about an hour more, and returning to that sign completes the lunar month.

6. The sun, journeying for a month, passes over the space of a sign which is the twelfth part of the heavens. Thus in twelve months he traverses the distance of twelve signs, and when he returns to the sign from which he started, he completes the space of the revolving year. Hence the sun measures once in twelve months the circle which the moon in the same number of months runs through thirteen times. The planets Mercury and Venus, with their orbits, encircling the sun's rays as on a centre, retreat backwards and delay their course;¹ thus because of their orbit they delay at the nodes² in their course through the signs.

7. This is best seen from the planet Venus, because when it follows the sun it appears in the sky after sunset, and brightly shining is called the Evening Star.³ At other times it precedes the sun, and rising before the dawn is called Lucifer. Hence sometimes they delay several days in a sign, sometimes they enter more quickly into another sign. Therefore because they do not spend uniformly a fixed number of days in the several signs, they make up by quicker movements the amount they previously delayed; so that while they delay in some signs, none the less, when they escape the compulsion of delay, they quickly make up their proper course.

8. The planet Mercury so completes its path in the firmament that, traversing the spaces of the

¹ Where the orbit of the planet intersects the ecliptic, in Greek *σημειοί*.
² *nec matutinis fulgeret Lucifer horis Hesperos emenso dederat qui lumen Olympo, Man. i. 177-8.*

spatia currens perveniat ad id signum, ex quo priore circulatione coepit facere cursum, et ita peraequatur eius iter, ut circiter tricenos dies in singulis signis habeat numeri rationem.

- 9 Veneris autem, cum est liberata ab impeditioe radiorum solis, xxx diebus percurrit signi spatium. Quo minus quadragenos dies in singulis signis patitur, cum stationem fecerit, restituit eam summam numeri in uno signo morata. Ergo totam circinationem² in caelo quadringentesimo et octogesimo et quinto die permensa³ iterum in id signum, ex quo signo prius iter facere coepit.
- 10 Martis vero circiter sescentesimo octogesimo tertio siderum spatia pervagando pervenit eo, ex quo initium faciendo cursum fecerat ante, et in quibus signis celerius percurrit, cum stationem fecit, explet dierum numeri rationem. Iovis autem placidioribus gradibus scandens contra mundi versationem, circiter cclx diebus in singula signa permetitur, et consistit post annum xi et dies cccxiii⁴ et redit in id signum, in quo ante xii annos fuerat. Saturni vero, mensibus undetriginta et amplius paucis diebus pervadens per signi spatium, anno nono et vicensimo et circiter diebus clx, in quo ante tricensimo fuerat anno, in id restituitur, ex eoque, quo minus ab extremo distat mundo, tanto maiorem circinationem rotae percurrendo tardior videtur esse.
- 11 Ei autem, qui supra solis iter circinationes peragunt,

¹ ergo totam *G* : ergotam *H*.
² circinationem *Ro* : circitionem *H*.
³ permansa *H*.

signs, it arrives on the three-hundred-and-sixtieth day at that sign, from which in its previous revolution it entered on its course. Its path is so averaged that it spends about thirty days in each sign.

9. The planet Venus, when it is freed from the hindrance of the sun's rays, traverses the space of some signs in thirty days; so far as it suffers an abatement from forty days in the several signs, after traversing a node, it regains that amount lost by delaying in the several signs. Therefore it completes the whole circuit in the firmament on the four-hundred-and-eighty-fifth day, in that sign from which previously it started on its journey.

10. Mars traverses the spaces of the constellations on about the six-hundred-and-eighty-third day, and reaches the place from which it previously made a beginning in making its journey; where it runs more quickly in the signs, it fulfils the proportionate number of days after passing a node. Jupiter, rising by more easy steps against the revolution of the firmament, measures about three hundred and sixty days against each sign, and after eleven years and three hundred and thirteen days it halts and returns to the sign where it had been twelve years before. Saturn, traversing a sign in twenty-nine months and a few days, takes twenty-nine years and about a hundred and sixty days to regain the sign in which it was thirty years before. From the fact that it is less distant from the furthest verge of the firmament, it seems to be more slow in traversing the greater circumference of its orbit.

11. Those planets which traverse their orbit above

⁴ cccxiii *Mar* : cccxiii *H*.

maxime cum in trigono fuerint, quod is inierit, tum non progrediuntur, sed regressus facientes morantur, doneque cum ¹ idem sol de eo trigono in aliud signum transitionem fecerit. Id autem nonnullis sic fieri placet, quod aiunt solem, cum longius absit abstentia quadam, non lucidis itineribus errantia per ea sidera obscuritatis morationibus impedire.² Nobis vero id non videtur. Solis enim splendor perspicibilis et patens sine ullis obscurationibus est per omnem mundum, ut etiam nobis appareant, cum facient eae stellae regressus et morationes. Ergo si tantis intervallis nostra species potest id animadvertere, quid ita divinationibus splendoribusque astrorum iudicamus obscuritatis obici posse?

12 Ergo potius ea ratio nobis ³ constabit, quod, fervor quemadmodum omnes res evocat et ad se ducit, ut etiam fructus e terra surgentes in altitudinem per calorem videmus, non minus aquae vapores a fontibus ad nubes per arcus excitari, eadem ratione solis impetus vehemens radiis trigoni ⁴ forma porrectis insequentes stellas ad se perducit et ante ⁵ currentes veluti refrenando retinendoque ⁶ non patitur progredi, sed ad se regredi, in alterius trigoni signum esse.

13 Fortasse desiderabitur, quid ita sol quinto a se signo potius quam secundo aut tertio, quae sunt propiora,⁷ facit in his fervoribus retentiones. Ergo, quemadmodum id fieri videatur, exponam. Eius

¹ doneque cum = donicum, *Munro* (ad *Lucr.* ii. 1116): doneque cum *H.*

² impedire *Schn*: -ri *H.*

³ ratio nobis *H S G*: rationibus *G.*

⁴ radiis trigoni *rec*: adius trigoni *H.*

⁵ et ante *Joc*: tantae *H*, ante *S.*

⁶ r&enendoq; *H.*

⁷ propiora *H.*

the path of the sun, especially when they are in the trigon ¹ which he has entered, do not go forward but retrograde and delay until the same sun has passed from that trigon into another sign. To some, this seems to happen because the sun, they say, being further away at a certain distance, hinders by the delay of darkness the planets wandering in their unilluminated paths. To us it seems otherwise. For the splendour of the sun is perceptible and patent through all the universe without any obscuration, so that these stars appear ² to us even when they retrograde or are stationary. Therefore if our vision can perceive it at such great distances, why do we judge that obscurity may be set against the prophetic splendours of the stars?

12. Therefore the consideration rather commends itself to us that, just as heat evokes all things and draws them to itself, as also we see the crops rising on high from the earth because of the heat, and the watery exhalations raised from the springs to the clouds along the rainbow, so in the same way the mighty force of the sun extending its rays in the form of a triangle draws to itself the planets as they follow, and, as it were curbing and restraining those which precede, prevents their onward movement and compels them to return to it and to be in the sign of another trigon.

13. Perhaps it will be asked, why does the sun cause delay by these heats, in the fifth sign away from itself rather than in the second and third? I will therefore explain how this seems to happen.

¹ Group of four signs answering to one side of an equilateral triangle described in the sun's apparent orbit.

² The planets even at night draw their light from the sun.

radii in mundo uti trigoni paribus lateribus¹ formae
 liniationibus extenduntur. Id autem nec plus nec
 minus est ad quintum² ab eo signo. Igitur si radii
 per omnem mundum fusi circinationibus vagarentur
 neque extentionibus porrecti ad trigoni formam
 liniarentur, propiora³ flagrarent. Id autem etiam
 Euripides, Graecorum poeta, animadvertisse videtur.
 Ait enim, quae longius a sole essent, haec vehementer
 tius ardere, propiora⁴ vero eum temperata habere.
 Itaque scribit in fabula Phaethonte⁵ sic:

καίει τὰ πόρρω, τᾶγγυθεν δ' εὐκρατ' ἔχει.⁶

14 Si ergo res et ratio et testimonium poetae veteris
 id ostendit, non puto aliter oportere iudicari, nisi
 quemadmodum de ea re supra scribuntur habemus.

Iovis autem inter Martis et Saturni circinationem⁷
 currens maiorem quam Mars, minorem quam Saturnus
 pervolat cursum. Item reliquae stellae, quo maiore
 absunt spatio ab extremo caelo proxumamque habent
 terrae circinationem,⁷ celerius videntur, quod quae-

¹ lateribus *G*: lateribusque *H S G*.

² quintum *Joc*: quintā *H*.

³ propiora *H^c S*: propiora *H*.

⁴ propiora *H*.

⁵ phaetonte *H*.

⁶ ΚΑΙΕΙΤΑΤΠΟΡΡΩΤΑΝΓΥΓΝΑΙΕΙΕΥΧΡΑΤΑΕΧΕΙ *H*: τᾶγγυθεν
Valcken: εὐκρατ' *Joc*.

⁷ circitionem *H*.

¹ The sun is separated from the opposite trigon by the
 space of a trigon on either side: each side of the equilateral
 triangle corresponding to a trigon.

² Euripides gave expression in his plays to the philosophical
 ideas of his time without engaging in purely philosophical
 writing.

Its rays are spread out in the firmament on the lines
 of the diagram of a triangle with equal sides. Now
 each side extends neither more nor less than to the
 fifth sign, from that in which the sun is.¹ For if the
 rays spread over the firmament wandered in circular
 orbits, and in their extension were not directed in the
 form of a triangle, the nearer regions would be burnt.
 Euripides,² the Greek poet, seems to have observed
 this. For he says that what is farther from the sun
 burns more vehemently, while it keeps what is
 nearer in a temperate state. And so he writes as
 follows in the *Phaethon*:³

He burns the distant: what is near he keeps
 temperate.

14. If then experience, calculation and the testi-
 mony of an ancient poet⁴ shows⁵ this, I think we
 should not judge otherwise than as we have written
 above on the matter.

Jupiter, traversing its orbit between Mars and
 Saturn, pursues a course longer than that of Mars,
 less than Saturn's. The other planets, also, the
 farther they are from the verge of the firmament,
 have an orbit nearest the earth and seem to move
 more swiftly, because each of them, traversing a

³ Vitruvius, VIII. pref. 1, quoted from the *Chrysippus* a
 passage almost expressed in philosophic terms. Here the
 sun is a king with his palace in Ethiopia. The preceding line
 runs: 'the hot fire of the king rising over the earth.'
 Grotius according to Schneider was the first to connect these
 two lines.

⁴ Vitruvius analyses the notion of 'authority' *auctoritas*,
 which occurs so often in his work, adding 'testimony' to the
res and *demonstratio* of I. i. 3.

⁵ The singular verb corresponds to the logical unity of the
 subject.

cumque earum¹ minorem circinationem peragens saepius subiens praeterit superiorem.

15 Quemadmodum, si in rota, qua figuli utuntur, inpositae fuerint septem formicae canalesque totidem ad extremum, in quibus hae cogantur circinationem facere, verseturque rota in alteram partem, necesse erit eas contra rotae versationem nihil minus adversus itinera perficere, et quae proximum centrum habuerit, celerius pervagari, quaeque extremum orbem rotae peragat, etiamsi aequae celeriter ambulet, propter magnitudinem circinationis multo tardius perficere cursum: similiter astra nitentia contra mundi cursum suis itineribus perficiunt circuitum, sed caeli versatione redundationibus referuntur cotidiana temporis circumlacione.

16 Esse autem alias stellas temperatas, alias ferventes, etiamque frigidas haec esse causa videtur, quod omnis ignis in superiora loca habet scandentem flammam. Ergo sol aethera, qui est supra se, radiis exurens efficit² candentem, in quibus locis habet cursum Martis stella; itaque fervens ab ardore solis efficitur. Saturni autem, quod est proxima extremo mundo tangit congelatas caeli regiones; vehementer est frigida. Ex eo Iovis, cum inter utriusque circuitiones habet cursum, a refrigeratione caloreque eorum medio convenientes temperatissimosque habere videtur effectus.

¹ earum *ed*: eorum *H*.

² effecit *H*.

¹ The illustration from the movements of ants was used by contemporary mathematicians. Schneider *ad loc.* quotes *Comedies* and Achilles Tatius (not the novelist).

² *Vehementer* with an adjective.

less orbit, more often moves under and passes the planet above it.

15. To illustrate¹ this: let us suppose that on a wheel such as potters use, seven ants are placed, and as many channels are made in the wheel round the centre as the lowest point, increasing in length to the most distant; let the ants be compelled to make a circuit in these channels and let the wheel be turned the other way; in spite of the revolution of the wheel, they will necessarily complete their journeys in the opposite direction. That which has the channel nearest the centre completes its wanderings more quickly; that which traverses the farthest circuit of the wheel, even if it walks as quickly, finishes its course much more slowly on account of the magnitude of the orbit. In like fashion, the planets advancing in a direction opposite to the movement of the firmament complete a circuit along their own paths. Yet in the revolution of the sky they are carried backwards, by the excess of it over their own motion, in the daily circuit of time.

16. The reason why some stars are temperate, others fiery and others cold, seems to be this, that all fire has a flame which rises to higher regions. Therefore the sun scorches with its rays the aether above it and causes it to burn, and the planet Mars has its course in these regions; hence it is made to burn by the heat of the sun. The planet Saturn, however, which is nearest to the verge of the firmament, touches the frozen regions of the sky; it is exceedingly cold.² Hence Jupiter, having its course between the circuits of either, seems to enjoy the most temperate effects of cold and heat, which suit its middle position.

De zona XII signorum et septem astrorum contrario opere ac cursu, quibus rationibus et numeris trans-eunt e signis in signa, et circuitum eorum, uti a praeceptoribus accepi, exposui; nunc de crescenti lumine lunae deminutioneque, uti traditum est nobis a maioribus, dicam.

II

1 BEROSUS, qui ab Chaldaeorum civitate sive natione progressus in Asia etiam disciplinam Chaldaicam¹ patefecit, ita est professus:

Pilam esse ex dimidia parte candentem, reliqua habere caeruleo colore. Cum autem cursum itineris sui peragens subiret sub orbem solis, tunc eam radiis et impetu caloris corripit convertique candentem propter eius proprietatem luminis ad lumen. Cum autem ea vocata ad solis orbem² superiora spectent, tunc inferiorem partem eius, quod candens non sit, propter aeris similitudinem obscuram videri. Cum ad perpendicularum esset ad eius radios, totum lumen ad superiorem speciem retineri, et tunc eam vocari primam.

¹ chaldaicam H.

² orbem Gr: orbis H.

¹ Berosus was a priest of Bel at Babylon, later he settled at Cos, *infra*, c. vi. 2. He dedicated his *Chaldaica* to Antiochus Soter. He invented a form of dial, c. viii. 1.

² Vitruvius' phrase 'city, or rather nation,' corresponds to the fact that the city of Babylon was in ruins beginning from its capture by Darius. Antiochus Soter, however, restored the temple of Bel.

I have explained the belt of the twelve signs, and the contrary operation and course of the seven planets; the causes and numerical relations by which they pass from sign to sign, and their revolutions as I have learned from my masters. I will now speak of the rising light and waning of the moon, as our predecessors have told us.

CHAPTER II

ON THE RISING AND WANING OF THE MOON

1. BEROSUS,¹ who sprang from the Chaldaean city, or rather nation,² expounded the Chaldaean discipline as far as Asia. He taught as follows:

The moon is a globe with one hemisphere luminous³ and the other of a dark blue colour. Now when it traverses the course of its orbit, and comes under the sun's disk, it is attracted by the sun's rays and violent heat, and, because of the property of the sun's light, the shining hemisphere of the moon turns to that light. But while those upper parts which are attracted look towards the sun's sphere, the lower hemisphere of the moon, which does not shine, seems dark because of its resemblance to the air. When the moon is perpendicular to the sun's rays, all its light is held back on its upper face, and it is then called the first moon.

³ Berosus uses the phrase *ἡμικύρῳτον σφαῖραν*, Stob. *Ecl.* I. 26. 12. From him Lucretius drew the description of the Chaldaean theory, v. 720–728: *versarique potest, globus ut, si forte, pilai dimidia ex parti candenti lumine tinctus, versandoque globum variantis edere formas, etc.*

2 Cum praeteriens vadat ad orientis caeli partes, relaxari ab impetu solis extremamque eius partem candentiae oppido quam¹ tenui linea ad terram mittere splendorem, et ita ex eo eam secundam vocari. Cotidiana autem versationis remissione tertiam, quartam in dies numerari. Septimo die, sol sit ad occidentem, [luna autem inter orientem et occidentem]² medias caeli teneat regiones, quod dimidia parte caeli spatio distaret a sole, item dimidiam³ candentiae conversam habere ad terram. Inter solem vero et lunam cum distet totum mundi spatium et lunae orienti⁴ sol trans contra sit⁵ ad occidentem, eam, quo longius arsit, a radiis remissam XIII die plena rota totius orbis mittere splendorem, reliquosque dies decrescentia cotidiana ad perfectionem lunaris mensis versationibus et cursu a sole revocationibus subire sub rotam radiosque eius, et iam mensuras dierum efficere rationes.

3 Uti autem Aristarchus⁶ Samius mathematicus vigore magno rationes varietatis⁷ disciplinis de eadem⁸ reliquit,⁹ exponam. Non enim latet lunam suum propriumque non¹⁰ habere lumen, sed esse uti speculum et ab solis impetu recipere splendorem.

¹ quam *ed*: quamquam *H*.

² luna—occidentem *G*: *om. H S. luna facile intellegitur.*

³ dimidiam *E*: -dia *H*.

⁴ orienti *E*: -tis *H G S*.

⁵ sol trans contra sit *Ro*: sol trans cum transit *H*.

⁶ aristarchus *G*: arhistartus *H*.

⁷ varietates *H G*. ⁸ *sc. luna.*

⁹ reliquid *H*. ¹⁰ non *add. Joo.*

¹ Berossus' optical theory of the conflict between the rays from the moon and the more powerful rays of the sun antici-

2. When the moon in its passage moves towards the eastern parts of the sky, it begins to be released from the sun's force, and the extreme edge of its shining hemisphere in a very thin line lets fall its splendour on the earth; and so therefrom it is called the second moon. Owing to the daily retardation of its revolution, the third and fourth moons and so on are numbered. On the seventh day let the sun be towards the west; the moon occupies the middle region of the sky and has half of the shining hemisphere turned upon the earth because it is distant from the sun by a space equal to the half part of the sky. But when the whole space of heaven separates the sun and moon, and the sun is opposed on the west to the rising moon, the moon, burning at a greater distance, is released from the sun's rays,¹ and on the fourteenth day sends forth its splendour with the full disk of its whole orb. During the remaining days there is a daily decrease until the lunar month is complete; the moon as it revolves along its course is recalled under the sun's disk and rays, and now² completes the order of the days of the month.³

3. I will now explain how Aristarchus the mathematician of Samos, by his powerful intelligence, left in his systematic works an explanation of the moon's phases. For it does not escape him that the moon has not its own proper light, and that it is like a mirror and receives its splendour from the sun's

pated Young's discovery of the absorption of light by interference.

¹ *etiam* = *et iam*; cf. *quoniam*, *nunc iam*.

² The whole theory of Berossus about the moon is to be read in the light of the phases of the moon as shown in the diagram, Pl. J.

Namque luna de septem astris circulum proximum terrae in cursibus minimum pervagatur. Ita quot¹ mensibus sub rotam solis radiosque uno die, antequam praeterit, latens obscuratur. Cum est cum sole, nova vocatur. Postero autem die, quo numeratur secunda, praeteriens ab sole visitationem facit tenuem extremae rotundationis. Cum triduum recessit ab sole, crescit et plus inluminatur. Cotidie vero discedens cum pervenit ad diem septimum, distans a sole occidente circiter medias caeli regiones, dimidia luce, et eius quae ad solem pars spectat, ea est inluminata.

4 Quarto² autem decimo³ die, cum in diametro spatio totius mundi absit ab sole, perficitur plena et oritur, cum sol sit ad occidentem, ideo quod totum spatium mundi distans consistit contra et⁴ impetu solis totius orbis in se recipit⁵ splendorem. Septimo decimo die cum sol oriatur, ea pressa est ad occidentem. Vicensimo et altero die cum sol est exortus, luna tenet circiter caeli medias regiones, et id quod spectat ad solem, id habet lucidum reliquis⁶ obscura. Item cotidie cursum faciendo circiter octavo et vicensimo die subit sub radios solis, et ita menstruas perficit rationes.

Nunc, ut in singulis mensibus sol signa pervadens auget⁷ et minuit dierum et horarum spatia, dicam.

¹ quod *H S.*

² quarta *G.*

³ decima *G.*

⁴ contra et *G*: contrah& *H.*

⁵ recipit *H G S.*

⁶ reliquis *S G*: reliquis *H G.*

⁷ auget *H S.*

¹ *pressa* = 'near'; cf. Fr. *près*.

force. For, of the seven planets, the moon traverses that circle which is nearest the earth and least in its range. Every month, therefore, it is darkened under the disk and rays of the sun, and lies hid for one day before it passes. When it adjoins the sun, it is called the new moon. On the next day, which is counted the second, it passes away from the sun, and gives a slight visibility to the edge of its disk. When it is three days' distance from the sun, it waxes and receives more light. When in its daily departure it comes to the seventh day, being distant from the western sun about half the region of the sky, it has half its light and that part which looks towards the sun is illuminated.

4. On the fourteenth day, when it is distant from the sun by the diameter of the universe, it becomes full, and rises when the sun is in the west, because being distant the whole space of the universe it stands face to face, and by the force of the sun receives into itself the splendour of the sun's whole orb. When the sun rises on the seventeenth day the moon is near¹ to the west. When the sun is risen on the twenty-second day the moon holds nearly the middle region of the sky; it keeps bright the part which looks towards the sun; in the other parts the moon is darkened. Further, making its journey from day to day, it is absorbed in the rays of the sun about the twenty-eighth day, and thus completes the order of the month.

In the next place I will describe² how the sun going through the signs, augments and diminishes each month the length of the day and of the hour.

² Manilius describes the signs of the zodiac in their order, i. 262-274.

1 NAMQUE cum arietis signum iniit et partem octavam pervagatur, perficit aequinoctium vernal. Cum progreditur ad caudam tauri sidusque vergiliarum, e quibus eminet dimidia pars prior tauri, in maius spatium mundi quam dimidium procurrit procedens ad septentrionalem partem. E tauro cum ingreditur in geminos exorientibus vergiliis, magis crescit supra terram et auget¹ spatia dierum. Deinde <e> geminis cum iniit ad cancrum, qui brevissimum tenet caeli spatium, cum pervenit in partem octavam, perficit solstitiale tempus, et peragens pervenit² ad caput et pectus leonis, quod eae partes cancro³ sunt attributae.

2 E pectore autem leonis et finibus cancri solis exitus percurrens reliquas partes leonis inminuit diei magnitudinem et circinationis⁴ reditque in geminorum aequalem cursum. Tunc vero a leone transiens in virginem progrediensque ad sinum⁵ vestis eius contrahit circinationem⁴ et aequat ad eam, quam taurus habet, cursus⁶ rationem. E virgine autem progrediens per sinum, qui sinus librae partes habet primas, in librae parte VIII perficit aequinoctium autumnale;⁷ qui cursus aequat eam circinationem,⁴ quae fuerat in arietis signo.

3 Scorpionem autem cum sol ingressus fuerit occi-

¹ augit *H S.*

² pervenit *Joc*: perveniens *H.*

³ Cf. canceres, *Cato R. R.* 157. 3.

⁴ circinationis-em *S*: circitionis-em *H.*

⁵ signum *H.*

⁶ cursus *G*: cursū *H S.*

⁷ autumnale *S*: autem tale *H.*

¹ pars = μοῖρα = degree.

² aversum taurum. *Man. i.* 264.

CHAPTER III

ON THE SUN'S COURSE THROUGH THE SIGNS

1. WHEN he enters the sign of the Ram and traverses the eighth degree,¹ he makes the vernal equinox. When he goes on to the tail² of the Bull and the constellation of the Pleiades from which the first half of the Bull stands out, the space which he enters is more than half the firmament³ as he moves to the north. When, after the Bull, he enters the Twins at the rising of the Pleiades, he rises higher above the earth and lengthens the day. Thereupon, after the Twins he enters the Crab, a sign which occupies the shortest space of the heavens; coming to the eighth degree, he completes the solstice, and in his progress reaches the head and breast of the Lion, these parts being assigned to the sign of the Crab.

2. Leaving the breast of the Lion and the limits of the Crab and passing through the remaining degrees of the Lion, he diminishes the length of the daylight and of his circuit, and returns to the movement which he had in the Twins. Passing then from the Lion to the Virgin and reaching the lap of her robe, he contracts his circuit and makes the amount of his course equal to that which the Bull holds. Proceeding from the Virgin over her lap which occupies the first degrees of the Balance, at the eighth degree of the Balance he completes the autumnal equinox. This passage equals the circuit which he made in the sign of the Ram.

3. When the sun enters the Scorpion at the setting

³ I.e. his visible journey between sunrise and sunset.

dentibus vergiliis, minuit progrediens meridianas partes longitudines dierum. E scorpione cum percurrente in sagittarium ad femina eius, contractiorem diurnum pervolat cursum. Cum autem incipit a feminibus sagittarii, quae pars est attributa capricorno, ad partem octavam, brevissimum caeli percurrit spatium. Ex eo a brevitate diurna bruma ac dies brumales appellantur. E capricorno autem transiens in aquarium adauget et aequat¹ sagittarii longitudine diei spatium. Ab aquario cum ingressus est in pisces favonio flante, scorpionis comparat aequalem cursum. Ita sol ea signa circum pervagando certis temporibus auget aut minuit dierum et horarum spatia.

Nunc de ceteris sideribus, quae sunt dextra ac sinistra zonam signorum meridiana septentrionalique parte mundi stellis disposita figurataque, dicam.

IV

¹ NAMQUE septentrio, quem Graeci nominant *arctum* sive *helicen*, habet post se conlocatum custodem. Non longe conformata est virgo, cuius supra umerum dextrum lucidissima stella nititur, quam nostri providemiatorem,² Graeci *protrugeten*³ vocant; candens autem magis spica⁴ eius est colorata. Item alia

¹ et aequat: exaequat *H.*

² providemiatorem *Scaliger*: providentiā maiores *H.*

³ προπρυγητήν *Scal*: propygethon *H.*

⁴ spica *Phil*: species *H.*

¹ Manilius describes the northern constellations, i. 308-370; the southern, i. 373-406.

of the Pleiades, he diminishes the length of the day on his southward journey. Passing from the Scorpion when he enters the Archer near his thighs, he traverses a still shorter daily course. Beginning from the thighs of the Archer, a part which is assigned to the Goat, at the eighth degree of the Goat he passes through the shortest space of the sky. Hence, from the brevity of the days, the winter (*bruma*) and the days (*brumales*) receive their names. Passing now from the Goat to the Water-carrier, he increases the length of the day, and equals the circuit of the Archer. From the Water-carrier he enters the Fishes when the west wind blows, and makes a circuit equal to that which he made in the Scorpion. In this way the sun travels through the signs at fixed times, and augments or diminishes the lengths of the day and of the hour.

I will next speak of the other constellations¹ which are situated and figured with stars on the right and left of the zodiac both towards the Meridian and to the north.

CHAPTER IV

ON THE NORTHERN CONSTELLATIONS

1. THE Waggon, which the Greeks call the Bear or *Helice*, has the Keeper of the Bear placed behind it. Not far distant is the constellation of the Virgin. Above her right shoulder rests a very bright star which we call the Vintager, the Greeks *Protrugetes*. But *Spica*, a still more brilliant star in that constellation, is coloured.² There is also another

² Manilius v. 270, has *spica horrida*. *Spica*, however, is said to be pure white.

contra est stella media genuorum custodis arcti:
qui arcturus dicitur est ibi delicatus.

2 E regione capitis septentrionis transversus ad pedes geminorum auriga stat in summo cornu tauri—itemque in summo cornu laevo et auriga pedis¹ una tenet parte stellam—et appelluntur² aurigae manui³ haedi, capra laevo umero. Tauri quidem et arietis insuper Perseus—dexterioribus subter currens basem vergiliis,⁴ at sinisterioris caput arietis—et manu dextra innitens Cassiepieae simulacro, laeva supra tauri⁵ tenet gorgoneum ad summum caput, subiciensque Andromedae pedibus.

3 Item pisces supra Andromedam, et eius ventris et equi sunt⁶ supra spinam aequi, cuius ventris lucidissima stella finit ventrem equi et caput Andromedae. Manus Andromedae dextra supra Cassio-piae simulacrum est constituta, laeva aquilonalem piscem. Item aquarii⁷ supra equi capitis est. Equi ungulae attingunt aquarii genua; Cassiopeia media est dedicata. Capricorni supra in altitudinem aquila et delphinus. Secundum eos est sagitta. Ab ea autem volucris,⁸ cuius pinna dextra Cephei manum adtingit et sceptrum, laeva supra Cassiopeiae innititur. Sub avis cauda pedes equi sunt subtecti.

4 Inde sagittarii, scorpionis, librae insuper serpens

¹ pedis *Mar*: pedes *H*.

² appellantur *H*: appelluntur *Gr*.

³ manui *Ro*: manus *H*.

⁴ vergilias a *H*: vergiliis at *Kr*.

⁵ supra tauri *Ro*: supra aurigā *H*.

⁶ andromedam et eius ventris et equique sunt *H*: que *om*.

Gr.

⁷ sc. simulacrum.

⁸ volucris *e, ed*: volueris *H*.

¹ Arcturus is yellow.

² Aratus, 167.

star opposite which is between the knees of the Keeper: this is called *Arcturus* and is of a delicate colour.¹

2. Opposite the top of the Waggon, across towards the feet of the Twins, is the Charioteer² standing on the horns of the Bull. Further, on the tip of the left horn the Charioteer also has at his feet a star on one side. Against the hands of the Charioteer, the Kids are stationed.³ *Capra* is on the left shoulder of the Charioteer. Above the Bull and the Ram stands Perseus;⁴ his right foot supporting the Pleiades; on his left, the head of the Ram; with his right hand he rests on the constellation of Cassiopeia; with his left he holds the Gorgon's head above the Bull and lays it at the feet of Andromeda.

3. The Fishes are beyond Andromeda and are level with her belly and the back of the Horse. A very bright star divides the belly of the Horse and the head of Andromeda. The right hand of Andromeda is placed above the constellation of Cassiopeia, and the left upon the Northern Fish.⁵ The constellation of the Water-carrier is against the Horse's head. The Horse's hoofs touch the knees of the Water-carrier. Cassiopeia is in the middle. Rising above Capricorn⁶ are the Eagle and the Dolphin. Next is the Arrow. On it follows the Swan with its right wing touching the hand and sceptre of Cepheus, and its left resting upon Cassiopeia. Under the tail of the Swan the feet of the Horse are concealed.

4. Then following the Archer, the Scorpion and the Balance, comes the Serpent touching the Crown

² Aratus, 166.

⁴ *Ibid.*, 249 ff.

³ *Ibid.*, 246.

⁵ *Ibid.*, 316.

summo rostro coronam tangit. Ad eum medium ophiuchos in manibus tenet serpentem, laevo pede calcans mediam frontem scorpionis. A parte¹ ophiuchi capitis non longe positum est caput eius, qui dicitur nisus² in genibus. Autem eorum³ faciliores obscuris stellis sunt conformati.

5 Pes ingeniculati ad id fulcitur capitis tempus serpentis, cuius arctorum, qui septentriones dicuntur, implicatus. Parve per eos flectitur delphinus; contra volucris⁴ rostrum proposita lyra. Inter umeros custodis et geniculati corona⁵ est ordinata.⁶ In septentrionali vero circulo duae positae sunt arctoe scapularum dorsis inter se compositae et pectoribus aversae. E quibus minor *cynosura*, maior *helice* a Graecis appellatur. Earumque capita inter se dispicientia sunt constituta, caudae capitibus earum adversae contra dispositae figurantur; utrarumque⁷ enim superando eminent.

6 In summo per caudas earum esse dicitur. Item serpens est porrecta, e qua stella quae dicitur polus⁸ elucet circum caput maioris septentrionis; namque quae est proxime draconem, circum caput eius involvitur. Una vero circum cynosurae caput iniecta est fluxu porrectaque proxime eius pedes. Haec autem

¹ a parte *Ro*: partem *H*.

² nisus *Phil*: nessus *H*.

³ eorum autem *Phil*: autem eorum *H*, *soloecismus*, *Quint.* I. 5. 39.

⁴ volucris *e₂ ed*: volueris *H*.

⁵ corona *e₂ ed*: coronatā (-tam *E*) *H*.

⁶ ordinata *rec*: orinata *H S*.

⁷ utrarumque . . . earum *Heringa*: utrorumque . . . eorum *H*.

⁸ polus *rec*: post plus *H*.

with the tip of his mouth. The Serpent-holder has the middle of the Serpent in his hands and treads with his left foot the forehead of the Scorpion.¹ The constellation which is called the Kneeler has its head not far from the head of the Serpent-holder. The tops of their heads are the more easily recognised because they are marked by not inconspicuous stars.

5. The foot of the Kneeler² rests on the temple of the Dragon in which that one of the Bears which is called the Waggon is enfolded. The Dolphin moves dimly³ among them; over against the beak of the Swan the Lyre is prominent. Between the shoulders of the Keeper and the Kneeler the Crown is set in array. In the northern circle, the two Bears are placed joined together with their shoulders back to back and their breasts turned away. Of these the less is called in Greek *Cynosura*,⁴ the greater *Helice*.⁵ Their heads look, one up, one down. Their tails are figured in opposite directions set against each other's heads, and are raised so as to project.

6. The highest point in the heavens is said to be between their tails. The Dragon is also spread out, and from this constellation the pole-star, so-called, shines against the head of the Great Bear. For the Bear which is nearest the Dragon has its head bent round. At the same time the Dragon is thrown in its flowing movement round the head of the Little Bear and reaches its feet. And the

¹ Aratus, 85. ² 'The Kneeler' is also called Hercules.

³ *parve*: οὐ μάλα πολλός, Arat. 316.

⁴ Lit. 'dog's tail,' from its shape.

⁵ Helice from sweeping round in a 'curve.'

intorta replicataque capite minoris ad maiorem, circa rostrum et capitis tempus dextrum. Item supra caudam minoris pedes sunt Cephei, ibique ad summum cacumen facientes stellae sunt trigonum paribus lateribus, insuper arietis signum. Septentrionis autem minoris et Cassiopiae simulacri complures sunt stellae confusae.

Quae sunt ad dextram orientis inter zonam sigmorum et septentrionum sidera in caelo disposita dixi esse; nunc explicabo, quae ad sinistram orientis meridianisque partibus ab natura¹ sunt distributa.

V

1 PRIMUM sub capricorno subiectus piscis austrinus caudam prospiciens ceti.² Ab eo ad sagittarium locus est inanis. Turibulum sub scorpionis³ aculeo. Centauri priores partes proximae sunt librae et scorpionis. Tenet⁴ in manibus simulacrum, id quod bestiam astrorum periti nominaverunt. Ad virginem et leonem et cancrum anguis porrigens agmen stellarum intortus succingit, regione cancri erigens rostrum,⁵ ad leonem medioque corpore sustinens craterem ad manumque virginis caudam subiciens, in qua inest corvos; quae sunt autem supra scapulas, peraeque sunt lucentia.⁶

¹ ob natura H.

² ceti Phil: cephei H.

³ scorpionis Phil: -nem H.

⁴ tenet Barbarus: tenent H.

⁵ rostrum S: nostrum H.

⁶ lucentia H.

¹ The descriptions of Vitruvius are best understood with the help of maps of the constellations: especially in Greek MS. Vat. 1087. Boll, *Sphaera*, Pl. I.

Dragon is twisted and folded back from the head of the Little Bear to the Great Bear about his snout, and the right temple of his head. Further, the feet of Cepheus are on the tail of the Little Bear. And there at the highest point are stars which form a triangle with its equal sides above the Ram. But many stars belonging to the Little Bear and to the constellation of Cassiopeia are confused.

The constellations which are to the right of the east between the Zodiac and the Waggon I have described as figured.¹ I will now explain those which are distributed by nature to the left of the east and in the parts south.

CHAPTER V

ON THE SOUTHERN CONSTELLATIONS

1. FIRST, under Capricorn lies the southern Fish looking towards the tail of the Whale. From that to the Archer is a void. The Altar is under the Scorpion's sting. The front part of the Centaur is nearest to the Balance and Scorpion. He holds in his hands a figure which the astronomers have named the Beast.² The Virgin, the Lion and the Crab are girt about with the Serpent,³ which in its twistings stretches through a procession of stars. It raises its snout to the Crab; against the Lion it supports the Cup with its middle; to the hand of the Virgin it raises its tail, on which rests the Crow. The stars above its shoulders are equally luminous.

² The modern constellation of the Wolf.
³ The Hydra, Aratus, 444 ff.

2 Ad anguis inferius¹ ventris, sub caudam subiectus est centaurus. Iuxta² cratera et leonem navis est, quae nominatur Argo, cuius prora obscuratur, sed videtur, ipsaque navicula et puppis per summam caudam cani iungitur.³ Geminos autem minusculus canis sequitur contra anguis caput. Maior item sequitur minorem. Orion vero transversus est subiectus, pressus ungula tauri,⁴ manu laeva tenens, clavam altera ad geminos tollens.

3 Apud⁵ eius vero basim canis parvo intervallo insequens leporem. Arieti et piscibus cetus est subiectus, a cuius crista ordinate utrisque piscibus disposita est tenuis fusio stellarum, quae graece vocitantur *harpedonae*.⁶ Magnoque intervallo introrsus pressus serpentium, attingit summam ceti cristam. Esse fuit per speciem stellarum flumen. Profluit initium fontis capiens a laevo pede Orionis. Quae vero ab aquario fundi memoratur aqua, profluit inter piscis austrini caput et caudam ceti.

4 Quae figurata conformataque sunt siderum in mundo simulacra, natura divinaque mente designata, ut Democrito physico placuit, exposui, sed tantum ea, quorum ortus et occasus possumus animadvertere et oculis contueri. Namque uti septemtrionis circum axis cardinem versantur non occidunt neque sub

¹ inferius *Mar*: interius *H*.

² iuxta *H*.

³ post iungitur *H* habet paginam aversam sine scriptura folii 133; cf. VII. ix. 2.

⁴ tauri *Phil*: centauri *H*.

⁵ apud *Phil*: caput *H*.

⁶ ἀρπεδόναι *Turnebus*: hermedonae *H*.

¹ Cf. ἡν εἶναι *Aristot.* The river is the Eridanus.

² The description not only follows *Aratus* but seems to have been written to a diagram based on the *Phaenomena*.

2. At the lower part of the Hydra's belly, under its tail, the Centaur is placed. Against the Cup and the Lion is the ship Argo; the bows are hidden but the mast and the parts about the stern are seen standing out. The Ship and its stern adjoins the Great Dog at the tip of its tail. The Twins are followed by the Little, and the Great, Dog, opposite the head of the Hydra. Orion lies across pressed by the hoof of the Bull, holding it in his left hand and with the right raising his club towards the Twins.

3. Near his feet is the Great Dog following the Hare at a short interval. Under the Ram and the Fishes comes the Whale; from its head there is a sprinkling of stars arranged in a band towards the two Fishes (called in Greek *harpedonae*), and at a great interval a downward weight of the winding stars touches the mane of the Whale. There was to be¹ a River under the semblance of stars.² It flows forth taking the beginning of its source from the left foot of Orion. The water which is said to be poured by the Water-carrier flows between the head of the Southern Fish and the tail of the Whale.

4. I have expounded in accordance with the principles of Democritus, the natural philosopher, the figures of the constellations³ which are shaped and formed in the firmament, and planned by nature and the divine spirit;⁴ but only those constellations whose risings and settings we can observe and see with our eyes. For just as the two Bears turn round the pole, neither setting nor going under the earth,

¹ Vitruvius goes back behind *Aratus* to the astronomical works of Democritus, which are only known to us in fragments; *Diels Vorsokratiker*, II. 390.

⁴ An echo of *Lucretius*, iii. 15: *ratio tua coepit vociferari | naturam rerum divina mente coorta.*

terram subeunt, sic circa¹ meridianum cardinem, qui est propter inclinationem mundi subiectus terrae, sidera versabunda latentiaque non habent egressus orientis supra terram. Itaque eorumfigurationes propter obstantiam terrae non sunt notae. Huius autem rei index est stella Canopi, quae his regionibus est ignota, renuntiant autem negotiatores, qui ad extremas Aegypti regiones proximasque ultimis finibus terrae terminationes fuerunt.

VI

1 DE mundi circa terram pervolitantia duodecimque signorum ex² septentrionali meridianaque parte siderum dispositione, ut sit perspectus docui. Namque ex ea mundi versatione et contrario solis per signa cursu gnomonumque³ aequinoctialibus umbris analemmatorum⁴ inveniuntur descriptiones.

2 Cetera ex astrologia, quos effectus habeant signa XII, stellae V, sol, luna ad humanam⁵ vitae rationem, Chaldaeorum ratiocinationibus est concedendum, quod propria est eorum genethliologiae⁶ ratio, uti possint ante facta et futura ex ratiocinationibus

¹ si circa *H S.*

² gnominum *H.*

³ humanae *S: -nā H.*

⁴ analemmatorum *H S G.*

⁶ genethliologiae *Joc: gentililogiae H.*

¹ *versabunda*, rare, *Lucr. vi. 581.*

² Canopus is quoted as an example of the principle stated in the next sentence. It is visible at Rhodes. Canopus seems

so round the southern pole which, because of the obliquity of the universe, lies under the earth, constellations are turning¹ in concealment without coming forth and rising above the earth. Hence the earth intervenes and prevents the knowledge of their configuration. A proof of this is the star Canopus,² which to us in these regions is unknown. Yet it (*i.e.* the fact of southern constellations) is reported by merchants who have been to the farthest parts of Egypt and the limits nearest to the ultimate bounds of the earth.

CHAPTER VI

ON ASTROLOGY

1. I HAVE described the revolution of the firmament round the earth and the arrangement of the twelve signs and of the constellations to the north and south so as to present them to a clear view. For from that revolution of the firmament and the contrary motion of the sun through the signs and the equinoctial shadows of the gnomons, the diagrams of the analemma are discovered.

2. For the rest, as to astrology, the effects produced on the human course of life by the twelve signs, the five planets, the sun and moon, we must give way to the calculations of the Chaldaean astrologers,³ because the casting of nativities is special to them so that they can explain the past and the future from astronomical calculations.

to have served as a substitute for a polar star to the south; cf. *Manilius, i. 218.*

³ Chaldaean = astrologer; *Babylonica Chaldaeorum doctrina . . . astrologorum: Lucr. vi. 727-728.*

astrorum explicare. Eorum autem inventiones reliquerunt, in quae sollertia acuminibusque fuerunt magnis, qui ab ipsa natione Chaldaeorum proflexerunt. Primusque Berossus in insula et civitate Coos cecidit ibique aperuit disciplinam, post ea studens Antipater iterumque Athenodorus,¹ qui etiam non e nascentia sed ex conceptione genethliologiae² rationes explicatas reliquit.

3 De naturalibus autem rebus Thales Milesius, Anaxagoras Clazomenius,³ Pythagoras Samius, Xenophanes⁴ Colophonius, Democritus Abderites rationes, quibus e rebus natura rerum gubernaretur⁵ quem admodum cumque effectus habeat, excogitatas⁶ reliquerunt. Quorum inventa secuti siderum et occasus tempestatumque significatus⁷ Eudoxus, Eudemos,⁸ Callippus,⁹ Meto,¹⁰ Philippus, Hipparchus, Aratus ceterique ex astrologia parapegmatorum disciplinis¹¹ invenerunt et eas posteris explicatas reliquerunt. Quorum scientiae sunt hominibus suspiciendae, quod tanta cura fuerunt, ut etiam videantur divina mente tempestatum significatus post futuros ante pronuntiare. Quas ob res haec eorum curis studiisque sunt concedenda.

¹ Athenodorus *Ro*: achinapolus *H*.

² genethliologiae *Joc*: gentililogiae *H*.

³ Clazomenius *Joc*: glagomeus *H*. ⁴ zenophanes *H*.

⁵ gubernaretur *e*₃: gubernarentur *H*.

⁶ excogitatas *ed*: excogitatus *H*.

⁷ significatus *H S*: significatos *E G*.

⁸ Eudemos *Gr*: euchemon *H S*, Eudemon *Joc*.

⁹ callistus *H*. ¹⁰ mello *H*: nomina restituit *Turnebus*.

¹¹ disciplinis *Joc*: disciplinas *H*.

¹ Vitruvius assigns to Berossus the first place in the succession of Greek writers on astrology, but Babylonian writings on astrology went back as far as Hammurabi, 2250 B.C.

Those who have sprung from the Chaldaean nation have handed on their discoveries about matters in which they have approved themselves of great skill and subtlety. And first,¹ Berossus settled in the island of Cos as a citizen and opened a school there. Then Antipater took up the pursuit, and further, Athenodorus, who left a method of casting nativities, not from the time of birth but from that of conception.

3. In natural philosophy, Thales of Miletus, Anaxagoras of Clazomenae, Pythagoras of Samos, Xenophanes of Colophon, Democritus of Abdera left elaborate theories on the causes by which nature was governed, and the manner in which each produced its effects. Eudoxus,² Eudemos,³ Callippus,⁴ Meton,⁵ Philippus,⁶ Hipparchus,⁷ Aratus,⁸ and others followed up their discoveries, and, with the help of astronomical tables,⁹ discovered the indications of the constellations, of their setting, and of the seasons, and handed down the explanations to after times. Their knowledge is to be highly regarded by mankind, because they so applied themselves, that they seem by divine inspiration to declare beforehand the indications of the seasons. Wherefore these topics may be referred to their care and attention.

¹ Of Cnidus; rejected astrology. Aratus versified his *Phaenomena*.

² Mathematician; of Pergamus.

³ Corrected the cycle of Meton.

⁴ Reformed Attic calendar from 432 B.C.

⁵ Of Opus; mathematician, edited Plato's *Laws*.

⁶ Of Nicaea; greatest mathematician of antiquity, c. 150 B.C.; corrected Aratus.

⁷ Of Soli; c. 270 B.C.; wrote the *Phaenomena*.

⁸ *parapegma* = column with astronomical tables.

VII

- 1 Nobis autem ab his separandae sunt rationes et explicandae menstruae dierum brevitates itemque depalationes. Namque sol aequinoctiali tempore ariete libraque versando, quas e gnomone partes habent novem, eas umbrae facit viii in declinatione caeli, quae est Romae. Idemque Athenis quam magnae sunt gnomonis partes quattuor, umbrae sunt tres, ad vii Rhodo v, ad xi Tarenti ix, ad ¹ quinque <Alexandriae> tres, ceterisque ² omnibus locis ³ aliae alio modo umbrae gnomonum aequinoctiales a natura rerum inveniuntur disparatae.
- 2 Itaque in quibuscumque locis horologia erunt describenda, eo loci sumenda est aequinoctialis umbra, et si erunt quemadmodum Romae gnomonis partes novem, umbrae octo, ⁴ describatur ⁵ in planitia et e media *pros orthas* erigatur ut sit ad normam quae dicitur gnomon. Et a linea, quae erit planities in linea gnomonis circino ⁶ novem spatia demetiantur; et quo loco nonae partis ⁷ signum fuerit, centrum constituatur, ubi erit littera A; et deducto circino ab eo centro ad lineam planitiae, ⁸ ubi erit littera B, circinatio circuli describatur, quae dicitur meridiana.
- 3 Deinde ex novem partibus, quae sunt a ⁹ planitia ad gnomonis centrum, viii sumantur et signentur in

¹ adquinq, ii. rhodo xv. adtaranti .xi. quinque ad tres H: *correxil Joc.*

² coterris H. ³ lonis H. ⁴ octogenae H.

⁵ describatur *Joc*: -bantur H.

⁶ circino *Joc*: circini H. ⁷ partes H S.

⁸ ad lineam planitie e, : ablinea planitia H.

⁹ a *Joc*: in H.

CHAPTER VII

ON THE PRINCIPLES OF DIALLING

1. WE must separate from other astronomical studies the description of the shortening and marking of the days, month by month, on the dial. For the sun, in his revolution, at the time of the spring and autumn equinoxes, casts a shadow, in the latitude of Rome, which is equal to eight-ninths of the height of the gnomon. Further, at Athens the shadows are three-quarters of the gnomon, at Rhodes five-sevenths, at Tarentum nine-elevenths, at Alexandria three-fifths; and in other places the shadows of the gnomon at the equinox are found to differ by different amounts, in accordance with the Nature of Things.

2. Therefore in whatever places dials are to be set out, the length of the shadow at the equinox is to be taken. If, as at Rome, there are nine parts of the gnomon, and eight parts of the shadow, let a line ¹ be drawn on the level, and from the middle let there be set upright and with a set-square, a perpendicular which is called the gnomon; and on the line where the level surface is, let nine parts be measured starting from the foot of the gnomon; where the end of the ninth part is marked, let a centre be taken and indicated by the letter A; and extending the compasses from that centre to a point in the line, to be indicated by the letter B, let the circumference of the circle be described which we call the meridian.² 3. Then of the nine parts which are between the centre of the gnomon and the point on the level line, let eight be taken and indi-

² See diagram, Pl. L.

¹ *pros orthas* seems to be the trade term for an upright line.

linea, quae¹ est in planitia, ubi erit littera c. Haec autem erit gnomonis aequinoctialis umbra. Et ab eo signo et littera c per centrum, ubi est littera a, linea perducatur, ubi erit solis aequinoctialis radius. Tunc a centro diducto circino ad lineam planitiae aequilatatio signetur, ubi erit littera e sinisteriore parte et i dexteriore² in extremis lineis circinationis. Et per centrum perducendum, ut aequa duo hemidictur *horizon*. Haec autem linea a mathematicis

4 Deinde circinationis totius sumenda pars est xv; et circini centrum conlocandum in linea circinationis, quod loci secat eam lineam aequinoctialis radius, ubi erit littera f; et signandum dextra sinistra, ubi sunt litterae g h. Deinde ab his <et per centrum> lineae³ usque ad lineam planitiae perducendae sunt, ubi erunt litterae t r. Ita erit solis radius unus hibernus, alter aestivus. Contra autem <e>⁴ littera i erit, qua⁵ secat circinationem linea,⁶ quae est traiecta per centrum, ubi erunt⁷ litterae y k l g, et contra k litterae erunt k h x l; et contra c et f et a⁵ erit littera n. Tunc perducendae sunt *diametro*⁸ ab g ad l et ab h <ad k>.⁹ Quae erit superior, partis erit aestivae, inferior hibernae. Eaeque *diametro*¹⁰ sunt aequae mediae dividendae, ubi erunt litterae o et m, ibique centra signanda. Et per ea signa et centrum a¹¹ lineae ad extremas lineae circinationis

¹ qua est H. ² i dexteriore *Joc*: et inde alteriore H.
³ <et per centrum> lineae *Joc*: lineis H.
⁴ e *add. Joc*. ⁵ qua *Kr*: qui H.
⁶ linea *Joc*: lineae H.
⁷ litterae i . k . l . m. et contra k lineae erunt k . h . x . i
H: y k l g . . . k h x l Gr.
⁸ diametro ab .c. ad .i. et ab .h. H: *corr. Joc*.
⁹ quae erit inferior partis erit aestiv(a)e superior hibernae H
(corr. Mar).
250

cated by a point c. This will be the equinoctial shadow of the gnomon. From the point marked c let a line be drawn through the centre a; and this will represent a ray of the sun at the equinox. Then extending the compasses from a let a line be drawn parallel to the level surface, with the letter e on the left side and the letter i on the right side of the circumference, let them be joined through the centre, so that they divide the circle into two equal semicircles. This line is called the horizon by the mathematicians.

4. Then the circumference is to be divided into fifteen parts, and the centre of the compasses is to be put at that point f in the circumference where it is cut by the equinoctial ray c, and the points g h are to be marked right and left. Then from these, through the centre, lines are to be carried through to the line of the plane where the letters t r are to be put. One line will mark the ray of the sun in winter, the other the ray of the sun in the summer. Over against e will be the letter i on the horizon which cuts the circumference and passes through the centre. In this quarter are the points y k l g. Over against k will be the points k h x l. And over against c f a will be the letter n. 5. Then diameters are to be drawn from g to l and from h to k. The upper will determine the summer portion, and the lower the winter portion. These diameters are to be equally divided in the middle at the letters o and m, and the centres marked. Through those letters and the centre a, a line is to be produced to the circumference at the points

¹⁰ aequ(a)e diametro H.

¹¹ centrum .c. H.

sunt perducendae, ubi erunt litterae q et p;¹ haec erit linea *pros orthas* radio aequinoctiali. Vocabitur autem haec linea mathematicis rationibus *axon*. Et ab eisdem centris deducto circino ad extremas diametros describantur hemicyclia,² quorum unum erit aestivum, alterum hibernum.

6 Deinde in quibus locis secant lineae paralleloae³ lineam eam quae dicitur horizon, in dexteriore parte erit littera s,⁴ in sinisteriore v. Et ab littera s ducatur linea parallelus axoni⁵ ad extremum hemicyclium, ubi erit littera y; et ab v⁶ ad sinistram hemicyclii item parallelus linea ducatur⁷ ad litteram x. Haec autem parallelus linea vocitatur *laetomus*.⁸ Et tum circini centrum conlocandum est eo loci, quo secat circinationem aequinoctialis radius, ubi erit littera d;⁹ et deducendum ad eum locum, quo secat circinationem aestivus radius, ubi est littera h. E centro aequinoctiali intervallo aestivo circinatio circuli menstrui agatur, qui *manaesus* dicitur. Ita habebitur *analemmatos* deformatio.

7 Cum hoc ita sit descriptum et explicatum, sive per hibernas lineas sive¹⁰ per aestivas sive per aequinoctiales aut etiam per menstruas in subiectionibus rationes horarum erunt ex *analemmatos*¹¹ describendae, subicianturque in eo multae varietates et genera

¹ q et p Gr: G . P . T . R . H.

² paralleloae Ro: parallelon & H.

³ littera s Joc: littera .e. H.

⁴ axoni Joc: axon H.

⁵ ab v Gr: ab .c. H.

⁶ ab v Gr: ab .c. H.

⁷ linea vocitatur Joc: lineae vocitantur H.

⁸ laetomus Turnebus: locithomus H.

⁹ littera d Mar: littera .e. H.

¹⁰ post lineas sive in H repetuntur aequinoctialis radius — secat circinationem.

q and p. This line will be perpendicular to the equinoctial ray; in mathematical calculations it is called the axis. From m and o as centres, the compasses are extended to the ends of the diameters and semicircles are described, of which one will be for the summer, the other for the winter.

6. Then, at the places where the parallel lines cut the line called the horizon, let the right-hand point be s and the left-hand point be v. From the letter s let there be drawn a line parallel to the axis, to the farther semicircle at the point y; and from v let there be drawn also a parallel line on the left of that semicircle to the letter x. This parallel line is called the *laetomus*.¹ Then the centre of the compasses is to be placed on the point marked d where the equinoctial radius cuts the circumference, and they are to be extended to the point h where the circumference is intersected by the summer radius. From the equinoctial centre with a radius to the summer intersection, let the circle of the months be drawn which is called *Manaeus*. This will complete the design of the *analemma*.²

7. The *analemma* in this way has been set forth and explained, whether the figures of the hours are to be marked by the *analemma* according to the winter lines or the summer lines or the equinoctial or indeed the monthly lines in accordance with the annexed figure. From the *analemma* there may be deduced many varieties and kinds of dials and they

¹ *laetomus* = cut to the left.

² Vitruvius seems to describe a diagram placed before the reader, but it is not possible to reconstruct with complete certainty the diagram which is lost, from his description.

horologiorum et describuntur rationibus his artificiosis. Omnium autem figurarum descriptionumque earum effectus unus, uti dies aequinoctialis brumalisque idemque solstitialis in duodecim partes aequaliter sit divisus. Quas ob res non pigritia deterritus praetermissis, sed ne multa scribendo offendam, a quibusque inventa sunt genera descriptionesque horologiorum, exponam. Neque enim nunc nova genera invenire possum nec aliena pro meis praedicanda videntur. Itaque quae nobis tradita sunt et a quibus sint inventa,¹ dicam.

VIII

1 HEMICYCLIUM excavatum ex quadrato ad enclimaeque succisum Berossus² Chaldaeus dicitur invenisse; scaphen sive hemisphaerium dicitur Aristarchus Samius, idem etiam discum in planitia; arachnen Eudoxus astrologus, nonnulli dicunt Apollonium; plinthium³ sive lacunar,⁴ quod etiam in circo Flaminio est positum, Scopinas Syracusius; *pro ta historumena*, Parmenion, *pro pan clima*, Theodosius et Andrias, Patrocles pelecinum, Dionysodorus⁵ conum, Apollo-

¹ inventi *H.*

² berossus *H.*

³ plinthium *Joc* : panthium *H.*

⁴ lacunar *G* : lacunas *H S.*

⁵ dioniso porusconum *H* : *corr. Mach.*

¹ Book IX. ii. 3. The following references relate to forms of dials.

² Of Perga. Book I. i. 17.

³ Book I. i. 6.

⁴ Prof. Granger's belief that *panthium* of *H* is right, that the Pantheon of Rome is meant, and that this was a great sundial, is not credible.

are drawn by these technical methods. But of all these figures and drawings, the result is the same: the length of the day at the equinoxes and at the winter and summer solstices is divided into twelve equal parts. Wherefore they have not been omitted because I shrank from the labour involved; but without transgressing by long recitals, I will set forth the kinds and the figures of dials with the names of their inventors. For I cannot now invent new kinds, and the work of other men is not to be put forth as my own. Therefore I will say what has been handed down, and by whom it has been invented.

CHAPTER VIII

ON VARIOUS DIALS AND THEIR INVENTORS

1. BEROSUS the Chaldaean is said to have invented the semicircular dial hollowed out of a square block and cut according to the latitude; Aristarchus¹ of Samos, the Bowl or Hemisphere, as it is said, also the Disk on a level surface; the astronomer Eudoxus, or as some say Apollonius,² the Spider; Scopinas³ of Syracuse, the *Plinthium*⁴ or Ceiling, of which an example is in the Circus Flaminus;⁵ Parmenio, the Dial for Consultation; Theodosius⁶ and Andrias, the Dial for All Latitudes; Patrocles, the Dovetail; Dionysodorus,⁷ the Cone; Apollonius, the Quiver.

⁵ Augustus divided the city into fourteen regions. The ninth was known as the Circus Flaminus. Vitruvius refers to a temple of Castor in the same region, Book IV. viii. 4.

⁶ Theodosius of Tripolis in Lydia, wrote on spherical trigonometry, 1st cent. B.C.

⁷ Of Melos, geometer, Strabo, XII. 548.

nius pharetram, aliaque genera et qui supra scripti sunt et alii plures inventa reliquerunt, uti conarachnen,¹ conicum² plinthium, antiboreum. Item ex his generibus viatoria pensilia uti fierent, plures scripta reliquerunt. Ex quorum libris, si qui velit, subiunctiones invenire poterit, dummodo sciat analematos descriptiones.

² Item sunt ex aqua conquisitae ab eisdem scriptoribus horologiorum rationes, primumque a Ctesibio³ Alexandrino, qui etiam spiritus naturalis pneumaticasque⁴ res invenit. Sed uti fuerint ea exquisita, dignum studiosis agnoscere. Ctesibius enim fuerat Alexandriae natus patre tonsore. Is ingenio et industria magna praeter reliquos excellens dictus est artificiosis rebus se delectare. Namque cum voluisset in taberna sui patris speculum ita pendere, ut, cum deduceretur susumque reduceretur, linea latens pondus deduceret, ita conlocavit machinationem.

³ Canalem ligneum sub tigno fixit ibique trocleas conlocavit; per canalem lineam in angulum deduxit ibique tubulos struxit; in eos pilam plumbeam per lineam demittendam curavit. Ita pondus cum decurrendo in angustias tubulorum premeret caeli crebritatem, vehementi decursu per fauces frequentiam caeli compressione⁵ solidatam extrudens in aerem patentem offensione tactus⁶ sonitus expresserat claritatem.

¹ conarachnen *Mar*: conarchenen *H*.

² conicum *Ro*: conatum *H*.

³ a Ctesibio *ed. Fl*: aclesbio *H*.

⁴ pneumaticasque *ed*: ineū atticassq *H*.

⁵ confressione *H S*.

⁶ offensionē tactu *H*: offensione tactus *Ro*.

The persons already enumerated and many others left behind them other discoveries, such as the Conical Spider, the Conical Ceiling and the Antiborean. Many also have left instructions for making Hanging Dials for travellers. From such works anyone who wishes can find instructions, provided he understands the method of describing the analemma.

² The same writers have also sought the methods of making water-clocks;¹ and first, Ctesibius² of Alexandria, who also discovered the nature of wind-pressure and the principles of pneumatics. It is worth a student's while to learn how these discoveries were made. Now Ctesibius was the son of a barber and was born at Alexandria. He was marked out by his talent and great industry, and had the name of being especially fond of mechanical contrivances. On one occasion he wanted to hang the mirror in his father's shop, in such a way that when it was pulled down and pulled up again, a hidden cord drew down the weight; and he made use of the following expedient.

³ He fixed a wooden channel under a beam of the ceiling, and inserted pulleys there. Along the channel he took the cord into a corner where he fixed upright tubes. In these he had a lead weight let down by the cord. Thus when the weight ran down into the narrow tubes, and compressed the air, the large amount of air was condensed as it ran violently down through the mouth of the tube and was forced into the open; meeting with an obstacle, the air was produced as a clear sound.

¹ Hero Alex. *ed. Schmidt*, I. 491-494. Vitruvius draws upon the same sources as Hero. Heiberg, *Gesch. d. Math.* 73.

² Book I. i. 7.

- 4 Ergo Ctesibius cum animadvertisset ex tractu caeli et expressionibus spiritus vocesque nasci, his principiis usus hydraulicas machinas primus instituit. Item aquarum expressiones automatopoetasque¹ machinas multaque deliciarum genera, in his etiam horologiorum ex aqua comparationes explicuit. Primumque constituit cavum ex auro perfectum aut ex gemma terebrata; ea enim nec teruntur percussu aut aquae nec sordes recipiunt, ut obturentur. Namque aequaliter per id cavum influens aqua sublevat scaphium² inversum, quod ab artificibus phellos sive tympanum dicitur. In quo conlocata est regula versatile tympanum.³ Denticulis aequalibus sunt perfecta, qui denticuli alius alium impellentes sunt tiones modicas faciunt et motiones. Item aliae regulae aliaque tympana ad eundem modum dentata una motione coacta versando faciunt effectus varietatesque motionum, in quibus moventur sigilla, vertuntur metae, calculi aut ova proiciuntur, bucinae canunt, reliquaque parerga.
- 6 In his etiam aut in columna aut parastatica horae describuntur, quas⁴ sigillum egrediens ab imo virgula significat in diem totum. Quarum⁵ brevitates aut crescentias cuneorum adiectus aut exemptus in singulis diebus et mensibus perficere cogit. Praeclusiones aquarum ad temperandum ita sunt constitutae. Metae fiunt duae, una solida, una cava, ex

¹ automato pictasque *H S: corr. Turnebus.*

² scaphium *Turn: scaphum H.* ³ *asyndeton ut saepe.*

⁴ quas *Joc: quae H.* ⁵ quarum *Joc: quorum H.*

¹ Plate M, based upon Barbaro *Vitruvius*, A.D. 1584, p. 433, illustrates the method of such contrivances.

² The upper part of Plate M exhibits an application to this special case: see Notes on M.

4. Ctesibius, therefore, when he observed that the air being drawn along and forced out gave rise to wind-pressure and vocal sounds, was the first to use these principles and make hydraulic machines. He also described the use of water-power in making automata and many other curiosities, and among them the construction of water-clocks. First he made a hollow tube of gold, or pierced a gem; for these materials are neither worn by the passage of water nor so begrimed that they become clogged.
5. The water flows smoothly through the passage, and raises an inverted bowl which the craftsmen call the cork or drum.¹ The bowl is connected with a bar on which a drum revolves. The drums are wrought with equal teeth, and the teeth fitting into one another cause measured revolutions and movements. Further, other bars, and other drums toothed after the same fashion, and driven together in one motion cause, as they revolve, various kinds of movement; therein figures are moved, pillars are turned, stones or eggs are let fall, trumpets sound, and other side-shows.

6. Among these contrivances also, the hours are marked on a column or pilaster; and these are indicated by a figure² rising from the lowest part and using a pointer throughout the day. The shortening and lengthening of the pointers was brought about through the addition or removal of wedges for each day and each month.³ To regulate the supply of water, stopcocks are thus formed. Two cones are made, one solid, one hollow, and so finished

³ The apparatus required the adjustment of the pointers, and this was done by wedges.

torno ita perfectae, ut alia in aliam inire convenireque possit et eadem regula laxatio earum aut coartatio efficiat aut vehementem aut lenem in ea vasa aquae influentem cursum. Ita his rationibus et machinabernum usum conlocationes.

7 Sin autem cuneorum adiectionibus et detractio-
non probabuntur fieri, quod cunei saepissime vitia
faciunt, sic erit explicandum. In columella horae
ex analemmatos transverse describantur, menstrua
aeque lineae columella signentur. Eaque columna
versatilis perficiatur, uti ad sigillum virgulaeque,
qua virgula egrediens sigillum ostendit horas,
columna versando continenter suis cuiusque mensibus
brevitates et crescentias faceret horarum.

8 Fiunt etiam alio genere horologia hiberna, quae
anaphorica¹ dicuntur perficiuntque rationibus his.
Horae disponuntur ex virgulis aeneis ex analemmatos
descriptione ab centro dispositae in fronte; in ea
circuli sunt circumdati menstrua spatia finientes.
Post has virgulas tympanum, in quo descriptus et
depictus est mundus signiferque circulus descriptioque
ex XII caelestium signorum fit figurata, cuius ex²
centro deformatio, unum maius, alterum minus.
Posteriori autem parti³ tympano medio axis versa-
tilis est inclusus inque eo axi aenea mollis catena est
involuta, ex qua pendet ex una parte phellos (sive

¹ anaphorica H.

² ex (e) Joc: & H.

³ parte G: parti H S: parti abl. Varro R. R. I. xiii. 5.

¹ When the sun is not shining.

by the lathe that one can enter and fit the other; the same rod, by loosening or tightening them, produces a strong or gentle current of water flowing into the vessels. Hence by this methodical contrivance, water-clocks are set up for use in the winter.¹

7. But if by adding or withdrawing wedges the shortening or lengthening of the days shall not be found to be correctly marked by using wedges (because very often the wedges are faulty), the solution must be reached as follows. The hours are to be indicated cross-wise on a small column, in accordance with the analemma. The lines of the months also are to be marked on the column. And this is to be made to revolve uninterruptedly, so that it turns to the figure and the rod (with which rod the figure as it moves on shows the hours), and so causes the shortening and lengthening of the hours, in their several months.

8. There are also made winter clocks of another kind, which are called Anaphorica, and they make them in the following fashion.² An analemma is described, and the hours are marked with bronze rods, beginning from a centre on the clock face. On this circles are described which limit the spaces of the months. Behind these rods there is a drum, on which the firmament and zodiac are drawn and figured: the drawing being figured with the twelve celestial signs. Proceeding from the centre the spaces are greater and less. On the back part in the middle of the drum is fixed a revolving axle. On the axle a pliable brass chain is coiled. On one end hangs a

² The figure indicates the relation of the various parts of the water-clock, Pl. N, Barbaro, *op. cit.* p. 435.

tympanum), qui ab aqua sublevatur, altera¹ aeque pondere phelli sacoma saburrale.²

9 Ita quantum ab aqua phellos sublevatur, tantum saburrae pondus infra deducens versat axem, axis autem tympanum. Cuius tympani versatio alias efficit, uti maior pars circuli signiferi, alias minor³ in versationibus suis temporibus designet horarum proprietates. Namque in singulis signis sui cuiusque⁴ mensis dierum numeri cava sunt perfecta, cuius bulla, quae solis imaginem horologiis tenere videtur, significat horarum spatia. Ea translata ex terebratione in terebrationem mensis vertentis perficit cursum⁵ suum. Itaque quemadmodum sol per siderum spatia vadens dilatat contrahitque dies et horas, sic bulla in horologiis ingrediens per puncta contra centri tympani versationem, cotidie cum transfertur aliis temporibus per latiora, aliis per angustiora spatia, mensuris finitionibus imaginis efficit horarum et dierum.

De administratione⁵ autem aquae, quemadmodum se temperet ad rationem, sic erit faciendum. Post frontem horologii intra conlocetur castellum in idque per fistulam saliat aqua⁶ et in imo habeat cavum. Ad id autem adfixum sit ex⁷ aere tympanum habens foramen, per quod ex castello in id aqua influat. In eo autem minus tympanum includatur cardinibus ex torno masculo et femina inter se coartatis, ita uti minus tympanum quemadmodum epitonium in maiore circumagendo arte leniterque versetur.

¹ altera *Joc* : -ro *H.*

³ minor *Joc* : minus *H.*

⁵ administrationē *H.*

⁷ ex *ed* : & *H.*

² saburrale *Joc* : -li *H.*

⁴ cuiusque *ed* : usque *H.*

⁶ saliat quae *H.*

¹ For equilibrium as a mechanical principle, see Book X. i. 1.

cork or drum raised by the water; on the other, a counterpoise¹ of sand equal in weight to the cork.

9. Thus, in so far as the cork is raised by the water, to that extent the weight of sand drags down and turns the axle, and the axle turns the drum. The revolution of this drum sometimes makes a greater part of the circle of the zodiac to indicate the proper length of the hour; sometimes a lesser part so to do. For in the several signs, holes are made to the number of the days of the several months; and the pin, which in dials seems to represent the sun, marks the spaces of the hours, and moving from one hole to another completes the course of the passing month. 10. Therefore just as the sun traversing the spaces of the constellations lengthens and contracts the days and hours,² so the index moving along the holes in the dial in the opposite direction to the revolving drum, passes daily sometimes over longer, sometimes over shorter spaces; thus it produces over the monthly periods the representation of the hours and days.

The supply of water and its adjustment to the machine is to be as follows. 11. Inside, behind the dial of the clock, a cistern³ is to be placed. The water is to enter by a pipe, and the cistern is to have a hole at the bottom. Against this at the side there is to be fixed a bronze drum with an opening, through which the water flows into it from the cistern. Within this is enclosed a lesser drum joined to it with tenon and socket, so that the lesser drum turning round within the greater, like a stopcock, fits closely and smoothly in its revolution.

² By the different lengths of the day in summer and winter.

³ *castellum*, a cistern or reservoir, Plin. *N.H.* XXXVI. 121.

12 Maioris autem tympani labrum aequis intervallis ccclxv puncta habeat signata, minor vero orbiculus in extrema circinatione fixam habeat ligulam, cuius cacumen dirigat ad punctorum regiones, inque eo orbiculo temperatum sit foramen, quia in tympanum aqua influit per id et servat administrationem. Cum autem in maioris tympani labro¹ fuerint signorum caelestium deformationes, id autem sit inmotum et in summo habeat deformatum cancri signum,² ad perpendicularum eius in imo capricorni, ad dextram spectantis³ librae, ad sinistram arietis signum,⁴ ceteraque inter eorum spatia designata sint, uti in caelo videntur.

13 Igitur cum sol fuerit in capricorni, orbiculi⁵ ligula⁶ in maioris tympani parte ex⁷ capricorni cotidie singula puncta tangens, ad perpendicularum habens aquae currentis vehemens pondus, celeriter per orbiculi foramen id extrudit ad vas. Tum⁸ excipiens eam, cum brevi spatio impletur, corripit et contrahit dierum minora⁹ spatia et horarum. Cum autem cotidiana versatione minoris¹⁰ tympani ligula ingrediatur in aquarii puncta,¹¹ descendit foramina perpendicularo et aquae vehementi cursu cogitur tardius emittere salientem. Ita quo minus celeri cursu vas excipit aquam, dilatatur horarum spatia.

¹ libro *H et a. c. S.*

² cancri signū *S*: caneri signorū *H.*

³ spectantis *ed*: -tes *H.*

⁴ signum *rec*: signi *H.*

⁵ orbiculi *Perr*: -lo *H.*

⁶ ligula *H G^h*: lingula *l.*

⁷ ex *Kr*: & *II.*

⁸ vas tum *Joc*: vastum *H.*

⁹ dierum minoris spatia *H*: minora *e, ed.*

12. The edge of the greater drum is to have 365 points marked at equal intervals. The lesser drum is to have on its outside circumference a tongue fixed, and is to direct the tip towards the places of the points. In the same drum a proportionate perforation is to be adjusted, because the water flows through it into the drum and guides the working. Now since the representations of the signs of the zodiac are on the margin of the greater drum, this is to remain unmoved. The sign of Cancer is to be figured at the top; perpendicularly below it, the sign of Capricorn is at the bottom. On the right of the spectator, the sign of Libra; on his left, that of Aries. The other signs are to be marked within their spaces as they appear in the sky.

13. Therefore, when the sun is in Capricorn,¹ the tongue in the lesser drum touches every day the several points in Capricorn on that part of the larger drum. The great weight of the running water being vertical, is quickly delivered through the perforation of the lesser drum into the vessel. The vessel which receives the water is soon filled, and arrests and contracts the spaces of the days and hours. When, however, by the continuous revolution of the lesser drum, the tongue enters all the points in Aquarius, the perforations leave the perpendicular, and after the downpour the water is compelled to send forth its current more slowly. Thus the slower is the flow by which the vessel receives the water, the more it extends the length of the hours.

¹ *capricorni sc. signo.*

¹⁰ minoris *Barb*: maioris *II.*

¹¹ in aquarii puncta *Ro*: in aquario cuncta *H.*

14 Aquarii vero pisciumque punctis uti gradibus scandens orbiculi foramen in ariete tangendo octavam partem aqua temperate salienti praestat aequinoctiales horas. Ab ariete per tauri et geminorum spatia ad summa cancri puncta partis octavae foramen se¹ tympani versationibus peragens et in altitudinem eo rediens viribus extenuatur, et in tardius fluendo dilatet morando spatia et efficit horas in cancri signo solstitiales. A cancro cum proclinat et peragit per leonem et virginem ad librae partis octavae puncta revertendo et gradatim corripiendo spatia contrahit horas, et ita perveniens ad puncta 15 librae aequinoctialis rursus reddit horas. Per scorpionis vero spatia et sagittarii proclivius deprimens se foramen rediensque circumactione ad capricorni partem VIII, restituitur celeritate salientis ad brumales horarum brevitates.

Quae sunt in horologiorum descriptionibus rationes et apparatus, ut sint ad usum expeditiores, quam aptissime potui, perscripsi. Restat nunc de machinationibus et de earum principiis ratiocinari. Itaque de his, ut corpus emendatum architecturae perficiatur, in sequenti volumine incipiam scribere.

¹ se *Ro* : seu *H*.

14. Then the perforation of the lesser drum mounts by the points of Aquarius and Pisces, as though up a staircase, and touches the eighth degree in Aries; the water duly marks the equinoctial hours by its outflow. From Aries, the perforation proceeding by the revolution of the drum and returning, by way of Taurus and Gemini, to the top points of Cancer at its eighth degree, loses its strength; thus the water flowing more slowly, by its delay is to lengthen the spaces, and so it produces the hours of the solstice in the sign of Cancer. When it inclines from Cancer and proceeds on its return through Leo and Virgo to the points of the eighth degree of Libra, it gradually limits the spaces and contracts the hours; arriving thus at the points of Libra it again restores the equinoctial hours. 15. Through the spaces of Scorpio and Sagittarius, the perforation drops more steeply, and returning in its revolution to the eighth degree of Capricorn, is restored by the swiftness of the current to the short winter hours.

The proportions and constructions used in making dials have now been described, as exactly as I could, with a view to their ready use. Now it remains to discuss machines and their principles. In the next book I will begin to describe these and thereby finish a complete encyclopaedia of architecture.

BOOK X

LIBER DECIMUS

1 NOBILI Graecorum et ampla civitate Ephesi lex vetusta dicitur a maioribus dura condicione sed iure esse non iniquo constituta. Nam architectus, cum publicum opus curandum recipit, pollicetur, cum sumptui adsit¹ futurum. Tradita aestimatione magistratui bona eius obligantur, donec opus sit perfectum. Absoluto autem, cum ad dictum inpena respondit, decretis et honoribus ornatur. Item si non amplius quam quarta in opere consumitur, ad aestimationem est adicienda, de publico praestatur, neque ulla poena tenetur. Cum vero amplius quam quarta in opere consumitur, ex eius bonis ad perficiendum pecunia exigitur.

2 Utinam dii immortales fecissent, ea lex etiam P. R. non modo publicis sed etiam privatis aedificiis esset constituta! Namque non sine poena grassarentur inperiti, sed qui summa doctrinarum subtilitate essent prudentes, sine dubitatione profiterentur architecturam, neque patres familiarum inducerentur ad infinitas sumptuum profusiones, et ut e bonis eicerentur, ipsique architecti poenae timore coacti diligentius modum inpensarum ratiocinantes explicarent, uti patres familiarum ad id, quod praeparavissent, seu paulo amplius adicientes, aedificia expedirent.

¹ adsit futurum *H.*

¹ *Adsit futurum for sit futurum.*

BOOK X

PREFACE

1. IN the renowned and spacious Greek city of Ephesus, a law is said to have been made of old by the forefathers of the citizens, in harsh terms but not unjust. For when an architect undertakes the erection of a public work, he estimates at what cost it will be done.¹ The estimate is furnished, and his property is assigned to the magistrate until the work is finished. On completion, when the cost answers to the contract, he is rewarded by a decree in his honour. If not more than a fourth part has to be added to the estimate, the state pays it and the architect is not mulcted. But if more than a fourth extra is spent in carrying out the work, the additional sum is exacted from the architect's property.

2. Would that the Gods had impelled the Roman people to make such a law not only for public, but also for private buildings! In that case unqualified persons would not swagger abroad with impunity, but persons trained in entirely accurate methods would profess architecture with confidence. Nor would owners be led on to unlimited and lavish expenditure, so that they are even dispossessed of their property; and the architects themselves, controlled by the fear of a penalty, would be more careful in calculating and declaring the amount of the cost. In this way the owners would finish their buildings to the sum provided or with the addition

Nam qui quadringenta¹ ad opus possunt parare, si adicient centum, habendo spem perfectionis delectationibus tenentur; qui autem adiectione dimidia aut ampliore sumptu onerantur, amissa spe et impensa abiecta, fractis rebus et animis desistere coguntur.

3 Nec solum id vitium in aedificiis, sed etiam in muneribus, quae a magistratibus foro gladiatorum scaenicisque ludorum dantur, quibus nec mora neque expectatio conceditur, sed necessitas finito tempore perficere cogit, id est sedes spectaculorum velorumque inductiones sunt et ea omnia, quae scaenicis moribus per machinationem ad spectationis populo comparantur. In his vero opus est prudentia diligens et ingenii doctissimi cogitata, quod nihil eorum perficitur sine machinatione studiorumque vario ac sollerti vigore.

4 Igitur quoniam haec ita sunt tradita et constituta, non videtur esse alienum, uti caute summaque diligentia, antequam instituantur opera, eorum expediuntur rationes. Ergo quoniam neque lex neque morum institutio id potest cogere et quotannis et praetores et aediles ludorum causa machinationes praeparare debent, visum mihi est, imperator, non esse alienum, quoniam de aedificiis in prioribus voluminibus exposui, in hoc, quod² finitionem summam corporis habet constitutam, quae sint principia machinarum, ordinata praeceptis explicare.

¹ quadringenta *ed*: quadraginta *H*.
² quod *Schn*: qui *H*.

¹ Augustus, 22 B.C., entrusted games to praetors, Dio Cassius, LIV. 2.

of a little more. For those who can provide 400,000 sesterces, and have to add 100,000, are content to be so bound, in the hope of completing the work: while those who are burdened with the addition of a half, or more of the expense, lose hope, and declining further expenditure are forced to give up with broken fortune and spirit.

3. And this defect is found not only in building, but also in the public spectacles which are given by magistrates; whether of gladiators in the forum, or of plays with a theatrical setting. In these neither delay nor expectation is permitted, but necessity compels the performance to take place within a fixed time. There is the seating for the shows, and there are the awnings to be drawn, and all those other things which, in accordance with theatrical tradition, are provided for popular spectacles by means of machinery. Herein the requisites are careful foresight and the resources of a highly trained intelligence. For nothing of this sort is done without mechanical contrivance to which an alert and masterly attention has been applied.

4. Therefore, since these things have so been handed down and determined, it does not seem irrelevant to elucidate their provision with care and all diligence before the work is entered upon. For since neither law nor custom can compel this, while every year the praetors¹ and aediles must prepare the machinery for the spectacles, I thought it not irrelevant, your Highness, after dealing with buildings in the former books, to explain in this book (which rounds off the entire completion of the treatise) what the principles of machinery are, and the rules which guide them.

- 1 MACHINA est continens e materia coniunctio maximas ad onerum motus habens virtutes. Ea movetur ex arte circulorum rotundationibus, quam¹ Graeci *cyclicen cinesin* appellant. Est autem unum genus scansionum, quod graece *acrobaticon* dicitur; alterum spirabile, quod apud eos *pneumaticon* appellatur; tertium tractorium, id autem Graeci *baru ison* vocitant. Scansionum autem machinae ita fuerunt conlocatae, ut ad altitudinem tignis statutis et transversariis conligatis sine periculo scandatur ad apparatus spectationem; at² spirabile,³ cum spiritus ex⁴ expressionibus impulsus et plagae vocesque *organicos* exprimantur.
- 2 Tractorium vero, cum onera machinis pertrahuntur, ut⁵ ad altitudinem sublata conlocentur. Scansionum ratio non arte sed audacia gloriatur; ea catenationibus [et transversariis et plexis conligationibus]⁶ et erismatum⁷ fulturis continentur. Quae autem spiritus potestate⁸ adsumit ingressus, elegantes artis subtilitatibus consequetur⁹ effectus. Tractoria¹⁰ autem maiores et magnificentia plenas habet ad utilitatem opportunitates et in agendo cum prudentia summas virtutes.

¹ quē H. ² at Ro: ut H. ³ spirabilē H, -lem S.

⁴ ex Kr; & H. ⁵ ut S G^c: aut H G.

⁶ et transversariis—conligationibus *interpolavit G: om. H S.*

⁷ erismatum *Joc: chrismatorum H.*

⁸ potestate *Joc: -tē H.*

⁹ consequetur *G: -quentur H S.* ¹⁰ *sc. ratio.*

¹ *συνεχής*, not involving action at a distance.

² *materia* is wrongly translated 'wood' by many writers; Gwilt is correct in translating 'materials.'

1. A MACHINE is a continuous¹ material² system having special fitness for the moving of weights. It is moved by appropriate revolutions of circles, which by the Greeks is called *cyclice cinesis*. The first kind of machine is of ladders (in Greek *acrobaticon*); the second is moved by the wind (in Greek *pneumaticon*); the third is by traction (in Greek *baru ison*³ or equilibrium). Now scaling ladders⁴ are so arranged that when the uprights are placed to a height and cross-pieces are tied to them, men may safely ascend to inspect military engines. But we have wind instruments when moving air is driven forth by pressure, and musical beats and vocal sounds are uttered by instruments.

2. Machines of draught draw weights mechanically so that they are raised and placed at an elevation. The design of the ladder prides itself not only on artifice but on military daring. It depends on using tie-pieces and the support of stays. But the design which gains an impulse by the power of moving air reaches neat results by the scientific refinement of its expedients. The traction machines offer in practice greater adaptation which reaches magnificence, and when they are handled carefully, supreme excellence.

¹ This third principle is seen in the water-clock of Ctesibius, Book IX. viii. 8, where the weights of the clock are in equilibrium.

⁴ ἀκροβατῶ = 'to climb aloft': military phrase, Polyæn scansion, found in late Latin, to be left here; cf. late Gk. ἀκροβάτης.

3 Ex his sunt quae *mechanicos* alia *organicos* moventur. Inter machinas et organa id videtur esse discrimen, quod machinae pluribus operis¹ ut vi maiore coguntur effectus habenti, uti ballistae² torculariorumque prela; organa autem unius operae prudenti tactu perficiunt quod est propositum, uti scorpionis seu anisocyclorum³ versationes. Ergo et organa et machinarum ratio ad usum sunt necessaria, sine quibus nulla res potest esse non impedita.

4 Omnis autem est machinatio rerum natura procreata ac praeceptrice et magistra mundi versatione instituta. Namque ni advertamus⁴ primum et aspiciamus continentem⁵ solis, lunae, quinque etiam stellarum, natura machinata versarentur,⁶ non habuissemus interdum lucem nec fructum maturitatis. Cum ergo maiores haec ita esse animadvertissent, e rerum natura sumpserunt exempla et ea imitantes inducti rebus divinis commodas vitae perfecerunt explicationes. Itaque comparaverunt, ut essent expeditiora, alia machinis et earum versationibus, nonnulla organis, et ita quae⁷ animadvertunt ad usum utilia esse studiis, artibus, institutis, gradatim agenda doctrinis curaverunt.

¹ operis *Schn*: operib; *H.* ² uallistae *H.*

³ anisocyclorum *Joc*: latinis osciclorū *H.*

⁴ namque enim advertamus *H.*

⁵ vel ut alii vocant, firmamentum, *Quint.* III. 11. 1.

⁶ *asyndeton.*

⁷ itaq: *H.*

¹ The predecessor of the mediaeval arquebus.

² The brilliant conjecture of Giocondo based on late Gk. ἀνισόκυκλος.

³ Gwilt paraphrases: 'the master movements of the universe itself.' This striking conception of machinery as natural,

3. Of these machines, some are moved mechanically, others are used like tools. There seems to be this difference between machines and instruments, that machines are driven by several workmen as by a greater force producing its effects, for example, projectile engines or wine presses. But instruments carry out their purpose by the careful handling of a single workman, such as the turning of a hand balista¹ or of screws.² Therefore both instruments and machinery are necessary in practice and without them every kind of work is difficult.

4. Now all machinery is generated by Nature, and the revolution of the universe guides and controls.³ For first indeed, unless we could observe and contemplate the continuous motion of the sun, moon and also the five planets; unless⁴ these revolved by the device of Nature we should not have known⁵ their light in due season nor the ripening of the harvest. Since then our fathers had observed this to be so, they took precedents from Nature; imitating them, and led on by what is divine,⁶ they developed the comforts of life by their inventions. And so, they rendered some things more convenient, by machines and their revolutions, and other things by handy implements. Thus what they perceived useful in practice they caused to be advanced by their methods, step by step, through studies, crafts, and customs.

extends the concept of nature and completes the Stoic pantheism.

¹ Supply *ni* from above.

² *habeo*, 'to know,' *Cic. Rep.* II. 33: *matrem habemus, ignoramus patrem*; cf. ἔχω.

³ Vitruvius states clearly here the inspiration of the craftsman.

5 Attendamus enim primum inventum de necessitate, ut vestitus, quemadmodum telarum organicis administrationibus conexus staminis ad subtemen non modo corpora tegendo tueatur,¹ sed etiam ornatus adiciat honestatem. Cibi vero non habuissimus abundantiam, nisi iuga et aratra bubus iumentisque omnibus essent inventa. Sucularumque et prelorum et vectium si non fuisset torcularis praeparatio, neque olei nitorem neque vitium fructum habere potuissemus ad iucunditatem, portationesque eorum non essent, nisi plostrorum seu serracorum per terram, navicularum per aquam inventae essent
6 machinationes. Trutinarum vero librarumque ponderibus examinatio reperta vindicat ab iniquitate iustis moribus vitam. Non minus quae sunt innumerabili modo rationes machinationum, de quibus non necesse videtur disputare, quando² sunt ad manum cotidiana, ut sunt molae,³ folles fabrorum, raedae, cisia, torni ceteraque, quae communes ad usum consuetudinibus habent opportunitates.⁴ Itaque incipiemus de is, quae raro veniunt ad manus, ut nota sint,⁵ explicare.

II

1 PRIMUMQUE instituemus de is, quae aedibus sacris ad operumque publicorum perfectionem necessitate comparantur. Quae fiunt ita. Tigna duo ad one-

¹ tueatur *Schn*: -antur *H*.

² quando *Gr*: quod non *H*.

³ molae *Ro*: motae *H*.

⁴ oportunitates *G S^c*: opportunitatib: *H*.

⁵ sunt *H*.

5. Let us first consider necessary inventions. In the case of clothing, by the organic arrangements of the loom, the union of the warp to the web not only covers and protects our bodies, but also adds the beauty of apparel. Again, we should not have plentiful food, unless yokes and ploughs had been invented for oxen and other animals. If windlasses, press-beams and levers had not been supplied to the presses, we should not have had clear oil or the produce of the vine for our enjoyment. And their transport would have been impossible, unless the construction of carts or waggons by land, and of ships by sea had been devised. 6. The equilibrium of balances and scales has been applied to free human life from fraud by the provision of just measures. Besides, there are innumerable mechanical devices about which it does not seem needful to enlarge (because they are to hand in our daily use), such as millstones, blacksmiths' bellows, waggons, two-wheeled chariots, lathes and so forth, which are generally suitable for customary use. Hence we will begin to explain, so that they may be known, machines which are rarely employed.

CHAPTER II

ON MACHINES DEPENDING ON EQUILIBRIUM

1. AND first we will explain the machines¹ which must be provided for temples, and for the execution of public works. These are made as follows. Two

¹ Sackur, *Vitruv. u. die Poliorketiker*, furnishes an excellent commentary on the tenth book of Vitruvius.

rum magnitudinem¹ ratione expediuntur. A capite a fibula coniuncta et in imo divaricata eriguntur, funibus in capitibus conlocatis et circa dispositis erecta retinentur. Alligatur² in summo troclea, quem³ etiam nonnulli rechamum dicunt. In trocleam induntur⁴ orbiculi <duo>⁵ per axiculos versationes habentes. Per orbiculum <summum>⁶ traicitur ductarius funis, deinde demittitur et traducitur circa orbiculum trocleae inferioris. Refertur autem ad orbiculum imum trocleae superioris et ita descendit ad inferiorem et in foramine eius religatur.⁷ Altera pars funis refertur inter imas machinae partes.

2 In quadris autem tignorum posterioribus, quo loci sunt divaricata, figuntur chelonia,⁸ in quae coiciuntur sucularum capita, ut faciliter axes versentur. Eae suculae proxime capita habent foramina bina ita temperata, ut vectes in ea convenire possint. Ad rechamum autem imum ferrei forfices religantur, quorum dentes in saxa forata accommodantur. Cum autem funis habet caput ad suculam religatum et vectes ducentes eam versant, funis <se>⁹ involvendo circum suculam extenditur et ita sublevat onera ad altitudinem et operum conlocationes.

3 Haec autem ratio machinationis, quod per tres orbiculos circumvolvitur, trispastos appellatur. Cum

¹ magnitudine *H.*

² alligatur . . . troclea *Joc*: alligantur . . . trocleae *H.*

³ quem *e₂ ed*: quae *H.*

⁴ induntur *Joc*: induuntur *H.*

⁵ duo *add. Joc.*

⁶ summum *add. Joc.*

⁷ religatur *ed*: -gantur *H.*

⁸ chelonia *e₂ ed*: helonia *H.*

⁹ *add. Joc.*

pieces of timber are carefully prepared, which answer to the size of the load. They are set up, connected¹ at the top with a brace, and spreading at the base. They are kept upright by ropes fastened at the top and adjusted round them. At the top a block is made fast: these some call *rechamus*. On this block two pulleys are fixed, which revolve upon axles. Over the top pulley the leading rope is passed. It is then let down and drawn round a pulley of the block below. It is returned to the lower pulley of the top block, and so comes again to the lower block and is secured to the eye of it. The other end of the rope belongs to the lower part of the machine.²

2. On the back faces of the timbers where they separate, socket-pieces are fixed, into which the ends of the windlasses are put, so that the axles may turn easily. The windlasses near their ends have two perforations so adjusted that handspikes can fit into them. To the bottom of the block, iron pincers are fixed, the teeth of which are adjusted to holes in the blocks of stone. Now when the rope has its end tied to the windlass, and the handspikes draw and turn the windlass, the rope in winding round the axle is made taut and so lifts up weights to their place in the work.

3. Now this kind of contrivance, because it is turned by three pulleys, is called *trispastos*.³ When,

¹ This passage seems to settle the reading *destinabantur, distinebantur* in *Caes. B. G. IV. 17. 5*; *binis utrimque fibulis ab extrema part destinabantur*, cf. *Holmes ad loc.* Caesar's account of the bridge was probably supplied by the engineer.

² The upper block seems to have had one pulley placed above the other. *imum* the superlative in a comparative sense. *Neuburger, fig. 270.*

³ *sc. rechamus.*

vero in ima troclea duo orbiculi, in superiore
tres versantur, id pentaspaston dicitur. Sin autem
maioribus oneribus erunt machinae comparandae,
amplioribus tignorū longitudinibus et crassitudini-
bus¹ erit utendum; eadem ratione in summo
fibulationibus, in imo sucularum versationibus²
expediendum. His explicatis antarii funes ante
laxi conlocentur; retinacula super scapulas machinae
longe disponantur, et si non erit, ubi religetur,
pali resupinati defodiantur et circum fistucatione
4 solidentur, quo funes alligentur. Troclea in summo
capite machinae rudenti contineatur, et ex eo
funis perducatur³ ad palum et quae est in palo
trocleam inligata. Circa eius orbiculum funis inda-
tur et referatur ad eam trocleam, quae erit ad
caput machinae religata. Circum autem orbiculum
ab⁴ summo traiectus funis descendat et redeat ad
suculam, quae est in ima machina, ibique religetur.
Vectibus autem coacta sucula versabitur, eriget
per se machinam sine periculo. Ita circa dispositis
funibus et retinaculis in palis haerentibus ampliore
modo machina conlocabitur. Trocleae et ductarii
funes, uti supra scriptum est, expediuntur.

5 Sin autem colossicotera amplitudinibus et pon-
deribus onera in operibus fuerint, non erit
suculae committendum, sed quemadmodum sucula
chelonis retinetur, ita axis includatur habens in
medium tympanum amplum, quod nonnulli rotam

¹ grassitudinibus *H.*

² versationibus *Joc*: venationibus *H.*

³ funis perducatur *Rode*: funes pducantur *H.*

⁴ ab summo *Joc*: ad summo *H* (a s. *G*^e).

¹ sc. μηχανήμα, Baumeister, p. 1621.

however, there are two pulleys in the lower block and
three in the upper block, it is called *pentaspaston*.¹
But if machines are to be prepared for greater loads,
we must use longer and thicker timbers. In the
same way we must use larger bolts at the top, and
larger windlasses below. When all is made ready,
the tackle,² which is previously loose, is to be attached;
the cables are to be carried over the shoulders of the
machine. If there is no place to which they may be
fixed, sloping piles are to be driven into the ground
and secured by ramming the ground round them; to
them the ropes are to be attached. 4. The block at
the top of the machine is to be attached by a cable.
And a rope is to be taken from the top to the inclined
pile and fastened to the block which is on the pile.
Passing over its pulley the rope is to be carried back
to the block which shall be bound to the top of the
machine. After passing round the pulley the rope
is to come down from the top and is to return to the
windlass which is below, and bound there. The
windlass being worked by handspikes will revolve:
and of itself will raise the machine without danger.
Thus the ropes are passed round, the cables are fixed
to the piles and the machine is in position for use. The
pulleys and the tackle are applied as it is described
above.

5. If, however, the works involve loads of immense
dimensions and weight, we must not trust to the
windlass. But an axle held in sockets like the
windlass is to be inserted having in the middle a large
drum,³ which some call a wheel: the Greeks,

¹ Cf. *ansarii*, C.I.L. VI. 1016a.

² *multaque per trocleas et tympana pondere magno | com-
movet atque levi sustollit machina nisu.* Lucr. iv. 905-6.

- appellant, Graeci autem *amphieren*,¹ alii *perithecium*
 6 vocant. In his autem machinis trocleae non eodem
 sed alio modo comparantur. Habent enim et in
 imo et in summo duplices ordines orbiculorum.
 Ita funis ductarius traicitur in inferioris² trocleae
 foramen, uti aequalia duo capita sint funis, cum erit
 extensus, ibique secundum inferiorem trocleam
 resticula circumdata et contenta utraeque partes
 funis continentur, ut neque <in dextram neque>³
 in sinistram partem possint prodire. Deinde capita
 funis referuntur in summa troclea ab exteriori parte
 et deiciuntur circa orbiculos imos et redeunt ad imum
 coiciunturque⁴ infimae trocleae ad orbiculos ex
 interiore parte et referuntur dextra sinistra; ad
 caput circa orbiculos summos redeunt.
- 7 Traiecti autem ab exteriori parte feruntur dextra
 sinistra tympanum in axe ibique, ut haereant,
 conligantur. Tum autem circa tympanum involutus
 alter funis refertur ad ergatam, et is⁵ circumactus⁶
 tympanum et axem. Se involvendo pariter exten-
 dunt, et ita leniter levant onera sine periculo.
 Quodsi maius tympanum conlocatum aut in medio
 aut in una parte extrema fuerit sine ergata, calcantes
 homines expeditiores⁷ habere poterunt⁸ operis
 effectus.
- 8 Est autem aliud genus machinae satis artificiosum
 et ad usum celeritatis expeditum, sed in eo dare
 operam non possunt nisi periti. Est enim tignum,
 quod erigitur et distenditur retinaculis quadrifariam.

¹ *amphieren* H: ἀμφίηρης ut ἀμφιήκης Hesych.

² *inferioris* G: -res H, inferius S. ³ *add. Joc.*

⁴ *coniciuntur* H S. ⁵ *is* G S^o: his H S.

⁶ *circumactus* e, *Joc*: circū auctus H.

⁷ *expeditiores* rec: expeditores H.

amphieres, or otherwise *perithecium*. 6. In these
 machines the blocks¹ are made in a different way.
 For they have below and above two pulleys arranged
 vertically. The guide rope passes into a hole in the
 lower block in such a way that the rope when it is
 taut has its two ends equally long. The rope being
 passed round and secured to the lower block, both ends
 of the rope are secured so that they cannot swerve to
 the right or left. Then the ends of the rope are
 carried back on the outside of the upper block and
 are taken over its lower pulleys, and return below.
 They are passed from the inside to the pulleys of the
 lower block and are carried up right and left and
 return to the top round the highest pulleys.

7. Passing from the outside they are carried right
 and left of the drum on the axle, and are tied so as to
 hold there. Then another rope is wound round the
 drum and carried back to the capstan. This rope
 is turned round the drum and axle, winds itself up
 and the ends are stretched equally and so gently
 raise the loads in safety. But if a greater drum is
 fixed either in the middle or on one of the ends, the
 capstan is dispensed with, and the drum, being
 trodden by men, can produce results more quickly.

8. There is another² kind of machine ingenious
 enough and suitable for speedy use; but only skilled
 workmen can deal with it. A pole is set up and is
 kept upright by cables in four different directions.

¹ The pulleys are not side by side, but one above the
 other.

² Like a crane (ill. Neuburger, *op. cit.* 209). Plate O.

⁸ *poterunt pro poterit Mar.*

Sub retinaculo chelonia¹ duo figuntur, troclea funibus² supra chelonia¹ religatur, sub troclea regula³ longa circiter pedes duos, lata digitos sex, crassa quattuor supponitur. Trocleae ternos ordines orbiculorum in latitudine habentes conlocantur. Ita tres ductarii funes in machina⁴ religantur. Deinde tres ductarii ad imam trocleam et traiciuntur ex interiore parte per eius orbiculos summos. Deinde referuntur ad superiorem trocleam et traiciuntur ab⁵ exteriori parte in interiorem per orbiculos imos.

9 Cum descenderint ad imum, ex interiore⁶ parte et per secundos orbiculos traducuntur in extremum et referuntur in summum ad orbiculos secundos; traieci redeunt ad imum et per imum⁷ referuntur ad caput; traieci per summos redeunt ad machinam imam. In radice autem machinae conlocatur tertia troclea; eam autem Graeci *epagonta*, nostri *artemonem* appellant. Ea troclea religatur ad trocleae radicem habens orbiculos tres, per quos traieci funes traduntur hominibus ad ducendum. Ita tres ordines hominum ducentes sine ergata celeriter

10 onus ad summum perducunt. Hoc genus machinae polyspaston⁸ appellatur, quod multis orbiculorum circuitationibus et facilitatem summam praestat et celeritatem. Una autem statutio tigni hanc habet utilitatem, quod ante quantum velit et dextra ac sinistra a latere⁹ proclinando onus deponere potest.

Harum machinationum omnium, quae supra sunt scriptae, rationes non modo ad has res, sed etiam

¹ celonia H. ² funibus *Joc*: funis H.

³ regula *ed*: *aregula* H.

⁴ i.e. in summo machinae *Joc*.

⁵ ex interiore *Joc*: exteriori H.

⁶ et per imum *Gr*: & primo H.

⁷ a latere *e*: adlatere H.

⁸ ab: ad H.

⁹ polyspastion H.

Where the cables meet at the top, two sockets are fixed; the block is fixed to the sockets with ropes. Under the block is put a piece of timber about two feet long, six inches wide, and four inches thick. The blocks, with three sets of pulleys in their width, are fixed so that three guide ropes are inserted in the machine. These are brought down to the lower block and pass from the side next the pole over the upper pulleys; thence they are carried to the upper block and pass over the lower pulley, from the outside to within.

9. When they come below they pass over the second pulleys from within outwards, and are brought back to the second pulleys above. Passing on they return below, and from below they return to the top. And passing over the top of the pulleys, they return to the lower part of the machine. Further, at the foot of the machine a third block is fixed; this is called *epagon* by the Greeks, *artemon*¹ by us. The block is secured to its foot with three pulleys, over which the ropes pass, which are given to men to work. Thus three sets of men working without a capstan quickly draw a load to the top. 10. This kind of machine is called *polyspaston*² (a compound pulley), because with its many pulleys it is very easy and quick to work. The use of a single pole has this advantage, that by inclining it beforehand it can deposit the load sideways right or left as much as is desired.

The use of all the contrivances described above is available not only for these purposes, but also for

¹ 'The guiding pulley of a machine for raising weights.'

² This machine was used by Archimedes in launching a ship for Hiero, Plut. *Marcellus*, 14.

ad onerandas et exonerandas naves sunt paratae, aliae erectae, aliae planae in carchesis versatilibus conlocatae. Non minus sine tignorū erectionibus et trocleis subductiones navium efficiuntur.

11 Non est autem alienum etiam Chersiphronos¹ ingeniosam rationem exponere. Is enim scapos columnarum e lapidicinis cum deportare vellet Ephesi ad Dianae fanum, propter magnitudinem onerum et viarum campestrē mollitudinem confisus carris,² ne rotae devorarentur, sic est conatus. De materia trientali scapos quattuor, duos transversarios interpositos,³ quanta longitudo scapi fuerit, complectet et conpeget⁴ et ferreos cnodacas⁵ uti subscudes in capitibus scaporum inplumbavit et armillas in materia ad cnodacas⁵ circumdandos infixit; item bucculis⁶ tigneis capita religavit; cnodaces⁵ autem in armillis inclusi liberam habuerunt versationem tantam; ita, cum boves ducerent subiuncti,⁷ scapi⁸ versando in cnodacibus et armillis sine fineolvebantur.

12 Cum autem scapos omnes ita vexerunt et instabant epistyliorum vecturae, filius Chersiphronos⁹ Metagenes transtulit ex scaporum¹⁰ vectura etiam in epistyliorum deductione. Fecit enim rotas circiter pedum duodenūm et epistyliorum capita in medias

¹ crestiphonos *H.*

² carris *S*: caris *H.*

³ interpositos *ed*: interpostios *H.*

⁴ cōnpeget *G* (*alternis temporibus futuro et praeterito utitur H quasi sermone Semitico*).

⁵ cnodac. *Turn*: chodac. *H.*

⁶ bucculis *S*: bacculis *H.*

⁷ subiuncti *G*: -tis *H S.*

⁸ scapi *Joc*: scapo *H.*

¹⁰ excaporum *H.*

⁹ cresiphonos *H.*

loading up and unloading ships: some being upright, others on the level, being fixed with revolving sockets.¹ In like fashion on the level (without erecting poles) blocks and ropes are adjusted in order to draw ships ashore.²

11. It is quite germane to our subject to describe an ingenious contrivance of Chersiphron.³ When he desired to bring down the shafts of the columns from the quarries to the Temple of Diana at Ephesus, he tried the following arrangement. For he trusted his two-wheeled carts, fearing lest the wheels should sink down in the yielding country lanes because of the huge loads. He framed together four wooden pieces of four-inch timbers: two of them being cross-pieces as long as the stone column. At each end of the column, he ran in iron pivots with lead, dovetailing them, and fixed sockets in the wood frame to receive the pivots, binding the ends with wood cheeks: thus the pivots fitted into the sockets and turned freely.⁴ Thus when oxen were yoked and drew the frame, the columns turned in the sockets with their pivots and revolved without hindrance.

12. Now when they had thus brought all the shafts, and set about bringing the architraves, Metagenes, the son of Chersiphron, applied the method of conveying the shafts to the transport of the lintels. For he made wheels about twelve feet in diameter, and

¹ *carchesium*: here it seems to mean the 'top' of a mast, or alternatively a similar socket or shoe resting on the ground. Cf. *Lucr. v. 418*: *summi carchesia mali*.

² *Caes. B. G. IV. 29. 2.*

³ Account probably based upon the treatise referred to, VII. *pref. 12.*

⁴ The frame contained the column, like the frame which contains a garden roller when it is drawn by a horse.

rotas inclusit; eadem ratione enodaces¹ et armillas in capitibus inclusit: ita cum trientes a bubus rotas, epistylia vero inclusa uti axes in rotis eadem ratione,³ qua scapi, sine mora ad opus pervenerunt. Exemplar autem erit eius, quemadmodum in palaestris cylindri exaequant ambulationes. Neque hoc potuisset fieri, nisi primum propinquitas esset—non enim plus sunt ab lapidicinis ad fanum milia passuum octo—nec ullus est clivus sed perpetuus campus.

- 13 Nostra vero memoria cum colossici Apollinis in fano basis esset a vetustate diffracta, et metuentes, ne cederet ea statua et frangeretur, locaverunt ex eisdem lapidicinis basim excidendam. Conduxit quidam Paconius. Haec autem basis erat longa pedes duodecim, lata pedes viii, alta pedes sex. Quam Paconius gloria fretus non uti Metagenes adportavit, sed eadem ratione alio genere constituit
- 14 machinam facere. Rotas enim circiter pedum xv fecit et in his rotis capita lapidis inclusit, deinde circa lapidem fusos sextantales⁴ ab rota ad rotam ad circinum compegit, ita uti fusus a fuso non distaret pedem esse unum. Deinde circa fusos funem involvit et⁵ bubus iunctis funem ducebant. Ita cum explicaretur, volvebat rotas, sed non poterat ad lineam via recta ducere, sed exhibat in unam

¹ chodaces *H.*

³ rationem *a. c. H.*

⁵ et *ed*: ut *H.*

² versabant *ed*: -bant *H G.*

⁴ sextantales *Joc*: sextantes *H.*

¹ Like a garden roller with a stone cylinder.
² Vitruvius' account of the temple is correct. It is unlikely that he was mistaken here. Wood, *op. cit.* 19, 265. There are quarries some miles up the Cayster on the left bank.

fixed the ends of the architraves in the middle of the wheels. In the same way he fixed pivots and sockets at the ends of the architraves. Thus when the frames of four-inch timber were drawn by the oxen, the pivots moving in the sockets turned the wheels, while the architraves being enclosed like axles in the wheels (in the same way as the shafts) reached the building without delay. (A similar machine¹ is used when rollers level the walks in the palaestrae.) This expedient would not have been possible unless, to begin with, the distance had been short. It is not more than eight miles from the quarries to the temple, and there are no hills but an unbroken plain.²

13. Within living memory, when the base of the colossal statue of Apollo in the temple had been cracked across by age, it was feared lest the statue should give way and be broken, and a contract was let out for cutting a base from the same quarries. A certain Paconius³ undertook the contract. The base was 12 feet long, 8 feet wide, 6 feet high. Paconius was so proud of his reputation that he did not convey it after the manner of Metagenes, but decided to construct a similar machine in another way.

14. He made two wheels about 15 feet in diameter and in them he enclosed the ends of the stone. Next, he fixed two-inch pieces less than a foot apart round the stone lengthwise from wheel to wheel. Then he wound a rope outside the wood pieces and drew the rope with a yoke of oxen. When the rope was pulled it caused the wheels to turn. However, he could not keep the machine straight along the road, but it kept

³ The same name occurs Suet. *Tib.* 61.

partem. Ita necesse erat rursus retroducere. Sic Paconius ducendo et reducendo pecuniam contricavit, ut ad solvendum non esset.

15 Pusillum extra progrediar et de his lapidicinis, quemadmodum sint inventae, exponam. Pixodarus autem cives Ephesiorum cogitarent fanum Dianae ex marmore facere decernerentque, a Paro, Proconneso,¹ Heraclea, Thaso² uti marmor peteretur,³ pascebat, ibique duo arietes inter se concurrentes alius alium praeterierunt et impetu facto unus cornibus percussit saxum, ex quo crusta candidissimo colore fuerat deiecta. Ita Pixodarus dicitur oves in montibus reliquisse et⁴ crustam cursim Ephesum, cum maxime de ea re ageretur, detulisse. Ita statim honores decreverunt ei et nomen mutaverunt: pro Pixodaro Euangelus nominaretur. Hodieque quotmensibus magistratus in eum locum proficiscitur et ei sacrificium facit, et si non fecerit, poena tenetur.

III

1 DE tractoriis rationibus quae necessaria putavi, breviter exposui. Quorum motus et virtutes duae

¹ proconesso *H.*

² Thaso *ed*: thasii *H.*

³ marmor peteretur *Mar*: marmo|rep&at *H.*

⁴ reliquiss& crustam *H.*

¹ Callistratus, another transport contractor, had a similar experience. *Athen. Mech.* 7.

² *trico, Vulg. Ecclus.* xxxii. 15.

swerving to one side.¹ Thus it was necessary to draw it back again. So Paconius by drawing it backwards and forwards frittered² his money away and went bankrupt.

15. I will make a small digression, and describe how these quarries were discovered. Pixodarus was a shepherd who lived in this neighbourhood. Now when the citizens of Ephesus planned to build a temple of marble and decided to obtain marble from Paros, Proconnesus, Heraclea, and Thasos, Pixodarus was driving his sheep and was pasturing them in the same place. And there two rams, butting together, overran one another, and, in the rush, one of them struck a rock with his horns and a chip of the whitest³ colour was thrown down. So Pixodarus is said to have left his sheep on the hills and to have run with the chip of marble to Ephesus at the time when there was a great discussion about the matter. Thus the citizens decreed him divine honours⁴ and changed his name: instead of Pixodarus he was to be named Evangelus. And to this day every month the magistrate sets out to that place and sacrifices to Evangelus. If he omits to do so he is subject to a penalty.

CHAPTER III

ON RECTILINEAR AND CIRCULAR TRACTION

1. I HAVE set forth briefly what I thought necessary about methods of Traction. Of these, the effective movements⁵ are two distinct and unlike

³ White and black are colours, although not always regarded as such by the physicist.

⁴ *Acts*, xiv. 11.

⁵ *motus et virtutes*, hendiadys.

res diversae et inter se dissimiles uti congruentes uti principia pariunt eos perfectus: una porrecti, quam Graeci *eutheiam* vocitant, altera rotunditatis, quam Graeci *cycloten*¹ appellant. Sed vero neque rotationis versationes onerum possunt facere levationes.

2 Id autem ut intellegatur, exponam. Inducuntur uti centra axiculi in orbiculos et in trocleis conductionibus et in sucula conlocatus vectium versationibus onerum facit egressus in altum. Cuius suculae cardines uti centra porrecti in cheloniis,² foraminibusque eius vectes conclusi capitibus ad circinum circumactis torni ratione versando faciunt oneris elationes. Quemadmodum etiam ferreus vectis cum est admotus ad onus, quod manuum multitudo non potest movere, supposita uti centro citro³ porrecta pressione, quod Graeci *hypomochlion* appellant, et lingua sub onus subdita, caput eius unius hominis viribus pressum id onus extollit.

3 Id autem quod brevior pars prior vectis ab ea pressione, quod est centrum, subit sub onus, et quo longius ab eo centro distans caput eius deducitur.⁴ Per id faciundo motus circinationis cogit pressionibus

¹ κυκλωτήν *Joc*: cycletoen *H*.

² cheloniis *S*: caeloniis *H*.

³ citro *adj. Gr.*: cito *H*.

⁴ deducitur per id *Ro*: per id deducitur *H*.

¹ The whole of the rest of this chapter seems to derive from the *Mechanica* (attributed wrongly to Aristotle), 850a-852a.

things, although they are co-operating principles in producing their results. There is the principle of the straight line (which the Greeks call *eutheia*); and that of the circle (which the Greeks call *cyclotes*). But neither rectilinear motion without circular, nor rotating movements without rectilinear, can produce the raising of loads.

2. I will illustrate this so as to make it understood. Axles are fixed as centres for the pulleys and fitted into blocks. The rope is taken round over the pulleys and drawn straight down; and being coiled round a windlass, when the levers are turned, causes the load to rise upwards. The pivots of the windlass being inserted, like centres, into the sockets, the levers are inserted into holes in the windlass, and their ends being pushed round in a circle and turning like a lathe, cause the movement upwards of the loads. After the same fashion, when an iron lever¹ is applied to a weight which a multitude of hands could not move, a fulcrum² is placed under it on the nearer side as a centre (which the Greeks call *hypomochlion*). The short end of the lever is placed under the load, and the long end of the lever, when it is pressed down by one man's strength, raises the load.

3. Now this lifting is accomplished because the short end of the lever is under the weight, and is nearer to the fulcrum where is the centre of motion; and in so far as the head of the lever which is pressed down is further distant from the fulcrum. When the lever is in action, the circular motion (*i.e.* of the

² *pressio*, Caes. *B.C.* II. 9. 6. Caesar here again, as in the case of the Rhine bridge, uses the technical knowledge of his engineers.

examinare paucis manibus oneris maximi pondus. Item si sub onus vectis ferrei lingua subiecta fuerit in altitudinem extolletur,¹ lingua fulta in areae angulum² pro pressione. Ita non tam faciliter quam per oppressionem, sed adversus nihilominus in pondus oneris erit exercitatum. Igitur si plus lingua vectis supra hypomochlion posita sub onus subierit et caput eius propius³ centrum pressionem habuerit, non poterit onus elevare, nisi, quemadmodum supra scriptum est, examinatio vectis longitudinis per caput neque ductionibus fuerit facta.

4 Id autem ex trutinis, quae staterae dicuntur, licet considerare. Cum enim ansa propius caput, unde lancula pendet, ibi⁴ ut centrum est conlocata et aequipondium in alteram partem scapi, per puncta vagando quo longius aut etiam ad extremum perducitur, paulo et impari⁵ pondere amplissimam pensionem parem⁶ perficit per scapi librationem, et examinatio longius ab centro recedens ita inbecillior.⁷ Aequipondii brevitatis maiorem vim ponderis momento deducens sine vehementia molliter ab imo susum versum egredi cogit futurum.

¹ extolletur rec : -litor H.

² post angulum H folii 145 paginam aversam propter membranae tenuitatem vacuam habet; in qua primum crux (Vol. I. pref. xvii) delineata cui tenuitas nihil obstat, multis annis post scriptor incertus addidit Goderān' pposit' a sinistro crucis, a dextro fortasse codex, quasi in bibliothecae indice.

³ proprius H. ⁴ ibi Mar : ubi H.


⁵ et impari Rode : etiam pari H.

⁶ parem Joc : parte H. ⁷ inbecilliora aequipondii H.

¹ A blank page was left in H. 145b. See Vol. I. pref. xvii. This probably contained a diagram of two positions of the

lever)¹ round the fulcrum causes the weight of a great load to be balanced by a few hands.² Also if the short arm of an iron lever is put under the load, and the long arm is raised from the fulcrum upwards against the load, instead of downwards, the short arm resting upon the ground, will have that for a load, and the corner of the actual load for a fulcrum. Thus—not so easily indeed as by pressing against the actual fulcrum—none the less by pressing against the weight of the load, the work will be done. Therefore if the shorter end of the lever, being applied above the fulcrum, goes too far under the load, and the longer arm has the fulcrum too near the centre, it will not be able to raise the load, unless (as it has been written above) the long arm of the lever is balanced from the end, and not by pressing down the centre.

4. We can consider this in the case of steel-yards which are called *staterae*. For when the handle of suspension is placed like a centre, nearer the end of the beam from which the scale hangs, and the weight moves along the points marked on the other side of the centre, the further it is taken (or even to the end), with a small and unequal weight, it is made equal to a very large weight by bringing the beam to a level. The further the balancing weight retreats from the centre, to that extent may it be of slighter amount. The small counter-weight brings down, as it moves, the more powerful weight, and causes it to rise gently and without violence up and down.

lever in the form of a cross  which was worked over by the illuminator.

¹ When a lever is in motion the weight moved and the weight causing motion tend to be inversely proportionate to the lengths of the two arms measured from the fulcrum.

- 5 Quemadmodum etiam navis onerariae maximae gubernator ansam gubernaculi tenens, qui *οιαξ*¹ a ratione pressionibus artis agitans, versat eam oneratam. Eiusque vela cum sunt per centrum mediam mali² pendentia, non potest habere navis celerem cursum, cum autem in summo cacumine antennae subductae sunt, tunc vehementiore progreditur impetu, quod non proxime calcem mali, progressa recipiunt in se vela ventum.³
- 6 Itaque uti vectis sub onere subiectus, si per medium premitur, durior est neque incumbit, cum autem caput eius summum deducitur, faciliter onus extollit, similiter vela, cum sunt per medium temperata, minorem habent virtutem, quae autem in capite mali summo conlocantur discedentia longius a centro, non acriore sed eodem flatu, pressione cacuminis vehementius cogunt progredi navem. Etiam remi circa scalmos strophis religati, cum manibus impelluntur et reducuntur, extremis progredientibus a centro parvis maris undis spumam impulsu vehementi protrudunt porrectam navem, secante prora liquoris raritatem.
- 7 Onerum vero maxima pondera, cum feruntur a phalangariis hexaphoris et tetraphoris,⁴ examinantur per ipsa media centra phalangarum, uti in diviso

¹ *οιαξ* *Joc*: *νοξ* *H*.

² mediam mali *Joc*: mediā ali *H*, media mali *G S*.

³ vela ventum *Joc*: velamentū *H*.

⁴ exaphoris et raphoris *H*.

¹ Ciceronian phrase is *ingens immanisque*.

5. Just as also the steersman of a great merchant vessel holds the handle of the tiller (which is called *οιαξ* by the Greeks) with only one hand, and moves it skilfully round the centre where the fulcrum is tightly set, and guides the ship laden with an abundant timber.² Further, when the sails are only half mast high, the ship cannot run swiftly; but when the yard-arms are drawn up to the tops of the masts, the ship sails with a more vehement course, because the sails take the wind, not near the foot of the mast (which is like a fulcrum), but at the mast-head from which the distance is greater.

6. Therefore just as when a lever is put under a load and pressed down about the middle, it is moved with difficulty, but when the longer arm is pressed down from the top, it easily raises the load; so when the sails are set half-mast high, they are less effective, but when they are set at the mast-head at a greater distance from the centre, without any further rising of the wind, with the summit as fulcrum, they cause the ship to sail a stronger course. When also the oars of a ship are tied to the tholes with loops, and pushed backwards and forwards, the ends of the blades,³ moving at a distance from the centre in the waves of the sea, drive the ship with a mighty impulse straight through the foam, as the bows cleave the yielding waters.

7. Again, when very heavy loads are carried by gangs of four or six porters, they are balanced exactly in the middle of the carrying-poles, so that

² *pinus* 'timber' used generically.

³ *parma* and *palma* interchanged in MSS.; cf. *πάλαμη* Hesych. for *πάραμη*.

oeris solido pondere certa quadam divisionis ratione aequas partis collis singuli ferant operarii. Mediae¹ enim partes phalangerum, quibus lora tetraphororum invehuntur, clavis sunt finitae, nec centri promoventur, premunt eum extra finem proprius² accesserunt, quemadmodum in statera pondus, cum examine progreditur ad fines ponderationem.

3. Eadem ratione iumenta, cum iuga eorum subiugiis³ onera. Cum autem in pares sunt eorum virtutes et unum plus valendo premit alterum, loro trajecto fit una pars iugi longior, quae inbecilliori⁴ auxiliatur iumento. Ita in phalangis⁵ et iugis cum in medio progreditur⁶ lorum ab medio,⁷ unam brevioram, alteram⁸ efficit partem longiorem. Ea ratione si per id centrum, quo loci perductum est lorum, utraque capita circumaguntur,⁹ longior pars amplior, brevior minorem agit circinationem.

9. Quemadmodum vero minores rotae¹⁰ duriores et difficiliore habent motus, sic phalangae et iuga, in quibus partibus habent minora a centro ad capita intervalla, premunt duriter colla, quae autem longiora habent ab eodem centro spatia, levant oneribus et trahentes¹¹ et ferentes. Cum haec ita ad

¹ mediae *G*^c: media *H*.

² proprius *H*.

³ subiugiis *Schn*: subiugiorum *H*.

⁴ inbecilliori *h*: -lior *H*.

⁵ phalangis *S*: palangis *H*.

⁶ progredit *H S*^c.

⁷ ad medio *H*.

⁸ alteram *G*.

⁹ circumagentur *Joc*: -gentes *H*.

¹⁰ rotae *ed*: notae *H*.

the undivided solid weight is shared in a definite proportion, and each labourer carries an equal part of the load on his neck. For the middle parts of the carrying-poles, on which the straps of the porters are fixed, are provided with pegs so that the straps do not slip out of their place. For when the load slips away from the middle, it presses upon that side to which it is nearer, just as in the case of the weight on a balance when it is adjusted nearer one end of the beam.

8. In the same way, yokes of oxen draw their loads evenly, when the yokes are arranged about the middle, by the thongs of the yoke-straps. But when the strength of the oxen is not equal, and one by its greater pull burdens the other, the thong is moved on so that one part of the yoke is longer so as to help the weaker beast. Thus in the case of carrying-poles¹ and yokes, when the suspending thong is not placed in the middle but on one side, where the thong departs from the middle, it renders one side shorter and the other longer. By this means when the two arms of the yoke turn about the centre at which the thong is placed, the longer part describes a greater circle, the shorter arm a less.

9. Now just as smaller wheels are harder and more awkward to turn, so when carrying-poles and yokes have a less interval from the centre to the end of the arm, they press upon the neck, but those which have longer spaces from the same centre, ease off the load both in hauling and carrying. Since

¹ phalanga, in the sense of 'roller,' *Caes. B.C. II. 10*. It seems only to occur in the plural.

¹¹ et trahentes *Mar*: extrahentes *H*.

centrum porrectionibus et circinationibus recipere motos,¹ tunc vero etiam plostra, raedae, tympana, rotae, coeleae, scorpionis, ballistae, prela ceteraque machinae isdem rationibus per porrectum centrum et rotationem circini versantum faciunt ad positum effectus.

IV

1 Nunc de organis, quae ad hauriendam aquam inventa sunt, quemadmodum variis generibus conparentur, exponam. Et primum dicam de tympano. Id autem non alte tollit aquam, sed exhaurit expeditissime multitudinem magnam. Ad torum aut circinum fabricatus <axis,>² capitibus lamna ferratis, habens in medio circa se tympanum ex tabulis inter se coagmentatis, conlocatur in stipitibus habentibus in se sub capita axis ferreas lamminas. In eius tympani cavo interponuntur octo tabulae transversae tangentes axem et extremam tympani circuitiorem, quae dividunt aequalia³ in tympano spatia. Circa frontem eius figuntur tabulae, relictis semipedalibus aperturis ad aquam intra concipiendam. Item secundum axem columbaria fiunt excavata in singulis spatiis ex una parte. Id autem cum est navali ratione picatum, hominibus calcantibus versatur et hauriendo per aperturas, quae sunt in frontibus tympani, reddit per columbaria secundum axem supposito labro ligneo habente una secum coniunctum canalem. Ita hortis ad inrigandum vel ad salinas ad temperandum praebetur aquae multitudo.

¹ motos *H*: (cf. *Am. Apoc.* XI. 13, terrae moto).

² add. *Joc.*

³ equalia *e*₂: aequali *H*.

¹ *E.g.* the wheels of a cart.

² Plate P from Fra Giocondo.

in this way such contrivances take movements at a centre, both rectilinear and circular, so also waggons, carts, drum-wheels and other wheels, screws, scorpions, balistae, presses and other machines produce the desired effect with parts moving about a centre along a straight line¹ and by a rotation round it.

CHAPTER IV

ON MACHINES FOR RAISING WATER, AND FIRST
THE TYMPANUM

1. I WILL now explain the machines which have been invented for raising water and how they are contrived in their different kinds. And first I will speak of the *tympanum*.² Now this does not raise the water to a great height, but draws a large amount in a short time. The axle is wrought in a lathe or made circular by hand and its ends are hooped with iron bands. Round the middle it has a drum of planks fitted together; and it is placed upon posts cased with iron, under the ends of the axle. Within the drum are inserted eight cross-pieces going from the axle to the circumference of the drum, and these are arranged round the drum at equal intervals. 2. Around the rim of the drum, boards are fixed with six-inch openings to receive the water. Further, along the axle, holes are cut, one for each bay. When it has been tarred ship-fashion, it is turned by men on a treadmill. The water which is drawn through the openings in the outside of the drum is delivered also through the holes next to the axle into a wooden basin having a trough connected with it. Thus an abundant supply of water is furnished for irrigating gardens, or for diluting salt in salt pits.

3 Cum autem altius extollendum erit, eadem ratio communicabitur. Sic rota fiet circum axem eadem magnitudine, ut ad altitudinem, quae opus fuerit, convenire possit. Circum extremum latus rotae figentur modioli quadrati pice et cera solidati. Ita cum rota a calcantibus versabitur, modioli pleni ad summum elati¹ rursus ad imum revertentes infundent⁴ in castellum ipsi per se quod extulerint.² Sin autem magis altis³ locis erit praebendum, in eiusdem rotae axe involuta duplex ferrea catena demissaque ad imum libramentum conlocabitur, habens situlos pendentes aereos congiales. Ita versatio rotae catenam in axem involvendo efferet situlos in summum, qui <cum>⁴ super axem pervehuntur, cogentur inverti et infundere in castellum aquae quod extulerint.²

V

1 FIUNT etiam in fluminibus rotae eisdem⁵ rationibus, quibus supra scriptum est. Circa earum frontes adfiguntur pinnae, quae, cum percutiuntur ab impetu fluminis, cogunt progredientes versari rotam, et ita modiolis haurientis et in summum referentes sine operarum calcatura ipsius fluminis impulsu versatae praestant, quod opus est ad usum.

2 Eadem ratione etiam versantur hydraletae,⁶ in quibus eadem sunt omnia, praeterquam quod in uno capite axis tympanum dentatum est⁷ inclusum.

¹ elati *rec*: &lati *H S*.

² extulerint *S*: extullerint *H*.

³ altis *Joc*: aliis *H*.

⁴ *add. Joc*.

⁵ eisdem *e₂*: eiusdē *H*.

3. When, however, the water is to be raised to a greater height, a similar method will be employed. A wheel is so constructed round the axle of such a size as shall suit the height required. Round the circumference of the wheel square buckets are to be fixed, made taut with pitch and wax. Thus, when the wheel is turned by men treading it, the buckets are raised full to the top, and on their return down, pour into a conduit what they have raised. 4. But if a supply is required at a still greater height, a double iron chain is made to revolve on the axle of the same wheel and let down to the lower level, with bronze buckets suspended to the chain, each holding 3 quarts. Thus the turning of the wheel makes the chain revolve round the axle, and carries the buckets to the top. These are carried over the axle; they are made to turn over and pour into the conduit the water they have raised.

CHAPTER V

ON MILL WHEELS

1. WHEELS are used in rivers in the same way as described above. Round the outside, paddles are fixed, and these, when they are acted on by the current of the river, move on and cause the wheel to turn. In this fashion they draw up the water in buckets and carry it to the top without workmen to tread the wheel. Hence, being turned by the force of the river only, they supply what is required.

2. Mill wheels are turned on the same principle, except that at one end of the axle a toothed drum is

⁶ hydraletae *Schn*: hydraulae *H*.

⁷ *out Schn*: & *H*.

Id autem ad perpendicularum conlocatum in cultrum
versatur cum rota pariter. Secundum id tympanum
maius item dentatum planum est conlocatum, quo
continetur. Ita dentes tympani eius, quod est in
axe inclusum, inpellendo dentes tympani plani¹
cogunt fieri molarum² circinationem. In qua
machina inpendens infundibulum³ subministrat molis
frumentum et eadem versatione subigitur farina.

VI

1 Est autem etiam cocleae ratio, quae magnam vim
haurit aquae, sed non tam alte tollit quam rota.
Eius autem ratio sic expeditur. Tignum sumitur,
cuius tigni quanta rata est⁴ pedum longitudo, tanta
digitorum expeditur crassitudo. Id ad circinum
rutundatur. In capitibus circino dividuntur circumi-
tiones eorum tetrantibus et octantibus in partes⁵
octo, eaeque lineae ita conlocentur, ut plano posito
tigno utriusque capitis ad libellam lineae inter
se respondeant, et quam magna pars sit octava⁶
circinationis tigni, tam magna spatia decidantur⁷
in longitudinem. Item tigno plano conlocato lineae
ab capite ad alterum caput perducantur ad libellam
convenientes. Sic et in rotundatione et in longitu-
dine aequalia spatia fient. Ita quod loci describuntur
lineae, quae sunt in longitudinem⁸ spectantes,
facient decusationes et in decusationibus finita
puncta.

¹ plani *Joc*: plane *H*. ² molarum *S*: malarum *H G*.
³ infunibulū *H*. ⁴ rata est *Gr*: ratus *H*.
⁵ partes *Joc*: pedes *H*. ⁶ octava *Joc*: -vae *H*.
⁷ didantur *H G*. ⁸ longitudinem *Schn*: -ne *H*.

fixed. This is placed vertically on its edge and turns
with the wheel. Adjoining this larger wheel there
is a second toothed wheel placed horizontally by
which it is gripped. Thus the teeth of the drum
which is on the axle, by driving the teeth of the
horizontal drum, cause the grindstones to revolve.
In the machine a hopper is suspended and supplies
the grain, and by the same revolution the flour is
produced.

CHAPTER VI

ON THE WATER SCREW

1. THERE is further an application of the screw
which draws a large amount of water, but does not
raise it as high as the wheel. The contrivance¹ is
as follows. A beam is taken as many inches thick
as it is feet long. This is rounded to an exact circle.
At the ends the circumference is to be divided by a
compass into quadrants and eighths and so to eight
parts; and the diagonals are to be so drawn that when
the beam is horizontal the lines at either end corre-
spond exactly. The whole length is to be marked
off into spaces equal to one-eighth of the circum-
ference. Again, the beam is to be laid level and
lines are to be drawn from one end to the other
guided by a level. Thus there will be equal divisions
both round the beam and along it. Where the
longitudinal lines are drawn, they will intersect the
cross-lines, and these intersections are to be marked
by points.

¹ Plate Q from Fra Giocondo. A similar illustration is
given in *p*, a Parisian MS. assigned by Rose to XI or XII c;
it should rather be dated c. 1500. The illustration was
probably contemporary with Fra Giocondo.

2 His ita emendate descriptis sumitur salignea tenuis aut¹ de vitice secta regula, quae uncta liquida pice oblique ad insequentes longitudinis et circumitionis² decusis, item ex ordine progrediens singula³ puncta praetereundo et circum involvendo collocatur in eam lineam recedens a primo in octavum punctum, in qua prima pars est eius fixa. Eo modo quantum progreditur oblique spatium et per octo puncta, tantundem et longitudine procedit ad octavum punctum. Eadem ratione per omne spatium longitudinis et rotunditatis singulis decusationibus oblique fixae regulae per octo crassitudinis divisiones involutos faciunt canales et iustam cocleae naturalemque imitationem.

3 Ita per id vestigium aliae super alias figuntur unctae pice liquida, et exaggerantur ad id, uti longitudinis octava pars fiat summa crassitudo. Supra eas circumdantur et figuntur tabulae, quae pertegant eam involutionem. Tunc eae tabulae pice saturantur et lamminis ferreis conligantur, ut ab aquae vi ne dissolvantur. Capita tigni ferrea. Dextra autem ac sinistra cocleam tigna conlocantur in capitibus utraque parte habentia transversaria confixa. In his foramina ferrea⁴ sunt inclusa inque ea inducuntur styli, et ita cocleae hominibus calcantibus faciunt versationes. Erectio autem eius ad inclinationem sic erit conlocanda, uti, quemadmodum Pythagoricum trigonum orthogonium describitur,

¹ aut *G*: ut *H*.

² longitudinis et circumitionis *Mar*: longitudines et circumitiones *H*.

³ singula *e*, *ed*: -li *H*.

⁴ ferrea *Ro*: ferret *H*.

2. When these points are accurately marked in this way, there is taken a thin strip of willow or osier and this being smeared with liquid pitch is fixed upon the first intersection. Thence it is drawn across obliquely to the next intersections of the longitudinal and circular line. In like manner proceeding in due course it passes the successive points and winds round them, being fixed at the several intersections. Thus moving back from the first to the eighth point it reaches and is fixed on the line in which the first part of it was fixed. In this way, as far as it advances obliquely through eight points of the circumference, so far it proceeds longitudinally to the eighth point. In the same manner, throughout the whole distance of the length and of the circumference, strips of wood are fixed obliquely at the several intersections and make channels which wind round through the eight divisions of the thickness: thus forming an accurate and natural imitation of a spiral shell.

3. Then along this track, strips are fixed one above another and smeared with liquid pitch, and are piled up until the entire thickness is one-eighth the length. Above the strips, planks are placed all round and fixed to cover the winding strips. Then the planks are soaked in pitch and bound together with iron hoops to protect them against the effect of the water. The ends of the wood are covered with iron. On the right and left of the screw, beams are placed at the ends, with cross-pieces placed on either side. In these are iron sockets into which the pivots of the screws are inserted, and so the screws are made to turn by a treadmill. 4. The fixing of the screw is to be done at such a slope that it corresponds to the manner in which the Pythagorean right-angled

sic id habeat responsum, id est uti dividatur longitudo in partes v, earum trium extollatur caput cocleae; ita erit ab perpendicularo¹ ad imas naris spatium earum partium² III. Qua ratione autem oporteat id esse, in extremo libro eius forma descripta est in ipso tempore.

Quae de materia fiunt organa ad hauriendam aquam, quibus rationibus perficiantur quibusque rebus motus utilitates, ut essent notiora, quam infinitas potui, perscripta sunt in illo tempore.

VII

1 INSEQUITUR nunc de Ctesibica machina, quae in altitudinem aquam educit, monstrare. Ea sit ex aere. Cuius in radicibus modioli fiunt gemelli³ paulum distantes, habentes fistulas furcillae figura⁴ similiter cohaerentes, in medium catinum concurrentes. In quo catino fiant asses in superioribus naribus fistularum coagmentatione subtili conlocati, qui praeobturantes⁵ foramina narium⁶ non patiuntur quod spiritu⁷ in catinum est expressum. Supra catinum paenula ut infundibulum⁸ inversum est attemperata et per fibulam cum catino cuneo trajecto continetur, ne vis inflationis aquae eam cogat elevari.⁹ Insuper

¹ a perpendicularo *Joc*: adpendiculū *H*.

² partium *Mar*: pedes *H*.

³ gememelli *H*.

⁴ furcillae sunt figura *H*: (sunt *del. Ro*).

⁵ praecobdurantes *H*.

⁶ foraminariū *H*.

⁷ spiritu *Joc*: -tus *H*.

⁸ infudibulū *H*.

⁹ elevari *Schn*: -re *H*.

triangle is described¹: that is, the length is to be divided into 5 parts of which the head of the screw is to be raised three. Thus there will be, between the perpendicular and the lower mouth, a length of 4 parts. How this is to be done is shown by a diagram at the end² of the book.

And there I have displayed as clearly as I could for information the contrivances made of wood for drawing water, their construction and the means by which they are moved so as to furnish very great advantages.

CHAPTER VII

ON THE WATER MACHINE OF CTESIBIUS³

1. WE next proceed to describe the Ctesibian machine⁴ which raises water to a height. It is to be of bronze. The lower part consists of two similar cylinders at a small distance apart, with outlet pipes. These pipes converge like the prongs of a fork, and meet in a vessel placed in the middle. In this vessel valves are to be accurately fitted above the top openings of the pipes. And the valves by closing the mouths of the pipes retain what has been forced by air into the vessel. 2. Above the vessel, a cover like an inverted funnel is fitted and attached, by a pin well wedged, so that the force of the incoming water may not cause the cover to rise.

¹ Book IX. *pref.* 6.

² *tempus*, 'the temple of the head.' Cf. Greek, κρόταφος βιβλίου τὸ ὑπισθεν μέρος, Suidas. The illustrations were put together at the end of the whole work, Sackur, 14.

³ This chapter is translated by Schmidt, *Hero Alex.* I. 494.

⁴ *Hero Alex. Pneum.* I. 28; Schmidt, *ill.* p. 133.

fistula, quae tuba dicitur, coagmentata in altitudine fit erecta. Modioli autem habent infra foramina inferiores fistularum asses interpositos supra foramina eorum, quae sunt in fundis. Ita de supernis in modiolis emboli masculi torno politi et oleo subacti conclusique regulis et vectibus conmoluntur.¹ Qui erit aer ibi cum aqua, assibus obturantibus² foramina cogent. Extrudent inflando pressionibus per fistularum nares aquam in catinum, e quo recipiens paenula spiritu³ exprimit per fistulam in altitudinem, et ita ex inferiore⁴ loco castello conlocato ad saliendum aqua subministratur.

⁴ Nec tamen haec sola ratio Ctesibii fertur exquisita, sed etiam plures et variis generibus ab eo liquore pressionibus coactae spiritus efferre ab natura mutuatos effectus ostendentur, uti merularum⁵ aquae motu voces atque *angubatae*, bibentiaque et eadem moventia⁶ sigilla ceteraque, quae delectationibus oculorum et aurium usu sensus eblandiantur.

⁵ E quibus quae maxime utilia et necessaria iudicavi selegi, et in priore volumine de horologiis, in hoc de expressionibus aquae dicendum putavi. Reliqua, quae non sunt ad necessitatem sed ad deliciarum voluntatem, qui cupidiores erunt eius subtilitatis, ex ipsius Ctesibii⁷ commentariis poterunt invenire.

¹ conmoluntur *e*, : conmoluntur *H*.

² obdurantibus *H*.

³ spiritu *Perr* : spiritus *H*.

⁴ inferiore *Joc* : interiore *H*.

⁵ merularum (aquae) *Turn* : merulerūque *H*.

⁶ moventia *Mar* (*intr. Liv*) : movent ea *H*.

⁷ ethesibi *H*.

¹ Hero Alex. (Schmidt) I. 91.

On the cover a pipe, which is called a trumpet, is jointed to it, and made vertical. The cylinders have, below the lower mouths of the pipes, valves inserted above the openings in their bases. 3. Pistons are now inserted from above rounded on the lathe, and well oiled. Being thus enclosed in the cylinders, they are worked with piston rods and levers. The air and water in the cylinders, since the valves close the lower openings, the pistons drive onwards. By such inflation and the consequent pressure they force the water through the orifices of the pipes into the vessel. The funnel receives the water and forces it out by pneumatic pressure through a pipe. A reservoir is provided, and in this way water is supplied from below for fountains.

4. Nor is this the only remarkable device of Ctesibius which is current. There are many others of various kinds which are driven by the pressure of water. The pneumatic pressure will be shown to produce effects borrowed from nature, both notes of blackbirds¹ by the motion of water, and walking automata²; little figures which drink and move; and other things which flatter the pleasure of the eyes and the use of the ears. 5. Of these I have chosen those which I have judged most useful and serviceable. In the last book I spoke about clocks; in this we have had to deal with water-pumps. The other things which are not for service, but for the purpose of our delight, can be found in the commentaries of Ctesibius by those who have a special wish for such ingenuity.

¹ Some such contrivance whereby the movement of an owl causes the blackbird to sing or be silent is described, *ib.*

- 1 DE hydraulicis autem, quas habeant ratiocinationes, quam brevissime proximeque attingere potero et scriptura consequi, non praetermittam. De materia compacta basi, ara¹ in ea ex aere fabricata conlocatur. Supra basim eriguntur regulae dextra ac sinistra scalari forma compactae, quibus includuntur aerei modioli,² fundulis ambulatilibus ex torno subtiliter subactis habentibus fixos in medio ferreos ancones³ et verticulis cum vectibus coniunctos, pellibusque lanatis involutis.⁴ Item in summa planitia foramina circiter digitorum ternum. Quibus foraminibus proxime in verticulis conlocati aerei delphini⁵ pendentia habent catenis cymbala⁶ ex ore infra foramina modiolorum⁷ calata.
- 2 Intra aram, quod loci aqua sustinetur, inest pnigeus⁸ uti infundibulum inversum, quem subter⁹ taxilli alti circiter digitorum ternum suppositi librant spatium imum una inter labra pnigeos¹⁰ et arae fundum. Supra autem cervicula eius coagmentata arcu sustinet caput machinae, qui¹¹ graece *canon musicus* appellatur. In cuius longitudine canales,¹² si tetrachordos est, fiunt quattuor, si hexachordos, sex, si octochordos, octo.

¹ ara *Turnebus*: aerea *H.* ² modioli *ed*: moduli *H.*

³ angones *H.* ⁴ involutis *Mar*: -tos *H.*

⁵ dulpini *H.* ⁶ cymbala *Joc*: -li *H.*

⁷ modiolorum *Joc*: modiorum *H.*

⁸ pnigeus *Turn*: inid genus *H.*

⁹ subter *Joc*: sup *H.* ¹⁰ pnigeos *Turn*: phiga eos *H.*

¹¹ qui *Ro*: quae *H.* ¹² canales, si *Joc*: sicanales *H.*

¹ Aristocles, a younger contemporary of Vitruvius, compares the water organ to a clepsydra, *Athen.* IV. 174c.

1. ON the principles of water organs,¹ I cannot omit to touch as briefly and precisely as possible, and commit them to writing.² A base is made of framed wood and a bronze vessel is placed upon it. On the base, uprights are set up right and left, with rungs like a ladder. Between these, bronze cylinders are enclosed. Pistons which move up and down are accurately wrought on a lathe, and with iron piston rods fixed in the middle. These rods are joined by pins to the levers, and the pistons are covered with leather and wool. Further, on the top surface of the cylinders are openings about three fingers (2½ in.) broad. Adjoining the openings and placed on pins are bronze dolphins with valves hanging by chains from their mouths and secured below the openings of the cylinders.

2. Within the chest where the water is stored there is an air-vessel, like a funnel inverted; beneath this, small blocks about three inches high are placed, and they keep even the lowest space between the lips of the air-vessel and the bottom of the chest. On the neck of the air-vessel a small box is constructed which carries the top of the instrument, which is called in Greek the *canon musicus*. Along this there are four channels, if the instrument is tetrachord; six if it is hexachord; eight if it is octochord.

¹ Schmidt, *op. cit.*, Vol. I. pp. 496-505, translates this chapter and gives two illustrations. Plate R is based upon the text with the help of Barbaro and Schmidt.

3 Singulis autem canalibus singula epitonia sunt inclusa, manubriis ferreis conlocata. Quae manubria, cum torquentur, ex arca patefaciunt nares in canales. Ex canalibus autem canon habet ordinata in transverso foramina respondentia naribus, quae sunt in tabula summa, quae tabula graece *pinax* dicitur. Inter tabulam et canona regulae sunt interpositae ad eundem modum foratae et¹ oleo subactae, ut faciliter inpellantur et rursus introrsus reducantur, quae obturant ea foramina plinthidesque appellantur. Quarum itus et reditus alias obturat⁴ alias aperit² terebrationes. Haec regulae habent ferrea choragia fixa et iuncta cum pinnis, quarum pinnarum tactus motiones efficit regularum continenter. Supra tabulam foramina quae ex canalibus habent egressum spiritus. Sunt anuli adglutinati, quibus lingulae omnium includuntur organorum. E modiolis autem fistulae sunt continentes coniunctae pniigeos³ cervicibus pertinentesque ad nares, quae sunt in arcula. In quibus asses sunt ex torno subacti et ibi conlocati, qui, cum recipit arcula animam, spiritum non patientur⁴ obturantes foramina rursus redire.

5 Ita cum vectes extolluntur, ancones deducunt⁵ fundos modiolorum ad imum delphinique, qui sunt in verticulis inclusi, calantes in eos cymbala, aere⁶ implent spatia modiolorum, atque ancones extollentes fundos intra modiolos vehementi pulsus crebritate et obturantes foramina cymbalis superiora, aera, qui est ibi clusus,⁷ pressionibus coactum in fistulas

¹ et oleo *Joc*: ex oleo *H*.

² pniigeos *Turn*: ligneis *H*.

³ patientur *ed*: patietur *H*.

⁴ deducunt *Joc*: deducunt *H*.

⁵ cymbala, aere *Rode*: cymbaliare *H*.

3. In the several channels are single stopcocks fitted with an iron handle. When the iron handle is turned, it opens an aperture from the chest into the channels. The canon has openings from the channels; and the openings are placed along the canon corresponding to the openings in the top board which, in Greek, is called the *pinax*. Between the *pinax* above and the canon below, bars are fixed with openings corresponding to those of the canon and the *pinax*. The bars are well oiled so that they easily pass backwards and forwards, closing and opening the holes in the channels. The bars are called *plinthides*.

4. To these *plinthides*, iron springs are attached which connect with the keys of the organ, so that to touch the keys forthwith moves the *plinthides*. On the *pinax*, rings are fixed round the holes which allow the passage of the air from the channels. And these rings receive the feet of the organ pipes. Now from the cylinders, there run lengths of piping to the neck of the air-vessel and communicate with the openings in the chest. Over these openings there are placed valves wrought on the lathe. These valves, when the chest is supplied with air, close the openings and do not allow the air to escape.

5. Thus when the levers are raised, the piston rods draw down the pistons towards the bottom of the cylinder, and the dolphins working on pivots, releasing the valves in the cylinders, fill the cavity of the cylinders with air. Thereupon the piston rods raise the pistons within the cylinders with rapid and violent strokes and close the openings above, with the valves; the air in the cylinders is forced by the pumping into

⁷ clusus *H* (cludentes *Manil*).

cogunt, per quas in pnigea¹ concurrunt et per eius cervices in arcam. Motione vero vectium vehementiore² spiritus frequens compressus epitoniorum 6 aperturis influit et replet animae canales. Itaque cum pinnae manibus tactae propellunt et reducunt continenter regulas alternis opturando³ foramina alternis aperiundo, e musicis artibus multiplicibus modulorum varietatibus sonantes excitant voces.

Quantum potui niti, ut obscura res per scripturam dilucide⁴ pronuntiaretur, contendi, sed haec non est facilis ratio neque omnibus expedita ad intellegendum praeter eos, qui in his generibus habent exercitationem. Quodsi qui parum intellexerit ex scriptis, cum ipsam rem cognoscet, profecto inveniet curiose et subtiliter omnia ordinata.

IX

1 TRANSFERTUR nunc cogitatio scripturae ad rationem non inutilem sed summa sollertia a maioribus traditam, qua in via raeda sedentes vel mari navigantes scire possimus, quot milia numero itineris fecerimus. Hoc autem erit sic. Rotae, quae erunt in raeda, sint latae per medium diametrum pedum quaternum [et sextantes],⁵ ut, cum finitum locum

¹ pnigea *Turn*: lignea *H.*

² vehementiore *Joc*: -res *H.*

³ obturando *Phil*: opturant *H.*

⁵ *del. Perrault, sed vide infra ix. 5.*

⁴ delucide *H.*

¹ The organist was called *hydraules*, Petron. 36.

² The diagram only shows one range of pipes, sometimes other rows were added with different intonation.

the pipes. Through these it rushes into the air-vessel and by the neck into the chest. By a stronger motion of the levers, the air is further compressed, flows in by the openings of the stopcocks and fills the channels with air. 6. Therefore when the keys are touched by the hands, they forthwith move the sliding bars backwards and forwards, closing some holes and opening others. By the art of music,¹ the notes of the organ are struck with manifold² and varied modulation.

I have striven to the best of my ability to describe clearly in writing a complicated machine. The task is not an easy one, nor accessible to the general understanding, except for those who have experience in matters of this kind. Yet if anyone grasps them imperfectly from my writings, a knowledge of the instrument will disclose the ingenuity and precision of its design.³

CHAPTER IX

ON MEASURING A JOURNEY

1. OUR next specification concerns a contrivance not without its uses, which we owe to the great skill of our predecessors. By this contrivance, whether we travel on land in a four-wheeled carriage, or by sea in a ship, we can learn how many miles we have covered. It is as follows. The wheels of the carriage are to be 4 feet in diameter, and on one

³ From the reference of Tertullian, *de baptismo* 8, the organ would seem to have been known to the Christian Church. In 1931 an organ dated A.D. 288 was found at Aquincum near Buda-Pesth with bronze manual. *Observer*, May 24, 1931.

habeat in se rota ab eoque incipiat progrediens in solo viae facere versationem, perveniendo ad eam finitionem, a qua coeperit versari, certum modum spatii habeat peractum pedes XII s.

2 His ita praeparatis tunc in rotae modiollo ad partem interiorem¹ tympanum stabiliter includatur habens extra frontem suae rutundationis extantem denticulum unum. Insuper autem ad capsum denticuloculamentum firmiter figatur habens tympanum versatile² in cultro conlocatum et in axiculo conclusum, in cuius tympani frontem denticuli perficiantur aequaliter divisi numero quadringenti convenientes denticulos tympani inferioris. Praeterea superiori tympano ad latus figatur alter denticulus prominens extra dentes.

3 Super autem, planum eadem ratione dentatum inclusum in alterum loculamentum conlocetur, convenientibus dentibus denticulo, qui in secundi tympani latere fuerit fixus, in eoque tympano foramina fiant, quantum diurni³ itineris miliariorum numero cum raeda possit exire.⁴ Minus plusve rem nihil impedit. Et in his foraminibus omnibus calculi rotundi conlocentur, inque eius tympani theca, sive id loculamentum est, fiat foramen unum habens canaliculum, qua calculi, qui in eo tympano inpositi fuerint, cum ad eum locum venerint, in raedae capsum et vas aeneum, quod erit suppositum, singuli cadere possint. Ita cum rota progrediens secum agat tympanum imum et denticulum eius singulis versationibus tympani superioris denticulos impulsu

¹ interiorem *Joc*: inferiorem *H*.

² versatile *ed*: -lem *H*.

³ diurni *ed Fl*: diuturni *H*.

⁴ exire = praeterire, *cf. Sen. Tac.*

wheel a point is to be marked. When the wheel begins to move forward from this point and to revolve on the road surface, it will have completed a distance of $12\frac{1}{2}$ feet¹ on arriving at the point from which it began its revolution.

2. As the next step, let a drum be secured to the inner side of the hub of the wheel with one tooth projecting from its exterior circumference. Above this, in the body of the carriage, let a box be securely fixed with a drum revolving perpendicularly, and fastened to an axle. On the outside edge of the drum 400 teeth are to be set at equal intervals so as to meet the teeth on the lower drum. Further, at the side of the upper drum there is to be fixed a second tooth projecting beyond the other teeth.

3. Now above there is to be placed a horizontal wheel toothed in the same manner, and enclosed in a similar case, with teeth which fit upon the single tooth which projects on the side of the second drum. In this drum openings are to be made equal in number to the miles which can be covered with the carriage in a day: whether the miles are more or less makes no difficulty. In all these openings, round stones are to be placed, and in the lining of the drum there is to be one opening attached to a small channel, where the stones placed in the drum when they come to the corresponding place can fall one by one into the carriage body and a bronze vessel which is placed below. 4. Thus when the wheel moves forwards and carries with it the lowest drum, in a single revolution, the wheel causes its one tooth to strike in passing the teeth in the upper drum. The effect

¹ Very near the value of π : $\frac{22}{7} = 3.142857$. The value $\frac{22}{7} = 3.14$. . . was known to Archimedes and probably earlier.

cogat praeterire, efficiet, <ut,>¹ cum cccc² imum
 versatum fuerit, superius tympanum semel circum-
 agatur³ et denticulus, qui est ad latus eius fixus,
 ergo cccc versationibus imi tympani producat. Cum
 versabitur, progressus efficiet spatia pedum milia
 quinque, id est passus mille. Ex eo quot calculi
 deciderint, sonando singula milia exisse monebunt.
 Numerus vero calculorum ex imo⁵ collectus summa
 diurni <itineris>⁶ miliariorum numerum indicabit.
 5 Navigationibus vero similiter paucis rebus com-
 mutatis eadem ratione efficiuntur. Namque traicitur
 per latera parietum axis habens extra navem pro-
 minentia capita, in quae includuntur rotae diametro
 pedum quaternum et s⁷ extantes habentes circa
 frontes adfixas pinnas aquam tangentes. Item
 medius axis in media navi <habet>⁸ tympanum cum
 uno denticulo extanti extra suam rotunditatem.
 Ad eum locum conlocatur loculamentum habens
 inclusum in se tympanum, peraequatis dentibus
 cccc convenientibus denticulo tympani, quod est in
 axe inclusum, praeterea ad latus adfixum extantem
 6 extra rotunditatem alterum dentem unum. Insuper
 in altero loculamento cum eo confixo inclusum
 tympanum planum ad eundem modum dentatum,
 quibus dentibus <convenit>⁹ denticulus, qui est ad
 latus fixus tympano, quod est in cultro conlocatum,
 ut eos¹⁰ dentes, qui sunt plani tympani, singulis

¹ *add. Joc.*² *cccc rec: ecce H.*³ *circumagatur Joc: -gitur H.*⁴ *semel rec: simul H.*⁵ *imo e₂ ed: uno H.*⁶ *add. Ro.*⁷ *et s extantes Gr: & sextantae H.*⁸ *add. Joc.*⁹ *add. Kr.*

will be that when the lower drum has revolved 400
 times, the upper drum will revolve once; and the
 tooth fixed on the side of the upper drum moves one
 tooth of the horizontal drum. Since, therefore, in
 400 revolutions of the lower drum, the upper drum
 will revolve once, as it moves it will record thereby a
 distance of 5000 feet, that is, of 1000 paces. Hence
 when a stone falls, it will announce by its sound the
 traversing of a single mile, and the number of the
 stones collected from below will indicate, by their
 total, the number of miles for the day's journey.

5. With a few changes, a similar procedure is
 adopted for sea voyages. For an axle is passed
 through the sides of the hull, with ends projecting
 beyond the ship. On these axles are projecting wheels
 with diameters of $4\frac{1}{2}$ ¹ feet, having paddles round
 the edge which touch the water. Also the middle
 of the axle in the middle of the ship has a drum with
 one tooth projecting beyond its circumference. At
 this place a case is fixed with a drum enclosed within,
 having 400 teeth at equal intervals corresponding to
 the teeth of the drum which is fixed on the axle. In
 addition, another single tooth is fixed to the side of
 the drum and projects beyond it. 6. Above, and
 adjoining it, another case is fixed, which contains a
 horizontal wheel toothed in the same way. Answer-
 ing to these teeth, there is the tooth which is fixed on
 the side of the vertical drum. This tooth at each
 revolution drives one of the teeth which belong to the

¹ *Barbaro, ad loc., suggests that the diameter was increased to allow for the drag of the water or wind.*¹⁰ *(ita) ut eos Schn: in eos H.*

versationibus singulos dens¹ inpellendo in orbem planum² tympanum verset. In plano autem tympano foramina fiant, in quibus foraminibus conlocabuntur calculi rotundi. In theca eius tympani, sive loculamentum est, unum foramen excavetur habens canaliculum, qua calculus liberatus ab obstantia cum ceciderit in vas aereum, sonitum significet.

7 Ita navis cum habuerit impetum aut remorum aut ventorum flatu, pinnae, quae erunt in rotis, tangentes aquam adversam vehementi retrorsus impulsu coactae versabunt rotas; eae autem involvendo se agent axem, axis vero tympanum, cuius dens circumactus singulis versationibus singulos secundi tympani dentes inpellendo modicas efficit circuitiones. Ita cum cccc ab pinnis rotae fuerint versatae, semel tympanum circumactum inpellet dente, qui est ad latus fixus, plani tympani dentem. Igitur circuitio tympani plani quotienscumque ad foramen perducet calculos, emittet per canaliculum. Ita et sonitu et numero indicabit miliaria spatia navigationis.

Quae pacatis et sine metu temporibus ad utilitatem et delectationem paranda, quemadmodum debeant fieri, peregi esse futurum.³

¹ dens *Ro*: dentes *H*.

² planum *Joc*: plenum *H*.

³ peregi esse futurum *H*: esse futurum *epexeget*. *Gr*: *del. Ro* (*cf. IX., pref. 16*).

horizontal drum and turns the horizontal drum round in a circle. Now in the horizontal drum, openings are to be made in which round stones are to be placed. One of these openings is to have a small channel adjoining it. Here when a stone can move without hindrance, it falls into the bronze vessel and announces this by a sound.

7. When, therefore, the ship receives an impulse from the force of the oars or the sails, the paddles fixed to the wheels touch the water which meets them, and being urged by a strong backward impulse, turn the wheels. These in turn move the axle by their revolutions; and the axle moves the drum, the tooth of which being driven round, strikes at each revolution a single tooth of the second drum, and produces the corresponding rotations. Thus when the wheels have been made to revolve 400 times by the paddles, the drum being once driven round will strike by the tooth placed on its side, a tooth in the horizontal drum. Therefore as often as the revolution of the horizontal drum brings the stones to the opening, it will let them drop through the small channel. And in this way, by the sound and number of the stones, it will indicate the miles traversed by the ship.

I have thus contrived the execution in proper form of the machines which may be carried out for useful purposes or for amusement in times of peace and tranquillity.¹

¹ This passage could only have been written when the empire was in a settled state, and completes the programme outlined in the preface to the whole work. The sequel resumes the military studies with which Vitruvius' career began.

1 Nunc vero quae ad praesidia periculi et necessitatem salutis sunt inventa, id est scorpionum et ballistarum rationes, quibus symmetriis comparari possint, exponam.

Omnes proportionales eorum organorum ratiocinatorum ex¹ proposita sagittae longitudine, quam id organum mittere debet, eiusque nonae partis fit foraminis in capitulis magnitudo, per quae² tenduntur nervi torti, qui bracchia continere ipsūm² tamen debent. Eorum foraminum capituli deformatur altitudo et latitudo. Tabulae, quae sunt in summo et in imo capituli, peritreta³ quae vocantur, fiant crassitudine unius foraminis, latitudine⁴ unius et eius dodrantis, in extremis foraminis unius et eius <s>. Parastaticae⁵ dextra ac sinistra praeter cardines altae foraminum IIII, crassae foraminum quinum; cardinis foraminis dimidi. A parastatica ad foramen spatium foraminis $s\bar{o}$, a foramine ad medianam parastaticam item foraminis $s\bar{o}$. Latitudo parastados mediae⁶ unius foraminis et eius $\bar{\tau}\kappa$, crassitudo foraminis unius.

3 Intervallum, ubi sagitta conlocatur in media parastade, foraminis partis quartae. Anguli quat-

¹ ex *Joc*: & *H*.

² quae *ed*: quas *H*.

³ peritreta *Voss ex Herone*: operae reliq; *H*.

⁴ latitudine *G*: *om. H*.

⁵ foraminibus unius et eius parastatice *H*.

⁶ medius *H*.

¹ *scorpio* is used here generally for a catapult; its specific meaning is that of a smaller machine worked by a single individual, Book X. i. 3. *Caes. B.G. VII. 25. 2.*

1. WE now turn to the inventions which serve both to protect against danger and to satisfy the needs of safety; I will set forth the construction of scorpions¹ and balistae with the proportions on which they are based.

All the dimensions² of the machines as designed are given from the proposed length of the arrow which the machine is to let fly. The ninth part of this gives the size of the opening in the frame. Through these openings twisted cords are stretched,³ which are to hold back the arms of the catapults themselves. 2. The height and breadth of the frame are fixed by the size of the holes. The cross-pieces at the top and bottom of the frame are called *peritreta*⁴ and are to be one hole thick, and one and three-quarters wide; at the ends, one and a half. The side-pieces right and left (without the tenons)⁴ holes high and five-eighths thick; the tenons half a hole. The side-piece to the hole, half a hole; from the hole to the middle upright, also half a hole. The breadth of the middle upright one hole and a third, its thickness one hole.

3. The aperture where the arrow is placed in the middle upright is to be $\frac{1}{4}$ of a hole. The four corners

² A unit of measurement is taken for military engines in the same way as for the orders of architecture. *Hero, Math. Gr. 142.* Vitruvius specifies the timber required by reference to this unit. Plate S.

³ The cords are wound as tightly as possible round the nuts above and below the cross-pieces. The arm passes between the cords and still further stretches them.

⁴ *peritreta.* *Hero, Math. Gr. 132 (Voss).*

tuor, qui sunt circa, in lateribus et frontibus lamnis ferreis aut stylis aereis et clavis configantur. Canaliculi, qui graece *syrinx*¹ dicitur, longitudo foraminum XVIII. Regularum, quas nonnulli bucculas appellant, quae dextra ac sinistra canalem figuntur, <longitudo>² foraminum XVIII, altitudo foraminis unius et crassitudo. Et adfiguntur regulae duae, in quas inditur sucula, habentes³ longitudinem foraminum trium, latitudinem dimidium foraminis. Crassitudo bucculae, quae adfigitur (vocitatur camillum seu, quemadmodum nonnulli, loculamentum) securiclatis cardinibus fixa, foraminis I, altitudo foraminis s—. Suculae longitudo foraminum ::, crassitudo suculae foraminis VIII.⁴

4 Epitoxidos longitudo foraminis s—,⁵ crassitudo:—. Item chelonii. Chelae, sive manucla dicitur,⁶ longitudo foraminum trium, latitudo et crassitudo s÷. Canalis fundi longitudo foraminis XVI, crassitudo foraminis ○, altitudo s÷.⁷ Columellae basis⁸ in solo foraminum VIII, latitudo in plinthide, in qua statuitur columella, foraminis s—, crassitudo FZ, columellae longitudo ad cardinem foraminum XII, latitudo foraminis s÷, crassitudo CCQ. Eius capreoli tres, quorum longitudo foraminum VIII, latitudo dimidium foraminis, crassitudo z. Cardinis longitudinis foraminis; columellae capitis longitudo ISK; antefixa latitudo foraminis ΔSQ, crassitudo I.

5 Posterior minor columna, quae graece dicitur

¹ *syrinx ex Herone, Turnebus: graece strix H.*

² *add. Mar.* ³ *habentes Phil: habens H.*

⁴ *crassitudo scutulae foraminum .VIII. H.*

⁵ *foraminum .s— H.*

⁶ *crassitudo:— item chelo. item geloni sive manucla d. H.*

⁷ *latitudo .s÷ H.* ⁸ *columella & basis H.*

which are on the sides and fronts are to be fixed with iron bands, or with bronze pins and nails. The length of the channel (which in Greek is called *syrinx*) is to be of 19 holes; of the strips (which some call cheeks) which are fixed right and left of the channel, the length is to be of 19 holes; their height and thickness, one hole. Two other strips into which the windlass¹ is put are fixed, having a length of three holes and a width of half a hole. The thickness of the frame which is attached (it is called a chamber or case) with dovetailed tenons is of one hole; the height, $\frac{7}{12}$ of a hole. The length of the windlass is 4 holes; the width, $\frac{3}{4}$.²

4. The hook (*epitoxis*) is $\frac{7}{12}$ of a hole long and $\frac{1}{4}$ thick. So also the socket-case. The trigger or handle, 3 holes long, $\frac{3}{4}$ wide and thick. The length³ of the bottom of the channel, 16 holes; its width one,⁴ and thickness $\frac{3}{4}$. The base of the column on the ground, 8 holes. The width of the column where it is fitted into the plinth, $\frac{3}{4}$; the thickness, $\frac{2}{3}$. The length of the column up to the tenon, 12 holes; $\frac{3}{4}$ of a hole wide; $\frac{5}{8}$ thick. The tenons are one hole long.⁵ The column has three stays 9 holes long; $\frac{1}{2}$ a hole wide; $\frac{2}{3}$ thick. The head of the column is $1\frac{1}{2}$ holes long. The width of the antefix is $1\frac{1}{2}$ holes, the thickness is one.

5. The smaller column at the back, which the

¹ The windlass is at the end of the pipe, and draws back the cord at the back of the arrow.

² *I.e. $\frac{3}{4}$.*

³ Vitruvius has given the scantling of the timber above as 19 holes. The channel itself is 3 holes less.

⁴ The symbol ○ seems to denote the foramen.

⁵ I have moved this sentence up, although its reference to both column and stays is clear.

VITRUVIUS

antibasis,¹ foraminum VIII, latitudo foraminis SI, crassitudinis FZ. Subiecto foraminum XII, latitudinis et crassitudinis eiusdem, cuius minor columna illa. Supra minorem columnam chelonium, sive pulvinus dicitur, foraminum IIS, altitudinis IIS, latitudinis SI[—]. Cherolabae² sucularum foraminum II S[—], crassitudo foraminis SFI, latitudo IS. Transversariis cum cardinibus longitudo foraminum ○, latitudo IS et crassitudo. Bracchi longitudo [IS]³ foraminum VII, crassitudo ab radice foraminis FZ, in summo foraminis CCZ; curvaturae foraminis VIII. Haec his proportionibus aut adiectionibus aut detraktionibus comparantur. Nam si capitula⁴ altiora, quam erit latitudo, facta fuerint,⁵ quae anatona dicuntur, de brachiis demetur, ut, quo mollior est tonus propter altitudinem capituli, brachii brevitatis faciat plagam vehementiorem. <Si>⁶ minus altum capitulum fuerit, quod catatonum⁷ dicitur, propter vehementiam brachia paulo longiora constituentur, uti facile ducantur. Namque quemadmodum vectis, cum est longitudine pedum quinque, quod onus IIII⁸ hominibus extollit, id, qui⁹ est x, duobus elevat,¹⁰ eodem modo brachia, quo longiora sunt, mollius, quod breviora, durius ducuntur.

¹ ante basis H.

² cherolabae Köchly: carchebi H.

³ del. Mar. ⁴ capitula e₂: -li H.

⁵ fuerint e₂ ed: fuerit H.

⁶ add. ed.

⁷ catatonum ed: catonum H.

⁸ quinque . . . IIII Köchly: IIII . . . quinque H.

Greeks call *antibasis*,¹ is of 8 holes; the width, $1\frac{1}{2}$ holes; the thickness, $\frac{2}{3}$. The prop has a length of 12 holes; and the breadth and thickness of the smaller column. Above the smaller column is a socket-piece or cushion as it is called, $2\frac{1}{2}$ holes long, the same thickness and $\frac{3}{4}$ of a hole broad. The handles of the windlass are $2\frac{7}{12}$ holes long; the thickness, $\frac{2}{3}$; the breadth, $1\frac{1}{2}$. The length of the cross-pieces and tenons is . . . holes; the width and thickness, $1\frac{1}{2}$. The length of the arm² is 7 holes; its thickness at the bottom, $\frac{2}{3}$; and at the top, $\frac{1}{2}$ a hole: its curve amounts to $\frac{2}{3}$ of a hole. 6. These proportions are attained in the work by additions or subtractions. For if the frames are too high for the breadth and these are called *anatona* [or 'tightened up'], something must be taken from the arms; so that the tension being relaxed, because of the height of the frame, the shortness of the arm may make the stroke more powerful. Let the frame be not so high and this is called *catatonum*,³ the arms will be made somewhat longer more effective so as to be easily pulled down. For just as when a lever five feet long raises a load with four labourers, that same load is raised by two labourers when the lever is 10 feet long; so the longer arms are pulled down more easily, the shorter arms with more difficulty.

¹ Hero gives ἀντιστάτης.

² The arms pass through the cords and are united by a string in which the notch for the arrow was placed.

³ = less tight.

⁹ id, qui Kr: idque H.

¹⁰ x, duobus elevat Köchly: ex duobus elevatum H.

1 CATAPULTARUM rationes, e quibus membris ex portionibus componantur, dixi. Ballistarum autem rationes variae sunt et differentes unius effectus causa comparatae. Aliae enim vectibus suculis, nonnullae polyspastis, aliae ergastis, quaedam etiam tympanorum torquentur rationibus. Sed tamen nulla ballista perficitur nisi ad propositam magnitudinem ponderis saxi, quod id organum mittere debet. Igitur de ratione earum non est omnibus expeditum, nisi qui geometricis rationibus numeros et multiplicationes habent notas.

2 Nam quae¹ fiunt in capitibus foramina, per quorum spatia contenduntur capillo maxime muliebri vel nervo funes, magnitudine ponderis lapidis, quem debet ea ballista mittere, ex ratione gravitatis proportione sumuntur, quemadmodum catapultis de longitudinibus sagittarum. Itaque ut etiam qui geometricè² non noverunt, habeant³ expeditum, ne in periculo bellico cogitationibus detineantur, quae ipse faciundo certa cognovi quaeque ex parte accepta praeceptoribus, finita exponam, et quibus rebus Graecorum pensiones ad modulos habeant rationem,

¹ namq̄ H.

² geometricè e₂ (cf. nosse Graece Aug): -cø Π.

³ habeant ed: habent H.

¹ mittere first means 'to let go.' The vernacular phrase mitte, 'chuck it,' is illuminating. Hence the solemn name of the mass, missa: 'the assemblage is dismissed, ite; missa est.'

² Euclid treats numbers geometrically, Books VII-X. It has been said of Newton that he could treat geometrically

1. I HAVE described the design of a catapult and the details which are combined in accordance with proportion. The design of the balista varies and its differences are adjusted for the purpose of a single effect. For some are worked by levers and windlasses, some by many pulleys, some by capstans, some by wheels. Yet all balistae are constructed with a view to the proposed amount of the weight of the stone which such a machine is to let fly.¹ Therefore only those craftsmen can deal with the design who are familiar with the geometrical² treatment of numbers and their multiples.

2. For the holes which are made in the frames (through the openings of which ropes are stretched, made especially of woman's hair or of the sinews of animals) are taken proportionately to the amount of the weight of the stone which the balista is to shoot, in accordance with gravity,³ just as in the case of catapults the *length of the arrows* furnishes the module. Therefore in order that persons who are ignorant of geometry may be equipped and may not be delayed by calculation amid the perils of war, I will specify in accordance with my own knowledge gained in practice and also in accordance with the instructions of my teachers. Further, I will set forth in detail the manner in which the Greek

problems which other mathematicians could only solve by analysis of a numerical character.

³ Specific gravity was discovered by Archimedes, Book IX., pref. 9 ff. The phrase 'centre of gravity,' κέντρον βάρους, was known before his time. Gow, *Greek Maths.* 238.

ad eam ut etiam nostris ponderibus respondeant, tradam explicata.

3 Nam quae ballista duo pondo saxum mittere debet, foramen erit in eius capitulo digitorum v; si pondo IIII, digitorum sex, VI,¹ digitorum VII; decem pondo digitorum VIII; viginti pondo digitorum x; XL pondo digitorum XII SK; LX pondo digitorum XIII et digiti octava parte; LXXX pondo digitorum XV; CXX pondo I pedis et sesquidigiti;² C et LX pedis 19;³ C et LXXX pes et digiti v;⁴ CC pondo pedis⁵ et digitorum VI; CC et X pedis⁵ et digitorum VI; CCCLX, pedis I s.

4 Cum ergo foraminis magnitudo fuerit instituta, describatur scutula, quae graece *peritretos* appellatur, cuius longitudo foraminum VIII,⁶ latitudo duo et sextae partis. Dividatur medium lineae discriptae⁷ et, cum divisum erit, contrahantur⁸ extremas partes eius formae, ut obliquam deformationem habeat longitudinis sexta parte, latitudinis, ubi est versura, quartam partem. In qua parte autem est curvatura, in quibus procurrunt cacumina angulorum, et foramina convertuntur, et contractura latitudinis redeat⁹ introrsus sexta parte, foramen autem oblongius sit tanto, quantam epizygis¹⁰ habet crassitudinem. Cum deformatum fuerit, circum dividatur, extremam ut habeat curvaturam molliter circumactam.

5 Crassitudo eius foraminis $\bar{\text{SI}}$ constituatur. Modioli

¹ VI Gr: et H. ² pondo IS et sesq. H.

³ pedis 19 Kr: C et LX pedes II. H.

⁴ (C et LXXX) pes & et digiti GJ H.

⁵ pedes H. ⁶ VIII Gr: vel H.

⁷ discripta H S. ⁸ contrahatur H.

⁹ redeant H.

¹⁰ epizygis Joc: opytigis H S.

weights are related to the modules, so that their relation may correspond to our weights.¹

3. For when a balista is to shoot a stone weighing two pounds, the aperture in the frame will be 5 digits; with four pounds, 6 digits; with <six> pounds, 7 digits; with ten pounds, 8 digits; with twenty pounds, 10 digits; with 40 pounds, $12\frac{1}{2}$ ² digits; with 60 pounds, $13\frac{1}{8}$ digits; with 80 pounds, 15 digits; with 120 pounds, one foot and $1\frac{1}{2}$ digits; with 160 pounds, one foot and 4 digits; with 180 pounds, one foot 5 digits; with 200 pounds, one foot 6 digits; with 210 pounds, one foot 6 digits; with 360 pounds, $1\frac{1}{2}$ feet.

4. When, therefore, the size of the hole is determined (as the module), let the cross-piece, *scutula*,³ which in Greek is called *peritretos*, be drawn; its length 8 holes; the breadth is to be $2\frac{1}{8}$ holes. The cross-piece when drawn is to be divided along the middle of the line, and when the middle is divided, the ends of the figure are to be contracted, so that it is bent obliquely to the extent of $\frac{1}{8}$ the length, and $\frac{1}{4}$ the breadth where the rope turns. The holes are to be made on the side of the curved part where the points of the angles converge; and the angles formed by contraction of the breadth are to turn $\frac{1}{8}$ inwards: the hole is to be longer than it is broad by the thickness of the bolt. When the frame is complete, it is to be dressed round so that it has the end of the curvature trimmed off.

5. The thickness of the frame is to be $\frac{9}{18}$ of a hole.

¹ The text is difficult to interpret owing to the notations employed. Plate S attempts to show the general design.

² SK = *semisque*.

³ *scutula* in the balista corresponds to *tabula* in catapult, c. x. 2.

foraminum duo, latitudo $\text{IS}\rho$, crassitudo praeterquam quod in foramine inditur foraminis $\text{s}\ \Gamma$, ad extremum autem latitudo foraminis $\text{II}-$. Parastatarum¹ longitudo foraminis vsf ; curvatura foraminis pars dimidia; crassitudo foraminis cc et partis Lx . Adicitur autem ad mediam latitudinem, quantum est prope foramen factum in descriptione, latitudine et crassitudine foraminis v , altitudo parte III .

6 Regulae, quae est in mensa, longitudo foraminum VIII ; latitudo et crassitudo dimidium foraminis. Cardines IIz , crassitudo foraminis $\text{I}\rho\eta$. Curvatura regulae $\Gamma\text{C}\kappa$. Exterioris regulae latitudo et crassitudo tantundem; longitudo, quam dederit ipsa versura deformationis et parastaticae latitudo ad suam² curvaturam κ . Superiores autem regulae aequales erunt inferioribus κ . Mensae transversarii foraminis $\text{ccc}\ \kappa$.

7 Climacidos scapi longitudo foraminum XIII , crassitudo IK , intervallum medium latitudo foraminis et³ parte quarta, crassitudo pars $\text{VIII}\ \kappa$. Climacidos superioris pars quae est proxima brachiis, quae coniuncta est mensae, tota longitudine dividatur in partes v . Ex his dentur duae partes ei membro, quod Graeci *chelen*⁴ vocant \bigcirc latitudo Γ , crassitudo η , longitudo foraminum III et semis κ ; extantia cheles foraminis s ; pterygomatos⁵ foraminis $\bar{\text{z}}$ et sicilicus.

¹ parastatorum *H.*

² & suam *H.*

³ et *Köchly*: ex *H.*

⁴ $\chi\eta\lambda\acute{\eta}\nu$ *Turn*: chelon *H.*

⁵ pterygomatos *Turn*: plentigomatos *H.*

¹ The boxes were fitted into the cross-pieces above and below, and contained the iron pins round which the cords

Of the box¹ the length is 2 holes; the breadth $1\frac{3}{4}$; the thickness, in addition to the part which is inserted in the hole, $\frac{9}{18}$; while at the end the breadth is $2\frac{1}{18}$. The length of the side-posts is $5\frac{9}{18}$; the curvature, $\frac{1}{2}$ a hole; the thickness is. . . .² Now there is added to the middle of their breadth, *i.e.* its size near the hole in the drawing: in breadth and thickness $\frac{1}{5}$, the height $\frac{1}{4}$.

6. The length of the cheek (on either side of the table) is 8 holes; the breadth and thickness $\frac{1}{2}$ a hole. The tenons are to be $\frac{2}{3}$ long and $\frac{1}{4}$ in thickness. The curvature of the cheek is $\frac{3}{4}$. The breadth and thickness of the outside cheek is as much. The length is given by the angle of the design, and the breadth of the side-piece which is in curvature. Now the upper cheeks shall be equal to the lower cheeks: the cross-pieces of the table (in thickness) $\frac{3}{4}$.

7. The length of the shaft of the ladder is 13 holes, its thickness one hole. The breadth of the middle spaces is a hole and a quarter: the depth $1\frac{1}{8}$. The part of the upper ladder which is nearest to the arms and conjoined to the table is to have its total length divided into five parts.³ Two parts are to be given to that detail which the Greeks call *chēlē*; its breadth $1\frac{1}{18}$; its thickness $\frac{1}{4}$; its length $3\frac{1}{2}$ holes.⁴ The projection of the claw is $\frac{1}{2}$ a hole, of the wings $\frac{3}{18}$. The

were wound. They were of bronze: *infra* xii. 1. The dimensions of the boxes are measured by a 'hole' taken from the width of the cord.

² The thickness of the side-posts of the catapult is $\frac{5}{18}$, *supra* x. 2. These proportions are of the height of the side-posts, and are probably guides to the curvature.

³ Of the remaining eight parts, three are above, and three below, the claw, which is two parts.

⁴ The reference of this is doubtful.

Quod autem est ad axona, quod appellatur frons transversarius, foraminum trium.

8 Interiorum regularum latitudo foraminis \bar{r} , crassitudo $\Xi\kappa$. Cheloni replum, quod est operimentum, $\approx\zeta$, crassitudo foraminis ² $\chi\eta\kappa$. Crassitudo quadrati, quod est ad climacida, foraminis $F\kappa$, in extremis κ , rutundi autem axis diametros aequaliter erit cheles, ad claviculas autem minus parte sexta decuma 9κ . Anteridon longitudo foraminum IIIS ,³ latitudo in imo foraminis \bar{r} , in summo crassitudo $\Gamma\kappa$. Basis, quae appellatur *eschara*,⁴ longitudo foraminum $::::$, anti-basis⁵ foraminum III , utriusque crassitudo et latitudo foraminis $:::$. Conpingitur autem dimidia altitudinis κ columna, latitudo et crassitudo IS . Altitudo autem non habet foraminis proportionem,⁶ sed erit quod opus erit ad usum. Bracchii longitudo foraminum VI , crassitudo in radice foraminis, in extremis F .

De ballistis⁷ et catapultis symmetrias, quas maxime expeditas putavi, exposui. Quemadmodum autem contentionibus eae temperentur e nervo capilloque tortis rudentibus,⁸ quantum comprehendere scriptis potuero, non praetermittam.

¹ scapo *Gr*: scapos *H*.

² foraminum *H*.

³ IIIS *Gr*: eius *H*.

⁴ schara *H*.

⁵ ante basis *H*.

part <from the claw> to the *axon* which <in Latin> is called the front cross-piece, is of 3 holes.

8. The breadth of the interior cheeks is $\frac{1}{4}$, the thickness $\frac{1}{8}$. The *replum*¹ or covering moulding of the claw is dovetailed into the shaft of the ladder with a breadth of $\frac{1}{8}$, and a thickness of $\frac{1}{12}$. The thickness of the square piece² on the ladder is $\frac{2}{3}$, at the ends one hole. The diameter of the round axle is equal to that of the claw, but at its pivots $\frac{1}{8}$ less. 9. The length of the supports is $4\frac{1}{2}$ holes, the breadth at the bottom $\frac{2}{3}$, at the top the thickness is $\frac{7}{12}$. The base, which is called *eschara*,³ is 4 holes long, the anti-basis⁴ 4 holes long; the breadth and thickness of both, half a hole. A stay is jointed on half-way up the column, with a breadth and thickness of $1\frac{1}{2}$ holes. The height has no proportion of modules but will be in accordance with requirements. The length of the arms is 6 holes, the thickness at the root one hole, at the ends $\frac{2}{3}$.

I have set forth the proportions which I thought most convenient for catapults and balistae. I will now describe the way in which they are controlled by tension, with ropes twisted of sinews and human hair, as far as I can comprise it in writing.

¹ Book IV. vi. 5. This guides the claw in its movement along the ladder.

² This contains the claw and has the replum attached to it.

³ Cf. *infra* xiv. 1.

⁴ A similar horizontal piece at right angles to the base.

⁶ proportione *H*.

⁷ De ballistas *H*.

⁸ rudentibus *rec*: rutudentibus *H*.

- 1 SUMUNTUR tigna amplissima longitudine; supra figuntur chelonia,¹ in quibus cluduntur suculae. Per media autem spatia tignorum insecantur² exciduntur formae, in quibus excisionibus cluduntur capitula catapultarum, cuneisque distinentur,³ ne in contentionibus moveantur. Tum vero modioli aerei in ea capitula includuntur et in eos cuneoli ferrei, quas *epizygidas*⁴ Graeci vocant, conlocantur.
- 2 Deinde ansae rudentum induntur per foramina capitulorum, in alteram partem⁵ traiciuntur, deinde in suculas⁶ coiciuntur² involvuntur, uti vectibus per eas ext^(enti)⁷ rudentes,⁸ cum manibus sunt tacti, aequalem in utroque sonitus habeant⁹ in responsum. Tunc autem cuneis ad foramina concluduntur, ut non possint se remittere. Ita traiectione in alteram partem eadem ratione vectibus per suculas extenduntur, donec aequaliter sonent. Ita cuneorum conclusionibus ad sonitum musicis auditionibus catapultae¹⁰ temperantur.

De his rebus quae potui dixi. Restat mihi de oppugnatoriis rebus, quemadmodum machinationibus et duces victores et civitates defensae esse possint.

¹ cheloniae H.

² *aryndeton* ut in sermone iudiciali.

³ distinentur H.

⁴ *επιζυγίδας* Turn: *epysycidas* H.

⁵ *pari&e* H.

⁶ suculas *Joc*: -lam H.

⁷ *extenti rudentes* *Joc*.

⁸ *extrudentes* H.

ON THE PREPARATION OF CATAPULTS AND BALISTAE

1. (Two square) beams of considerable length are taken; sockets are fixed on them in which windlasses are enclosed. Now in the middle parts of the beams, rebates are cut and hollowed out. In these hollows, the frames of the catapults are fitted, and kept apart by wedges to prevent their moving when the ropes are stretched. Next, bronze boxes¹ are fitted into the frames, and iron pins are placed in them, which the Greeks call *epizygides*.

2. From these pins the ends of the ropes are passed through the holes of the frame and cross over to the other end. Thence they are taken and coiled round the windlass, so that when the ropes are stretched by the levers, and struck by hand, they may resound evenly on either side. Then they are secured by wedges at the holes so that they cannot become loose. Passing to the other end, they are stretched on the windlasses by the levers until they give an equal note.² So by the application of wedges, the catapults are tuned to the right note by a musical ear.

On these matters I have said what I could. It remains to me, as I deal with sieges,³ to explain the machinery by the help of which generals may gain victories, and cities be defended.

¹ This description completes the account of the boxes in the last chapter.

² Book I. i. 8.

³ *Oppugnatoria* is the Latin for *πολιορκητικά*.

⁹ *habeant* *Joc*: *habent* H.

¹⁰ *catapultae* H.

- 1 PRIMUM ad oppugnationis aries sic inventus memoratur esse. Carthaginienses¹ ad Gadis oppugnandas castra posuerunt. Cum autem castellum ante cepissent,² id demoliri³ sunt conati. Postea sumpserunt tignum idque manibus sustinentes capite summos lapidum ordines deiciebant, et ita gradatim ex ordine totam communionem dissipaverunt.
- 2 Postea quidam faber Tyrius nomine Pephrasmenos hac⁴ ratione et inventione inductus malo statuto ex eo alterum transversum uti trutinam suspendit et in reducendo et inpellendo vementibus⁵ plagis deiecit Gaditanorum murum. Ceras⁶ autem Carchedonius⁷ de materia primum basim subiectis rotis fecit supraque compegit arrectariis et iugis varas et in his suspendit arietem coriisque bubulis textit, uti tutiores essent, qui in ea machinatione ad pulsandum murum essent conlocati. Id autem, quod tardos conatus habuerat,
- 3 testudinem arietariam appellare coepit. His tunc

¹ chartaginienses H. ² coepissent H.

³ demolliri H. ⁴ hac G: ac H S.

⁵ vementibus Lachm: venientibus H.

⁶ ceras Gr: caeteras H.

⁷ carchedonius Gr: chalchedonius H (Καρχηδόνιος Ath), cf. Carchedonius, Plaut. Poen. prol. 53.

¹ Vitruvius, as usual, begins with an historical sketch. He drew upon sources older than Athenaeus Mechanicus who was either later than or a contemporary of Vitruvius. The Marcellus to whom Ath. dedicates his work may well have been the nephew of Augustus. Hero and Philo Byzantius probably belong to the end of the first century A.D. The works of these three writers are given in *Mathematici Veteres*, Paris, 1693.

1. In the first place, the invention¹ of the battering-ram for sieges is related in the following manner. The Carthaginians had pitched their camp for the siege of Cadiz. Having already captured a fort, they set about demolishing it. Since they lacked iron tools for this purpose, they took a beam, and raising it by manual labour, they swung the end repeatedly against the top of the wall and brought down the top courses of the masonry. Thus they broke up the whole fortification little by little and in order.

2. Subsequently a Tyrian engineer² named Pephrasmenos, following the method of this invention, set up a pole and from it suspended a cross-beam, like the beam of a balance. This he drew backward and thrust forward, and by its violent blows overthrew the walls of Cadiz. Ceras³ the Carthaginian first made a wooden platform⁴ with wheels underneath, upon which he constructed penthouses with uprights and cross-pieces. In these he suspended a ram which he protected with oxhides, for the greater safety of the mechanics who were posted there to attack the wall. The contrivance, because it moved slowly, he was the first to call the "ram tortoise." 3. After these first steps had been

² Athen. *Math. Vett.* 3 gives the name as *Pephasmenos*.

³ Ceras occurs among the names of the families of the Nethinim who returned with Nehemiah: *LXX. I Esdras*, v. 29.

⁴ Athen. *Math. Vett.* 3.

primis gradibus positis ad id genus machinationis,¹ postea cum Philippus, Amyntae filius, Byzantios² oppugnaret, Polyidos³ Thettalos⁴ pluribus generibus et facilioribus explicavit, a quo receperunt doctrinam Diades et Charias,⁵ qui cum Alexandro militaverunt.

Itaque Diades scriptis suis ostendit se invenisse turres ambulatorias, quas etiam dissolutas in exercitu circumferre solebat, praeterea terebram et ascendentem machinam, qua ad murum plano pede transitus esse posset, etiam corvum demolitorem, quem nonnulli gruem appellant. Non minus utebatur ariete subrotato, cuius rationes scriptas reliquit. Turrem autem minimam ait oportere fieri ne minus altam cubitorum LX,⁶ latitudinem XVII, contracturam autem summam imae partis quintam, arrectaria in turris in imo dodrantalia, in summo semipedalia. Fieri autem ait oportere eam turrem tabulatorum⁷ decem, singulis partibus in ea fenestratis.⁸ Maiorem vero turrem altam cubitorum CXX, latam cubitorum XXIII(s),⁹ contracturam¹⁰ item quinta parte, arrectaria pedalia in imo, in summo sedigitalia.¹¹ Hanc magnitudinem turris faciebat tabulatorum XX, cum haberent singula tabulata circumitionem cubitorum ternum. Tegebat autem coriis crudis, ut ab omni plaga essent tutae.

¹ machinationes H S.

² Byzantios Ro (Byζαντίους Ath): byzantio H, bizantio S G.

³ pholydos H, pholidos S G.

⁴ thethalos H S, thetalos G.

⁵ carias H.

⁶ LX Joc (ξ Ath): novem H = IX.

⁷ tabulatorum ed. Fl: tabularum H.

⁸ Athen. περίπτερος.

⁹ add. ex Ath.

¹⁰ contracturam ed: contra fracturam H.

taken towards this kind of machine, when Philip the son of Amyntas was besieging Byzantium, Polyidos a Thessalian made a variety of designs with easier construction; his method was continued by his pupils, Diades and Charias, who accompanied Alexander on his campaigns.¹

Diades, then, in his books² shows that he invented Movable Towers, the parts of which he used to assemble and carry round with the army; in addition to this, the Borer and the Climbing Machine by which a passage from the level up the wall was possible; further, the Grappling-hook for demolition which some call the Crane. 4. Moreover, he used to employ a ram on wheels for which he left detailed descriptions. He says that the smallest tower should be 60 cubits high and 17 broad, and that it should be contracted at the top, by $\frac{1}{8}$ of the width at the foot. The uprights for the towers should be 9 inches at the bottom and 6 inches at the top. He says further that the tower should be ten stories high, with openings like windows on each side. 5. The largest tower is to be 120 cubits high, $23\frac{1}{2}$ wide, the contraction at the top $\frac{1}{8}$; the uprights one foot at the bottom, six inches at the top. He used to construct this size of tower with 20 stories, and the several stories had a balcony three cubits wide. These he further covered with raw hides to preserve them from attack.

¹ Athen. loc. cit.

² Athen. op. cit. pp. 4, 5, gives a summary closely corresponding to the rest of this chapter. Sackur op. cit. 64. Athenaeus interpolates phrases that are superfluous and sometimes display misunderstanding.

¹¹ sedigitalia Ro (Ath): semipedalia H.

6 Testudinis arietariae comparatio eadem ratione perficiebatur. Habuerat autem intervallum ratione altitudinem praeter fastigium xvi, fastigii xxxii,¹ altitudo ab strato² ad summum cubita xvi.³ Exhibat autem in altum et supra medium tectum fastigium non minus cubita duo, et supra extollebatur turricula cubitorum quattuor, tabulatorum turritabulato summo statuebantur scorpionis⁴ et catapultae, inferioribus congerebatur aquae magna⁵ multitudo ad extinguendum, si qua⁶ vis ignis immitteretur. Constituebatur autem in eam arietaria⁷ machina, quae graece dicitur *criodocis*,⁸ in qua conlocabatur torus perfectus in torno, in quo insuper constitutus aries rudentium⁹ ductionibus et reductionibus efficiebat magnos operis effectus. Tegebatur autem is coriis crudis quemadmodum turris.

7 De terebra has explicuit scriptis rationes. Ipsam machinam uti testudinem in medio habentem conlocatum in orthostatis canalem, quemadmodum in catapultis aut ballistis fieri solet, longitudine cubitorum l, altitudine cubiti, in quo constituebatur transversa sucula. In capite autem dextra ac sinistra trocleae¹⁰ duae, per quas movebatur quod inerat in eo canali capite ferrato tignum. Sub eo autem in ipso canali inclusi tori¹¹ crebriter celeriores et vehementiores efficiebant eius motus. Supra

¹ xxxii *Sackur*: xxx *H.*

² ab strato *ed*: abstracto *H.*

³ xvi (*15 Ath*): vii *H.*

⁴ iii. quo *Gr*: in quo *H.*

⁶ si qua *rec*: siq; *H.*

⁸ criodocis *H.*

⁹ rudentium *Joc*: prudentium *H.*

¹⁰ trocliae *H.*

¹¹ inclusi tori *Laet*: inclusit uti *H.*

6. The construction of the Ram Tortoise was carried through with the same method. It had a breadth of 32 cubits, a height (not including the gable) of 16 cubits, and the height of the gable from the platform to the summit, of 16 cubits. Now the gable rose up above the middle of the roof not less than 2 cubits. Above this there was raised a small tower 4 cubits wide, of 3 stories;¹ in the top story of this there were placed scorpions and catapults,² in the lower stories a large quantity of water was stored to extinguish whatever flames should be kindled. Now there was constructed in the tortoise a machine for the ram, which in Greek is called *criodocis*. In this was fixed a roller finished on the lathe, on which the ram was placed, and being drawn forwards and backwards by ropes, produced great effects. This was covered with raw hides in the same way as the tower.

7. The method of constructing the Borer he described as follows: the machine itself was like the Tortoise, having, in the middle, a channel resting upon uprights (as is customary in catapults or balistas) 50 cubits long and a cubit high, on which there was placed a windlass crosswise. At the front were two pulleys, right and left, by which the beam with its iron front³ was moved along the channel. Under the beam in the channel itself rollers were fixed at frequent intervals and rendered its movements quicker and more violent. Above the beam

¹ Vitruvius' text is quite clear if we take *in* as iii, from which it is almost indistinguishable.

² These were small machines for sharpshooting.

³ The Borer had a sharp iron point to pierce the wall, not to batter it down like the Ram. Athenaeus confuses the construction of the two, *op. cit.* 5.

autem ad tignum, quod inibi erat, arcus tegebantur ad canalem crebriter, uti sustinerent corium crudum, quod ea machina erat involuta. De corace nihil putavit scribendum, quod animadverteret nihil machinam nullam habere virtutem. De accessu, quae *epibathra* graece dicitur, et de marinis machinationibus, quae per navium aditus habere posset, scripsit tantum; pollicitum esse vehementer animadverti neque rationes eorum eum explicavisse.

Quae sunt a Diade¹ de machinis scripta, quibus sint conparationibus, exposui. Nunc quemadmodum a praeceptoribus accepi et² utilia mihi videntur, exponam.

XIV

1 TESTUDO, quae ad congestionem fossarum paratur (eaque etiam accessus ad murum potest habere), sic erit facienda. Basis compingatur, quae graece *eschara*³ dicitur, quadrata habens quoque versus latera singula pedum XXI⁴ et transversaria III. Haec autem contineantur⁵ ab alteris duobus crassis 18, latis 5; distent autem transversaria inter se circiter pedes III s.⁶ Supponanturque in singulis intervallis eorum arbusculae, quae graece *anaxopodes*⁷ dicuntur,

¹ a Diade *Joc*: ademade *H*.

² accepi et *S^o G^o*: accipiet *H*. ³ ἐσχάρα *Joc*: thera *H*.

⁴ XXI *Kr* (πῆχειων ἰδ̄ *Ath*): xxv *H*.

⁵ contineantur *Joc*: -atur *H*.

⁶ pedes III s *Kr* (δύο πῆχεις καὶ παλαιστὴν ἓνα *Ath*): pede & s *H*.

⁷anaxopodes *H*.

¹ Arrian reports the use of the *epibathra* by Alexander, *Anab.* IV. 27. 1.

thus placed arches were placed frequently along the channel to hold up the raw hide with which the machine was enveloped. 8. Diades did not think it necessary to write about the Grappling-hook because he perceived that the machine had no value. Concerning the Climbing Machine, which in Greek is called *epibathra*,¹ and concerning the use, in naval engineering, of such a machine for boarding a ship, he just made mention. I noted especially that after making a promise he failed to explain their proportions.

I have set forth² the writings of Diades on the construction of machines. I will now set forth what I myself was taught, so far as it is of use.

CHAPTER XIV

ON THE TORTOISE FOR FILLING DITCHES

1. THE Tortoise which is applied to filling ditches³ (and it thus furnishes an approach to the wall of the besieged) is to be constructed as follows. Let the base, which in Greek is called *eschara*, be made square, having on each side a length of 21 feet, with four cross-pieces. Now these are to be held together by two others 18 inches thick, and 6 inches broad. Let the cross-pieces be at intervals of 3½ feet. Timbers are to be fixed underneath in their several intervals (these are called *anaxopodes*⁴ in Greek),

³ Sackur sees Byzantine influences in the extant text of this chapter, p. 121. But there is little trace of this influence in the MS. tradition, Vol. I. *pref.* xv. n.

⁴ χελώνη χωστρίς, Diod. II. 27, *testudo* . . . sequendi loci causa, Caes. B.C. II. 2.

⁵ Athen. *op. cit.* δ.

VITRUVIUS

in quibus versantur rotarum axes conclusi lamnis ferreis. Eaeque arbusculae ita sint temperatae, ut habeant cardines et foramina, quo vectes traiectiones earum expediant, uti ante et post et ad dextrum seu sinistrum latus, sive oblique ad angulos opus fuerit, ad id per arbusculas versatis progredi possint.

2 Conlocentur autem insuper basim tigna duo in utramque partem proiecta pedes senos, quorum circa proiectorum figantur altera proiecta duo tigna ante frontes pedes XII,¹ crassa et lata uti in basi sunt scripta. Insuper hanc conpactionem exigantur postes compactiles praeter cardines pedum VIII, crassitudine quoquo versus palmopedales, intervalla habentes inter se sesquipedes. Ea concludantur superne intercardinatis² trabibus. Supra trabes conlocentur capreoli cardinibus alius in alium³ conclusi, in altitudine excitati pedes VIII. Supra capreolos conlocetur quadratum tignum, quo capreoli³ coniungantur. Ipsi autem laterariis circa fixis continerentur teganturque tabulis maxime prinis,⁴ si non, ex cetera materia, quae maxime habere potest virtutem, praeter pinum aut alnum; haec enim sunt fragilia et faciliter recipiunt ignem. Circum tabulata conlocentur crates⁵ ex tenuibus virgis creberrime textae⁶ maximeque recentibus. Percrudis coriis duplicibus consutis, fartis alga aut paleis in aceto maceratis, circa tegatur machina tota. Ita ab his reiciuntur plagae ballistarum et impetus incendiorum.

¹ XII (πῆχαις η Ath): VII H.

² intercardinatis H S G^o: interordinatis G S^o.

³ alius an alium H.

⁴ prinis Gr: primis H.

⁵ crates S^o G^o: grates H.

⁶ textae rec: texta H.

in which the axles of the wheels turn, and are sheathed in iron plates. And these timbers are to be constructed with pivots and holes whereby levers are passed through and cause them to turn, so that the machines can move front or back, right or left, or sideways as may be necessary, by the turning of the wheels by help of the timbers.

2. Let two beams be laid on the base projecting 6 feet on either side, and on the projecting parts let there be fixed two other beams projecting in front 12 feet and with the thickness and breadth as described for the base. On this frame let there be put up frame-posts 9 feet high not including the tenons, 15 inches square and 18 inches apart. Let these be joined above by beams mortised together. Above the beams let there be fixed rafters locked in one another by tenons and rising to a height of 9 feet. Above the rafters is a squared ridge-piece by which they are to be joined together. 3. Further, they are to be held together by purlins and covered by planks; best if of holm-oak, otherwise of wood which is very strong, but not of pine or alder; for these are brittle and inflammable. Around the framework are to be placed wattles, closely interwoven, of thin twigs which are to be as green as possible. The whole machine is to be covered¹ with double oxhide very raw sewn together and filled in with sea-weed or straw which is soaked in vinegar. For by these expedients the shots of the balistae and the danger of fire will be repelled.²

¹ This expedient was used by the Tyrians during the siege by Alexander, Diod. XVII. 45.

² Sackur, *op. cit.*, pp. 67-75, gives an elaborate discussion with illustrations.

1 Est autem et aliud genus testudinis, quod reliqua omnia habet, quemadmodum quae supra scripta sunt, praeter capreolos, sed habet circa pluteum et pinnae ex tabulis et superne subgrundas proclinatas, supraque tabulis et coriis firmiter fixis continentur. Insuper vero argilla cum capillo subacta ad eam crassitudinem inducatur, ut ignis omnino non possit ei machinae nocere. Possunt autem, si opus fuerit, eae machinae ex viii rotis esse, sed ad loci naturam ita opus fuerit temperare. Quae autem testudines ad fodiendum comparantur (*orynges*¹ graece² dicuntur), cetera omnia habent, uti supra scriptum est, frontes vero earum fiunt quemadmodum anguli trigoniorum, uti a muro tela cum in eas mittantur, non planis frontibus excipiant plagas sed ab lateribus labentes, sine periculoque fodientes, qui intus sunt, intuentur.

2 Non mihi etiam videtur esse alienum de testudine, quam Hagetor³ Byzantius fecit, quibus rationibus sit facta, exponere. Fuerat enim eius baseos longitudo⁴ pedum LX, latitudo XIII. Arrectaria, quae supra compactionem erant quattuor conlocata, ex binis tignis fuerant compacta, in altitudinibus singulo pedum xxxvi, crassitudine palmopedali, latitudine sesquipedali. Basis eius habuerat rotas viii, quibus agebatur. Fuerat autem earum altitudo pedum vi s̄, crassitudo pedum iii, ita fabricata triplici

¹ ὀρυγγες Gr (ex Hesych): origines H.

² graeci H S.

³ Hagetor Gr (Agetor Joc): hector H.

⁴ longitudo G: -dine H S.

1. THERE is also another kind of tortoise which has everything in the manner above described except the rafters. Instead it has a parapet and battlements made of boards with sloping eaves above; these are held together by boards and skins securely fixed. Over these clay kneaded with hair is applied to such a thickness that fire cannot damage the machine. If it is required, these machines can be on eight wheels; but it will be necessary to adjust them to the lie of the ground. Now the tortoises which are designed for digging (in Greek they are called *orynges*¹) follow the description in every respect but that their fronts are made like the angles of triangles, so that when arrows are shot against them from the walls the blows which they receive do not fall upon a plane surface, but slip along the sides, and the men within are protected² and dig without danger.

2. It now seems appropriate to explain the methods which Hagetor³ of Byzantium used for his tortoise.⁴ The length of the base was 60 feet, the breadth 13. The uprights which were set up on the frame, four in number, were each made of two timbers, of a height for each of 36 feet, and 15 inches broad with a thickness of 18 inches. The base had eight wheels on which it moved. The wheels had a height of 6 feet 9 inches, a thickness of 3 feet and were made of

¹ ὀρυξ (Hesych. ὀρύγι) 'a tool, for digging.' It had a single edge like a hoe, *μονοπόχαν ὀρυγα*, *Anth. Pal.* VI. 297.

² *intueor* in pass. sense, *Amm. Marc.* XXIII. 5. 13.

³ *Athen. op. cit.* 5.

⁴ Plate T.

materia: alternis se contra subsudibus¹ inter se coagmentatae lamnisque ferreis ex frigido ductis alligatae.

3. Hæc in arbusculis, sive amaxopodes dicuntur, habuerant versationes. Ita supra transtrorum planitiem, quæ supra basin fuerat, postes erant erecti pedes XVIII ÷,² latitudine s ÷,³ crassitudine f2, clusæ continebant totam compactionem latae pedum 1 ÷, crassæ s ÷. Supra eam capreoli extollebantur altitudine pedum XII; supra capreolos tignum conlocatum coniungebat capreolorum compactiones. Item fixa habuerant lateraria in transverso, quibus insuper contabulatio circumdata contegebat inferiora.

4. Habuerat autem mediam contabulationem supra trabiculas, ubi scorpiones et catapultæ conlocabantur. Et erigebantur arrectaria duo compacta pedum XXXV,⁴ crassitudine sesquipedali, latitudine PII, coniuncta capitibus transversario cardinato tigno et altero mediano inter duos scapos cardinato et lamnis ferreis religato. Quo insuper conlocata erat alternis materies inter scapos et transversarium traiecta e chelonis et anconibus⁵ firmiter inclusa. In ea materia fuerunt ex torno facti axiculi duo, e quibus funes alligati retinebant arietem.

5. Supra caput eorum, qui continebant arietem, conlocatum erat pluteum turriculæ similitudine ornatum, uti sine periculo duo milites tuto stantes prospicere possent et renuntiare, quas res adversarii

¹ subsudibus H.

² XVIII Joc (δωδεκαπήχεις Ath): XXVIII. H S.

³ latitudine (Ro) s ÷ Joc (παλαιστὰς γ Ath): latitudinis ÷ H.

⁴ XXXV (τριάκοντα πήχεις Ath): XXXV H.

⁵ anconibus H.

three layers of wood jointed together with alternating tenons and secured with plates of chilled iron.

3. They revolved in blocks (or as they are called *amaxopodes*). Above the cross-pieces of the floor which was above the base, posts were erected 18 feet high, 9 inches broad and 8 inches thick, and one foot 9 inches apart. Above the posts, beams one foot 9 inches wide and 9 inches thick were carried round and held the framing together. Above the framing struts¹ were raised with a height of 12 feet; above the struts a beam was fixed which received the joints of the struts. They had side-pieces placed obliquely on which boarding was carried to protect the lower parts.

4. The machine had in the middle aisle a floor upon joists, where the scorpions and catapults were placed. There were also set up two upright pieces jointed together, 45 feet high, 18 inches wide and 9 inches thick, joined at the top with a dovetailed cross-piece, and a second half-way up, mortised between the two uprights and secured with iron plates. Above this, between the uprights and the cross-piece, a wooden frame was placed consisting of blocks and firmly held by clamps. In this frame two axles turned on the lathe were placed, and the ram was controlled by ropes attached to the axles.

5. Above the heads of those who worked the ram, a shelter was placed built after the fashion of a turret, so that the two soldiers standing in safety could look out and report the movements of the enemy.

¹ These struts probably ran out from the base, were united by the beam and tied to the uprights of the frame by the sloping side-pieces.

conarentur. Aries autem eius habuerat longitudinem pedum cix, latitudine in imo palmopedali, crassitudine pedali, contractum capite in latitudine¹ pes, crassitudine s̄.

6 Is autem aries habuerat de ferro duro rostrum, ita uti naves longae solent habere, et ex ipso rostro laminae ferreae iiii circiter pedum xv fixae fuerant in materia. A capite autem ad imam calcem tigni contenti fuerunt funes iiii² crassitudine digitorum viii, ita religati, quemadmodum navis a puppi ad proram continentur, eique funes praecinctura e transversis erant religati habentes inter se palmipedalia spatia. Insuper coriis crudis totus aries erat involutus. Ex quibus autem funibus pendeat,³ eorum capita fuerunt ex ferro factae quadruplices⁷ catenae, et ipsae coriis crudis erant⁴ involutae. Item habuerat protectura eius ex tabulis arcam compactam et confixam, in qua rete⁵ rudentibus maioribus extentis, per quarum asperitates non labentibus⁶ pedibus, faciliter ad murum perveniebatur. Atque ea machina sex modis movebatur: progresso, item latere dextra et sinistra, porrectiones non minus in altitudinem extollebantur et in imum inclinatione dimittebantur. Erigebatur autem machina in altitudinem ad disiciendum murum circiter p. c, item a latere⁷ dextra ac sinistra procurrendo praestringebat non minus p. c. Gubernabant eam homines c

¹ latitudine *Joc*: altitudine *H*.

² iiii *Ro* (τρισί *Ath*): iiii *H*.

³ pendeat *Mar*: -bant *H*.

⁴ erant *S G*^o: erat *H G*.

⁵ rete (δίκτυον *Ath*) add. *Ro*.

⁶ labentibus *Joc*: habentibus *H*.

⁷ a latere *Joc*: altera *H*.

The ram was 104¹ feet long, with a breadth in the lower part of 15 inches, and a foot thick; tapering towards the head to a foot in width² and a thickness of 9 inches.

6. Now the ram had a beak of hardened iron like those of ships of war, and from it four iron plates, 15 feet long, were fixed to the timber. From the head to the butt of the ram three ropes were stretched 6 inches thick bound to the ends of the ram in the same way as ships³ are held together from the stern to the bows, and these ropes were wound round obliquely, at intervals of 15 inches by another rope which encircled them. The whole ram was enveloped with raw skins above the ropes. The ends of the ropes by which it hung were made of quadruple iron chains, and they also were wrapped in raw skins. 7. The shelter⁴ attached to the ram had a casing made of planks securely fixed, by which when a net of great ropes was stretched (over the roughness of which the feet were kept from slipping) there was an easy access to the wall. The whole machine could be moved in six⁵ ways: in a straight line; right and left. Moreover, the thrust of the machine was directed upwards and let fall at an angle. Now the machine could be raised upwards to demolish the wall to about 100 feet; and by its lateral movements, right and left, it could strike at a length of not less than 100⁶ feet. It

¹ Athen. gives 180 feet.

² Literally, 'in contraction at the top a foot wide.'

³ Acts xxvii. 17.

⁴ *protectura*, probably a technical phrase.

⁵ Backwards and forwards each way; the raising and dropping of the ram is additional.

⁶ The length of 100 feet measures the amount of the wall affected.

habentem pondus ¹ talentum quattuor milium, quod fit CCCCLXXX pondo.

XVI

¹ DE scorpionibus et catapultis et ballistis etiamque testudinibus et turribus, quae maxime mihi videbantur idonea et a quibus essent inventa et quemadmodum fieri deberent, explicui. Salarum autem et carchesiorum et eorum, quorum rationes sunt inbecilliores, non necesse habui scribere. Haec etiam milites per se solent facere. Neque ea ipsa omnibus locis neque eisdem rationibus possunt utilia esse, quod differentes sunt munitiones munitionibus ² nationumque fortitudines. Namque alia ratione ad audaces et temerarios, alia ad diligentes, aliter ad ² timidos machinationes debent comparari. Itaque his praescriptionibus si qui adtendere voluerit ex varietate eorum eligendo in unam comparationem conferre, non indigebit auxiliis, sed quascumque res ex ³ rationibus aut locis opus fuerit, sine dubitatione poterit explicare. De repugnatoriis vero non est scriptis explicandum. Non enim ad nostra scripta hostes comparant res oppugnatorias, sed machinationes eorum ex tempore sollerti consiliorum celeritate sine machinis saepius evertuntur. Quod etiam Rhodiensibus memoratur usu venisse.

³ Diognetus ⁴ enim fuerat Rhodius architectus, et ei

¹ pondos *H S.*

² monitiones munitionibus *H S.*

³ ex *Ro*: & (et) *H.*

⁴ diogenes *H.*

had a weight of 4000 talents (which makes 480,000 pounds) and was controlled by 100 men.

CHAPTER XVI

ON MACHINERY FOR DEFENCE

1. WITH reference to scorpions and catapults and balistae, and also tortoises and towers, I have explained the details which seemed to me most suitable, stating the names of their inventors, and how they should be constructed. But I did not hold it necessary to write about ladders, cranes, etc., of which the principles are simpler. For the troops are accustomed to make these of themselves. And the measures to be taken cannot be used to advantage in the same way in all places. For there are differences between one mode of fortification and another, and in the military spirit of nations. Thus military engines should be provided in one manner against a bold and rash enemy, in another manner against a watchful enemy, and differently against the pusillanimous.

2. Therefore whoever will attend to these instructions so as to choose from their variety and combine in one provision, will not lack assistance, but will be able to set forth with assurance whatever is necessary to suit occasion and place. Measures of defence, however, are not to be prescribed. For the enemy does not enter on a siege in order to follow our precedents, and his engineering is more often baulked on the spur of the moment by swift and inventive tactics. And this, it is recorded, happened to the Rhodians.

3. Diognetus was an architect of Rhodes, and

de publico quotannis certa merces pro arti tribuebatur ad honorem. Eo tempore quidam architectus ab Arado nomine Callias Rhodum cum venisset, acroasin fecit exemplaque protulit muri et supra id machinam in carchesio¹ versatili constituit, qua helepolim² ad moenia adcedentem corripuit et transtulit intra murum. Hoc exemplar Rhodii cum vidissent, admirati ademerunt Diogneto,³ quod fuerat quotannis constitutum,⁴ et eum honorem ad Calliam⁵ transtulerunt.

4 Interea rex Demetrius, qui propter animi pertinaciam Poliorcetes⁶ est appellatus, contra Rhodum bellum comparando Epimachum Atheniensem nobilem architectum secum adduxit. Is autem comparavit helepolim⁷ sumptibus inmanibus industria laboreque summo, cuius altitudo fuerat p. cxxv, latitudo pedum lx. Ita eam ciliciis et coriis crudis confirmavit, ut posset pati plagam lapidis ballista inmissi p. ccclx; ipsa autem machina fuerat milia p. ccclx. Cum autem Callias⁸ rogaretur ab Rhodiis, contra eam helepolim⁹ machinam pararet, ut illam, uti pollicitus erat, transferret intra murum, negavit posse.

5 Non enim omnia eisdem rationibus agi possunt, sed sunt alia, quae¹⁰ exemplaribus non magnis similiter magna facta habent effectus; alia autem exemplaria

¹ carchesio *ed*: carceso *H*.

² qua helepolim *Joc*: quem lepidolim *H*.

³ diogeni *H*.

⁴ constitutum et *S*: et constitutum *H*.

⁵ galliam *H*.

⁶ poliorcetes *H*.

⁷ heliopolim *H*.

⁸ gallias *H*.

⁹ heliopoliam *H*.

¹⁰ alia quae *Ro*: alique *H*.

received from the state¹ a fixed salary proportionate to his professional skill and as an honorarium. In his time a certain architect from Aradus, Callias by name, came to Rhodes and gave a public lecture, at which he displayed the drawings of a city wall, and thereupon he set up a machine with a revolving crane which seized a siege engine² as it approached the ramparts, and removed it within the city. When the Rhodians saw the design, they admired it, and withdrew the appointed salary from Diognetus and gave the post to Callias.

4. Meanwhile King Demetrius, who on account of his stubbornness of mind was named the Besieger, prepared for war³ against Rhodes and brought with him Epimachus, a famous architect of Athens. And he produced an elaborate siege engine at immense cost both in money and labour. Its height was 125 feet, and its breadth 60, and it was so secured with goatskins and undressed oxhide that it could withstand the blow of a stone weighing 360 pounds, hurled by a balista. The engine itself was 360,000 pounds in weight. But when Callias was asked by the Rhodians to construct a machine to countervail the City-taker and bring it within the walls as he had promised, he said he could not.

5. For not everything can be done by a single method; there are some things which, done on a large scale, produce effects corresponding to those instances which are done on a small scale, there are

¹ Hippodamus seems to have held a similar position at Athens; Vitruvius at Rome. At Athens c. 100 B.C. there was an architect to superintend the temples, *C.I.A.* II. 404.

² *helepolis*, *lit.* 'City-taker.' *Athen. op. cit.* 7; *Diod.* XX.

91.

³ 305-4 B.C.

non possunt habere, sed per se constituuntur; nonnulla vero sunt, quae in exemplaribus videntur; verisimilia, cum autem crescere coeperunt, dilabantur. Ut etiam possumus hic animum advertere. Terebratur terebra foramen semidigitale, digitale, sesquidigitale. Si¹ eadem ratione voluerimus palmare facere, non habet explicationem, semipedale autem maius ne cogitandum quidem videtur omnino.

6 Sic item in nonnullis exemplaribus videntur, quae² ad modum in minimis fieri videntur, atque eodem modo in maioribus. Id eodem modo Rhodii eadem ratione decepti iniuriam cum contumelia Diogneto³ fecerunt.⁴ Itaque posteaquam viderunt hostem pertinaciter infestum, periculum servitutis, machinationem ad capiendam urbem comparatam, vastitatem civitatis expectandam, procubuerunt Diogneto rogantes, ut auxiliaretur patriae.

7 Is primo negavit se facturum. Posteaquam ingenuae virgines et ephebi cum sacerdotibus venerunt ad deprecandum, tunc est pollicitus his legibus, uti, si eam machinam cepisset,⁵ sua esset. Is ita constitutis, qua machina accessura erat, ea regione murum pertudit et iussit omnes publice et privatim quod quisque habuisset aquae,⁶ stercoris, luti per eam fenestram per canales progredientes effundere ante murum. Cum ibi magna vis aquae, luti, stercoris nocte profusa fuisset, postero die helepolis⁷ accedens,

¹ sic H.

² diognito H.

³ coepisset H.

⁴ quae Rouse: quem H.

⁵ fecerunt S^c: fecerint H G S.

⁶ aqua H. ⁷ heliopolis H.

¹ Vitruvius anticipates the Law of Diminishing Returns, namely, that the increasing of the scale of operations, as in mechanical production, is not followed by a correspondingly increased value in use. Athen. *op. cit.* 7.

other things which cannot follow precedents, but are determined to their own results; but there are some¹ which are promising in sample, but collapse when they begin to increase in scale, as we can perceive from this case: a hole is bored by an auger, half an inch, an inch, 1½ inches in diameter; if we wish in the same way to bore a hole 3 inches wide, our method does not apply; for a hole of 6 inches or more, the notion seems generally inconceivable.

6. Thus also there are things which seem to be done exactly on a smaller scale, and in the same way on a larger scale. By the same rule and the same principle the Rhodians, deceived herein, inflicted injury with violence² on Diognetus. Therefore when they saw the stubborn enemy in the field against them, the danger of enslavement, the engine designed to take their city, the impending desolation of the state, they fell at the feet of Diognetus and implored him to come to the rescue of his native city.

7. First he gave a refusal. Afterwards, when girls and youths of noble birth came along with the priests to intercede, he promised to help on the terms that if he captured the siege engine, it should be his own. This was settled. He made a breach in the ramparts where the machine was to come, and ordered everyone publicly and in private to collect water, sewage and mud and, coming forth, to pour it along channels through the breach in front of the rampart. After a great amount of water, mud, sewage, had been poured down overnight, the next day the siege engine came along; and before

² For this sense of *contumelia*, Caes. B.G. III. 13, Tac. *Hist.* III. 31.

antequam adpropinquaret ad murum, in umido voragine facta consedit nec progredi nec egredi postea potuit. Itaque Demetrius, cum vidisset sapientia Diogneti se deceptum esse, cum classe sua discessit. 8 Tunc Rhodii Diogneti sollertia liberati bello publice gratias egerunt honoribusque omnibus eum et ornamentis exornaverunt. Diognetus eam helepolim¹ reduxit in urbem et in publico conlocavit et inscripsit 'Diognetus e manubiis id populo dedit munus.' Ita in repugnatoriis rebus non tantum machinae, sed etiam maxime consilia sunt comparanda.

9 Non minus Chio cum supra naves sambucarum machinas hostes comparavissent, noctu Chii² terram, harenam, lapides progresserunt in mare ante murum. Ita illi postero die cum accedere voluissent, naves supra aggerationem, quae fuerat³ sub aqua, sederunt nec ad murum accedere nec retrorsus se recipere potuerunt, sed ibi malleolis confixae incendio sunt conflagratae. Apollonia⁴ quoque cum circumsederetur et specus hostes fodiendo cogitarent sine suspitione intra moenia penetrare, id autem a speculatoribus esset Apolloniatibus renuntiatum, perturbati nuntio propter timorem consiliis indigentes animis deficiebant, quod neque tempus neque certum locum scire poterant, quo emersum facturi fuissent hostes.

¹ heliopolim *H.* ² Chii *ed*: hii *H S G.*

³ fuerat *rec*: -rant *H.*

⁴ appollonia *H*: appollonia *S.*

¹ Polyb. VIII. 6, describes the *sambuca*.

it drew up to the wall, it was engulfed in the wet ground and stuck nor could it get on or get out. Thereupon Demetrius perceived that he had been tricked by the skill of Diognetus, and sailed away with his fleet. 8. The Rhodians, therefore, being freed from their enemy by the artifice of Diognetus, gave him public thanks and decorated him with every honour and distinction. Diognetus brought the siege engine into the city, set it up in a public place with the inscription: *DIOGNETUS DEDICATED THIS TO THE PEOPLE FROM THE SPOILS OF WAR.* In defence therefore not only machines but, far more, are stratagems to be devised.

9. At Chios also, when the enemy had constructed storming-bridges¹ on board ship, the Chians overnight heaped up earth, sand, stones into the sea before the walls. Thus when the enemy next day wished to draw near, their ships grounded on the heaped material which was under water. The ships could neither approach the wall nor draw backwards, but being pierced by burning missiles, they were set ablaze and consumed on the spot.² Again, when Apollonia³ was besieged, and the enemy designed by digging tunnels to penetrate unsuspected within the walls, this was reported by spies to the citizens of Apollonia. They were panic-stricken at the news and their spirits failed them in their lack of resource. For they could not know the time or the place for certain where the enemy were likely to emerge.

² Athen., *op. cit.* 9, refers to this same siege in somewhat different terms.

³ In Illyria. It was attacked by Philip V in 214 B.C., Livy, XXIV. 40.

10 Tum vero Trypho Alexandrinus ibi fuerat architectus; intra murum plures specus¹ designavit et fodiendo terram progrediebatur extra murum dumtaxat extra sagittae missionem et in omnibus vasa aenea suspendit. Ex his in una fossura, quae contra hostium specus fuerat, vasa pendentia ad plagas ferramentorum sonare coeperunt. Ita ex eo intellectum est, qua regione adversarii specus agentes intra penetrare cogitabant. Sic liniatione cognita temperavit² aenea aquae ferventis et picis de superne contra capita hostium et stercoreis humani et harenae coctae candentis. Dein noctu pertudit terebra³ foramina et per ea repente perfundendo qui in eo opere fuerunt hostes omnes necavit.

11 Item Massilia cum oppugnaretur et numero supra xxx speculatum⁴ agerent, Massilitani suspicati totam quae fuerat ante murum fossam altiore fossura depresserunt. Ita specus omnes exitus in fossam habuerunt. Quibus autem locis fossa non potuerat fieri, intra murum barathrum amplissima longitudine et amplitudine uti piscinam fecerunt contra eum locum, qua specus agebantur, eamque e puteis et e portu impleverunt. Itaque cum specus esset repente naribus apertis, vehemens aquae vis inmissa supplantavit fulturas, quique intra fuerunt, et ab aquae multitudine et ab ruina specus omnes sunt oppressi.

12 Etiam cum agger ad murum contra eos comparare-

¹ specus *H S G*. ² temperavit *E G*: temperaret *H S*.

³ pertudit terebra *H*, ptudit terebra *S*.

⁴ speculatum *H*, specus *ex verbo subauditur*?

10. But at that time Trypho of Alexandria was the architect in charge. Within the walls he planned tunnels and, removing the soil, advanced beyond the wall the distance of a bowshot. Everywhere he hung bronze vessels.¹ Hence in one excavation which was over against the tunnel of the enemy, the hanging vases began to vibrate in response to the blows of the iron tools. Hereby it was perceived in what quarter their adversaries purposed to make an entrance with their tunnel. On learning the direction, he filled bronze vessels with boiling water and pitch overhead where the enemy were, along with human dung and sand roasted to a fiery heat. Then in the night he pierced many openings, and suddenly flooding them, killed all the enemy who were at work there.

11. Again, when Marseilles was besieged² and the enemy drove more than 30 tunnels,³ the inhabitants were on their guard, and made a deeper ditch than the one in front of the ramparts. Hence all the tunnels came out into this. But where inside the wall a ditch could not be made, they dug a moat, like a fish-pond, of great length and depth, over against the quarter where the tunnels were being made, and filled it from the wells and from the harbour. Hence when a tunnel had its passage suddenly opened, a strong rush of water flowed in and threw down the props. The troops within were overwhelmed by the collapse of the tunnel and the flood of water.

12. Again, when a mound was heaped up against

¹ The same expedient is described in the siege of Barca by the Persians, Herod. IV. 200. ² 49 B.C., Caes. B.C. II. 1 ff.

³ *speculatum* cannot be right.

tur et arboribus excisis coque conlocatis locus operibus exaggeraretur, ballistis vectes ferreos candentes in id mittendo totam munitionem coegerunt conflagrare.¹ Testudo autem arietaria cum ad murum pulsandum accessisset, permiserunt laqueum et eo ariete constricto, per tympanum ergata circumagentes suspenso capite eius non sunt passi tangi murum. Denique totam machinam malleolis candentibus et ballistarum plagis dissipaverunt. Ita eae victoriae civitatum² non machinis, sed contra machinarum rationem architectorum sollertia sunt liberatae.

Quas potui de machinis expedire rationes pacis bellicae temporibus et utilissimas putavi, in hoc volumine perfeci. In prioribus vero novem de singulis generibus et partibus comparavi, uti totum corpus omnia architecturae membra in decem voluminibus haberet explicata.

¹ conflagrare *H.*

² victoriae civitatum *idem quod* civitates victrices: *cf.* uligines paludum, *Tac. Ann.* I. 17. 5.

the walls, and the site was further raised by cutting down trees and laying them there, the citizens shot red-hot iron bars from their balistae and caused the earthwork to blaze up. Again, when the ram tortoise came to demolish the wall, they let down a rope and caught the head of the ram. Then they wound the rope round a drum, using a windlass, and by keeping the ram raised, they prevented it from touching the wall. In the end they demolished the whole engine with fiery missiles¹ and blows from the balista. Thus these victorious cities were liberated not by military engines, but, in face of their employment, by the skill of the architects.

In this book I have fully set forth the mechanical methods which I could furnish, and which I thought most useful in times of peace and war. Now in the previous nine books I have dealt with the other several topics and their subdivisions, so that the whole work, in the ten books, describes every department of architecture.

¹ Caesar refers several times to the use of fire by the besieged, *loc. cit.*

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* This index has been constructed throughout by reference to the text of *H.* This circumstance and the special reference to craftsmanship has involved at least a hundred variations from the index of Rose and Müller-Strübing (ed. 1867), an edition which, following Mr. Krohn, I treat as the vulgate.

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NOTE ON THE ILLUSTRATIONS

The illustrations are intended, in the spirit of Vitruvius himself X. viii. 6, rather to indicate the principles on which machines are constructed than to exhibit the details of such construction which, he says, can only be understood in the presence of the machines themselves. The attempted restorations of the water-clock Pl. N, and the water-organ Pl. R are to be understood in this sense.

Plate K requires a further note. The problem of the Mesolabium is to find the proportion between the sides of two cubes one of which has double the content of the other. This is solved by taking two mean proportionals. The analytic solution is given in a note, p. 206.

The Mesolabium solves the problem geometrically.

It consists of three square frames with diagonals, moving in grooves so that MFGN can pass behind AEFM, and NGHQ, behind MFGN. Let QH be bisected at D.

Then the second frame is made to slide under the first, and the third under the second in such a way that the points at which the diagonals disappear, B and C, are in a straight line with AD. Let the line AD and the line EH be produced until they meet at K. By the similarity of the triangles, it may be shown that AE BF CG DH are in continued proportion; hence if $AE = 2DH$, $BF^3 = 2CG^3$.

The Cheirotometon was represented in a drawing—*quoscribitur*—and had reference to the impression made by a ring. We have seen how the perspective treatment of stage scenery revolutionised the art of painting. It is probable therefore that the cutting of intaglios with reference to perspective projection, explains the revolution which produced the masterpieces of the fifth century. The phrase 'cheirotometon' or 'hand-cut' is peculiarly appropriate because the

diamond-point, as contrasted with more mechanical tools, was used with greater freedom and revealed the touch of the artist.

Middleton, *Ancient Gems*, app. xxvi, refers to the impossibility of representing a rounded surface in a plane projection. Hence, some such diagram as Pl. K, fig. 3, would guide the artist. Let B . . B represent the plane containing the surface of the stone to be cut; and A . . A a line perpendicular to this plane. Let I . . I represent the depth of the intaglio; and S . . S the raised surface of the impression. Let C be taken as the vanishing-point of the intaglio. As a matter of fact, the subject of an intaglio is so near the imaginary spectator that a vanishing-point can usually be left out of account. There are exceptions. The chair on a gem of Dexamenos is rather absurd, Middleton, *op. cit.*, fig. 11. It clashes with the perspective of the figure. Hence a vanishing-point is sometimes necessary.

In addition to the vanishing-point which is the same for the intaglio and for the impression, there is the more difficult matter of adjusting the depth of the intaglio to the desired impression. As the eye moves from the vanishing-point, the corresponding points on the intaglio appear nearer to the centre of the picture, than the points on the actual impression. This appears from the dotted line R which indicates the ray from a point in the intaglio. The horizontal line drawn from the end of R shows the corresponding point in the impression, which is more distant from the centre, than the ray from the intaglio.

For Granger's belief that the Pantheon was a huge sundial, see *Journal R.I.B.A.*, 26 Nov. 1932. It is not credible—cf. D. S. Robertson, *Class. Rev.*, 1934, 229.

It is possible to form some idea of the automata constructed by Ctesibius and others. Plate M is based mainly on Barbaro *Vitruvio* A.D. 1584, p. 433. The motive power is supplied by an inverted bowl resting on water which rises or falls by a supply through a funnel (not shown), regulated as in the water-clock, Pl. N. A pull in the opposite direction is exercised by a bag of sand. It will appear that a small turn of the axle will cause a considerable movement of the vertical toothed wheel, and this movement is transmitted by the horizontal toothed wheel and is magnified in the large wheel turning on the same axle. A figure rising, as shown, from the large

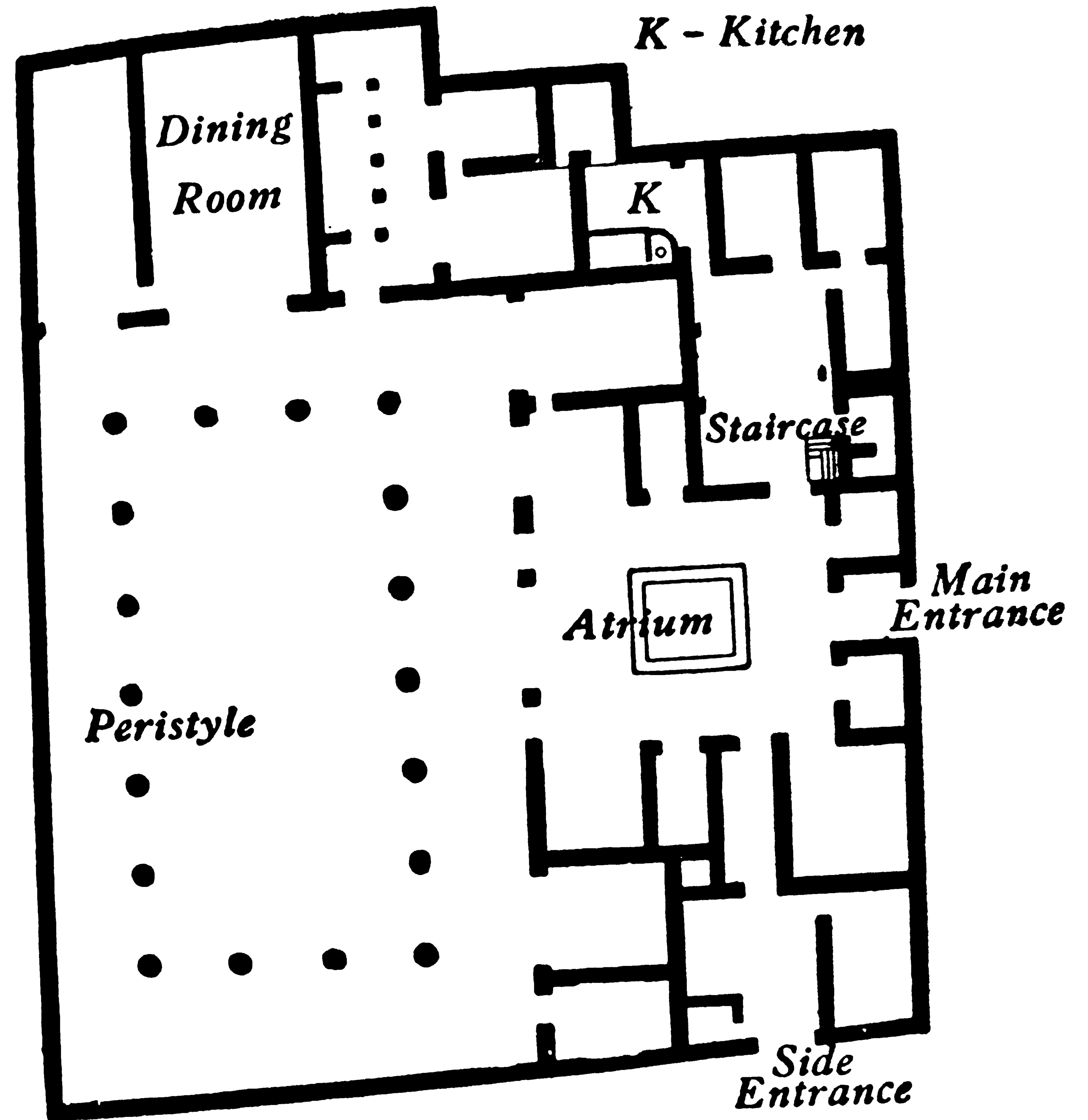
NOTE ON THE ILLUSTRATIONS

PLATE I.

wheel, carries a pointer which, by some use of wedges, is kept in contact at its upper end with the pillar. The pillar by its eccentric position in regard to the large wheel, varies by its distance by which the figure in its revolution, is separated from the pillar. In this way, the figure at its greatest distance from points to the bottom of the pillar, and as it approaches nearer the pointer attached to it rises towards the top of the pillar, thus indicating the markings on the pillar. The difficulty of adjusting the pointer to the fixed pillar by wedges, suggested an alternative arrangement by which not only the figure but the pillar is made to revolve, IX. viii. 7. But the principle of the mechanism is the same. The reader must again be warned that precision of detail is not to be expected.

Plates O, P, Q, are taken from the small Junta edition of Vitruvius of 1522, and are due to Fra Giocondo. They illustrate the principles of the Pulley, the Tympanum, and the Water-screw.

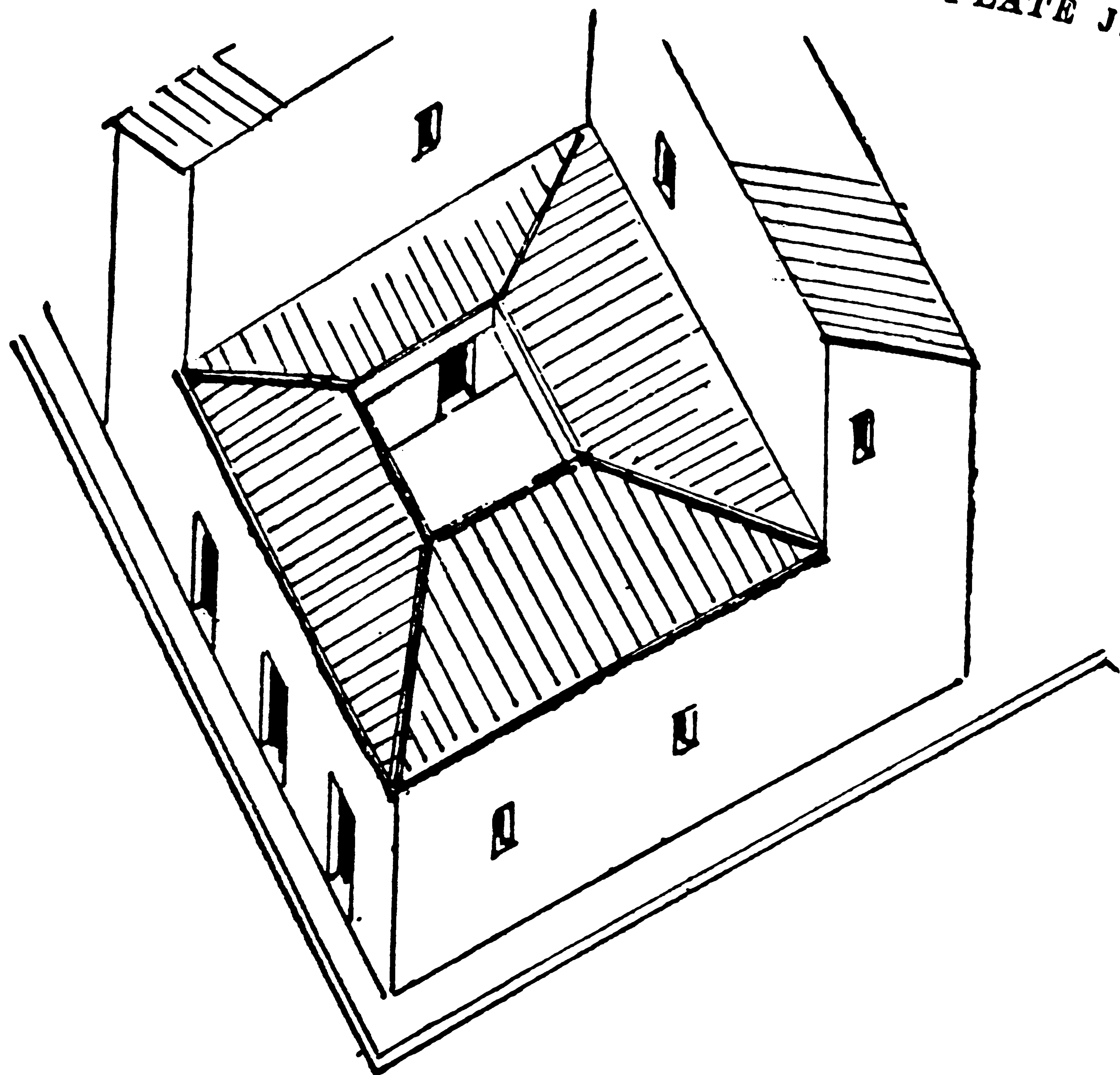
The attempted restoration of the Water-organ, Plate R, owes something to the valuable illustration of W. Schmidt, *Hero*, I, p. 500. But as will be seen on comparison, my own figure is simplified.



PLAN OF HOUSE

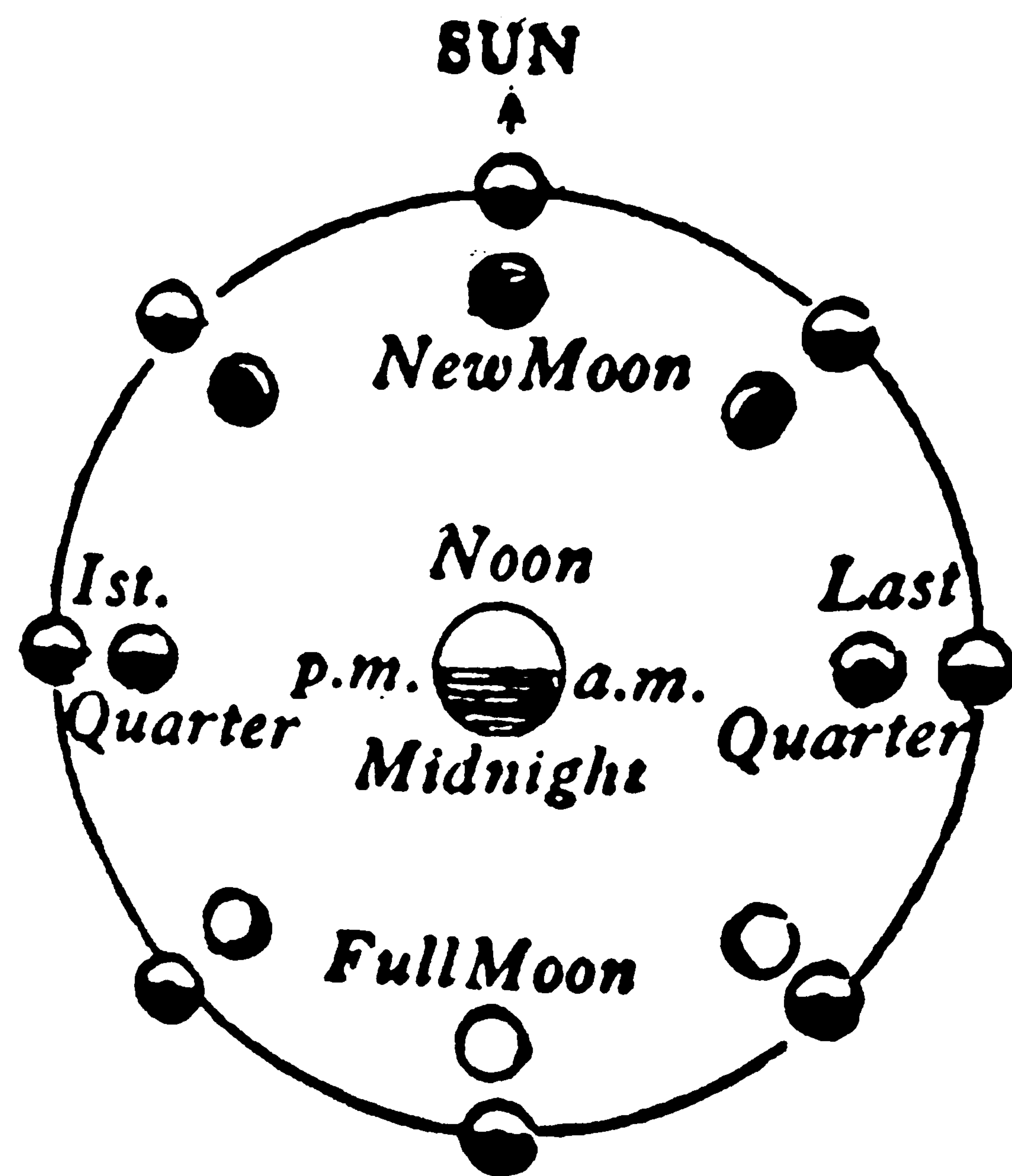
Book VI. iii. 3

Domus Vettiorum, Pompeii.



DISPLUVIATE ROOF

Book VI. III. 2.



PHASES OF THE MOON

Book IX. II. 1.

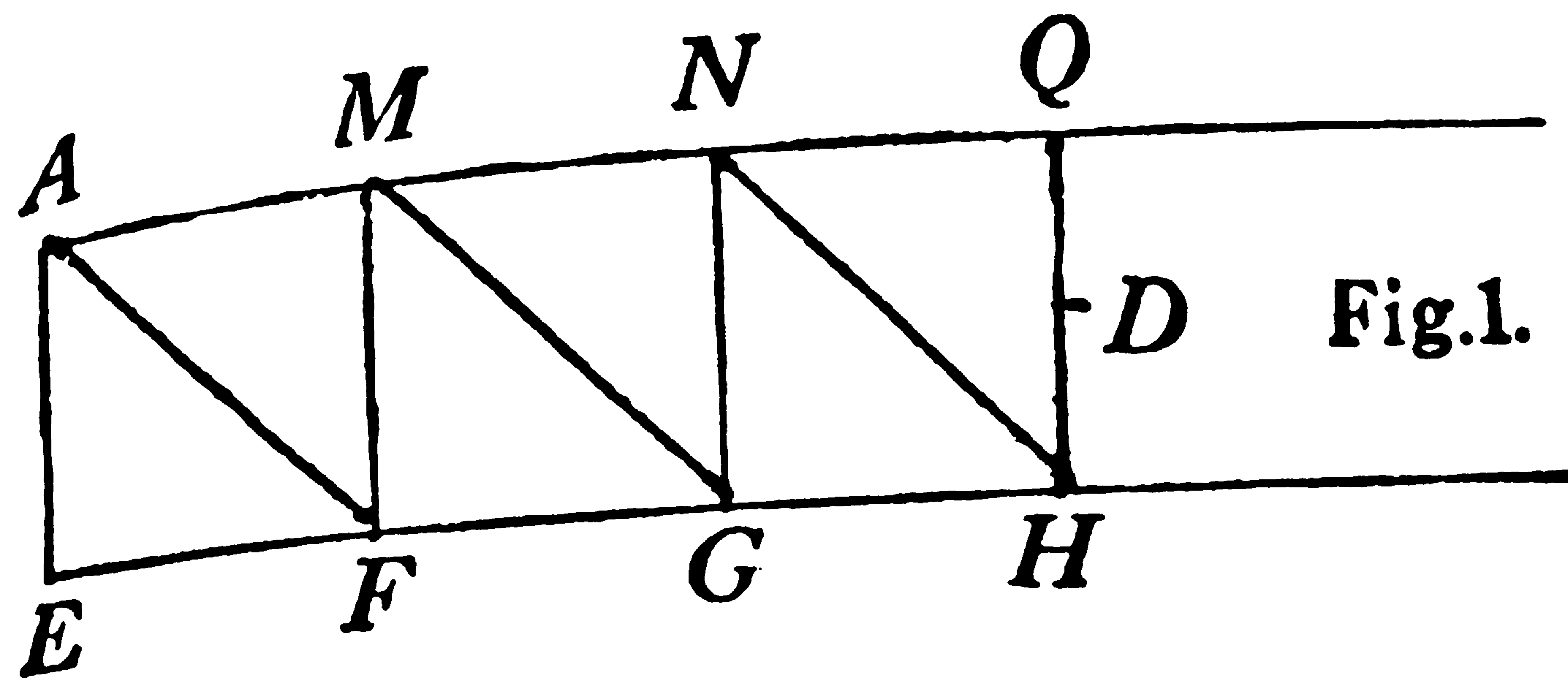


Fig. 1.

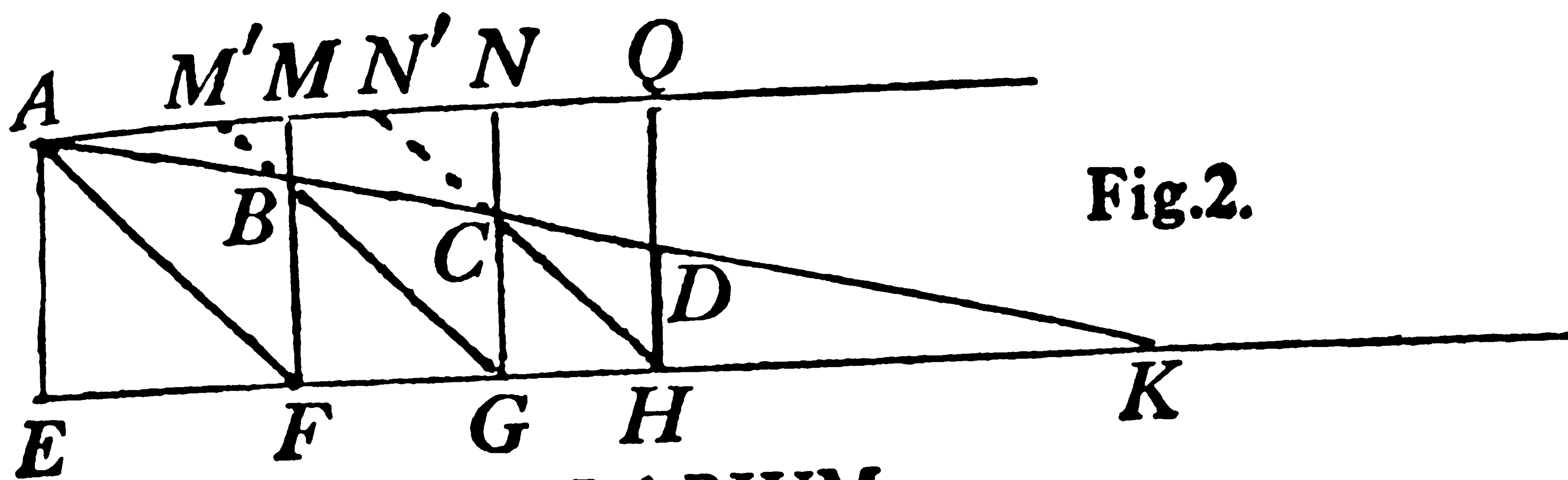


Fig. 2.

MESOLABIUM

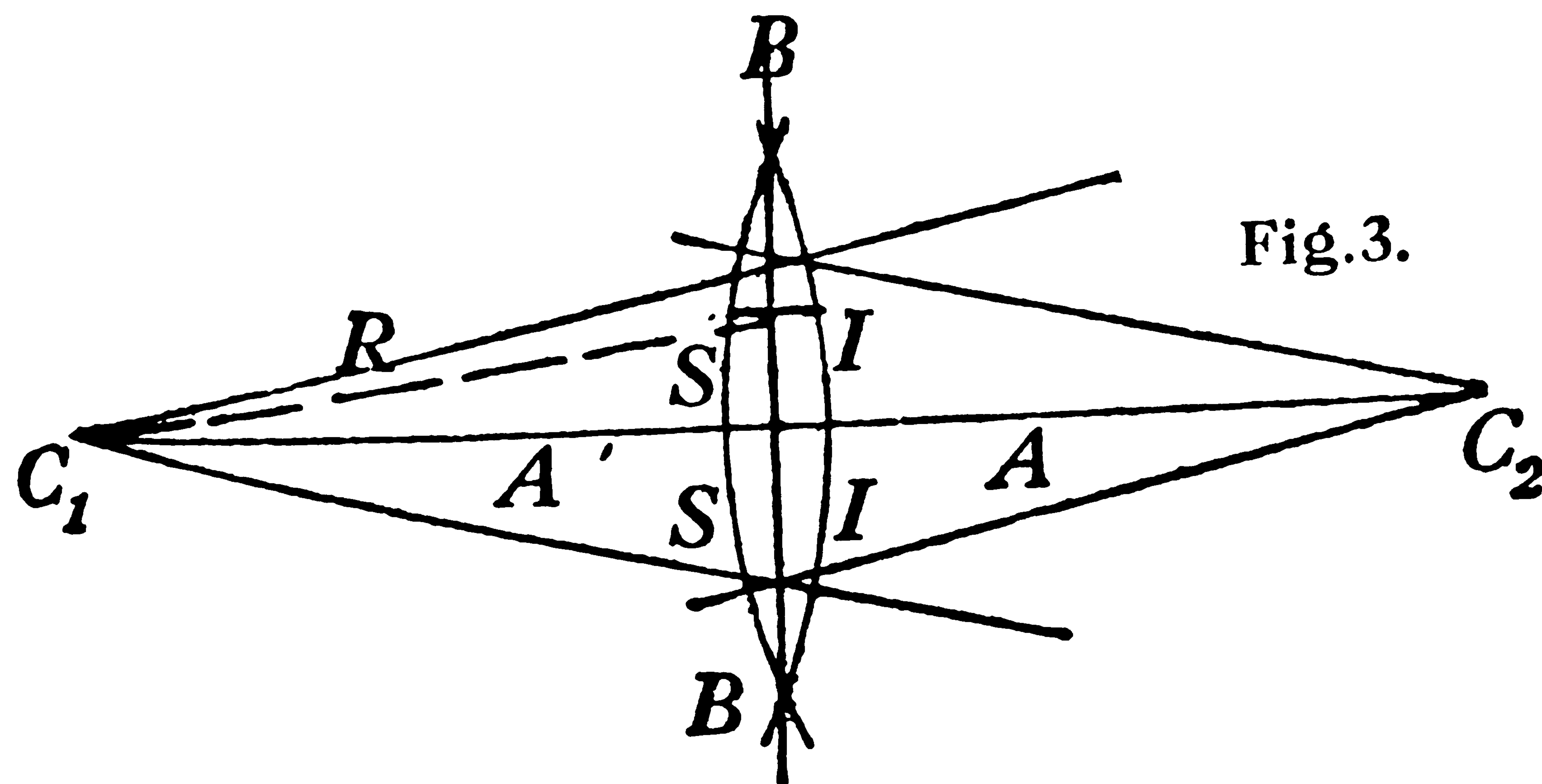
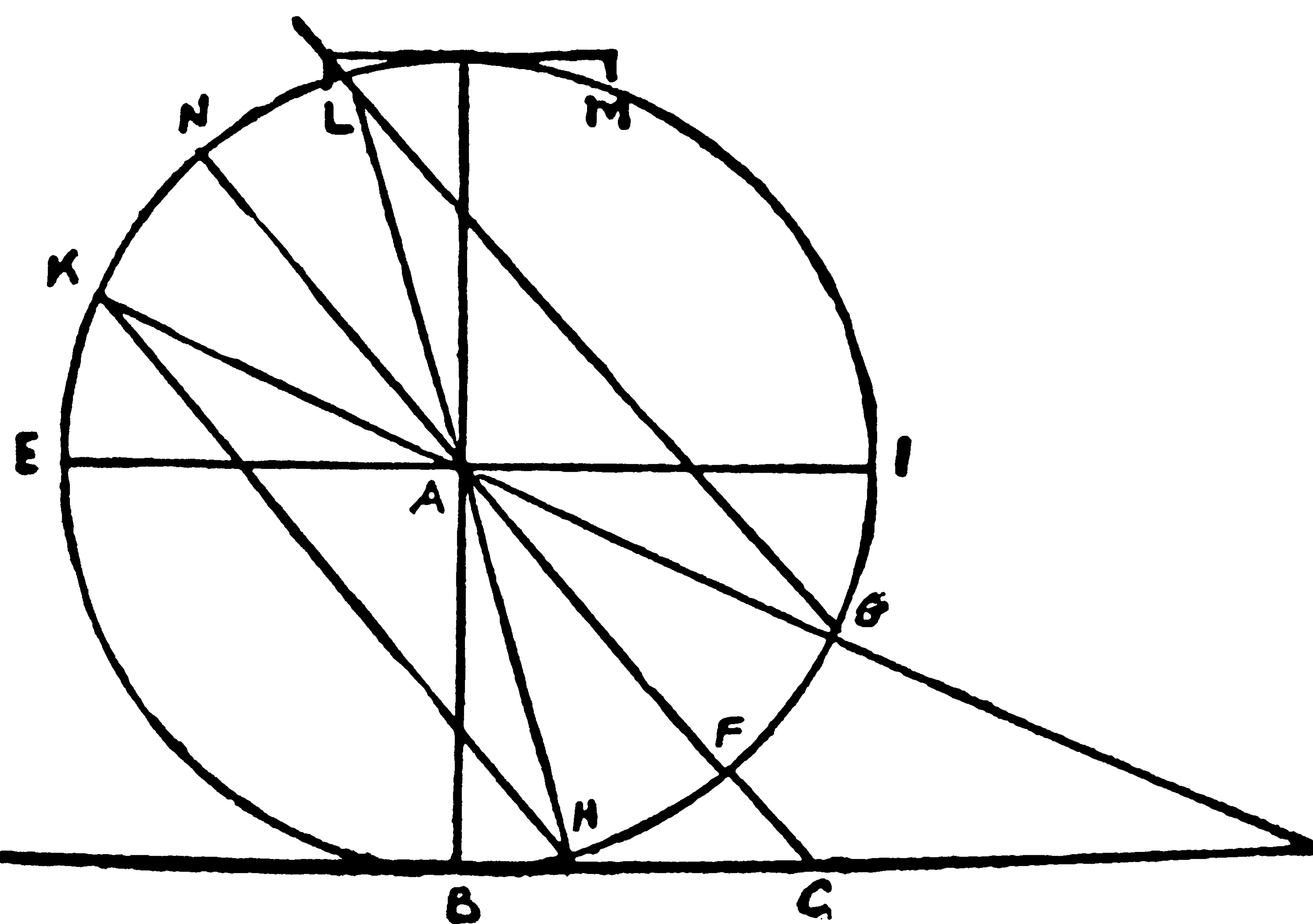


Fig. 3.

CHEIROTOMETON

Book IX. pref. 14.

PLATE L.



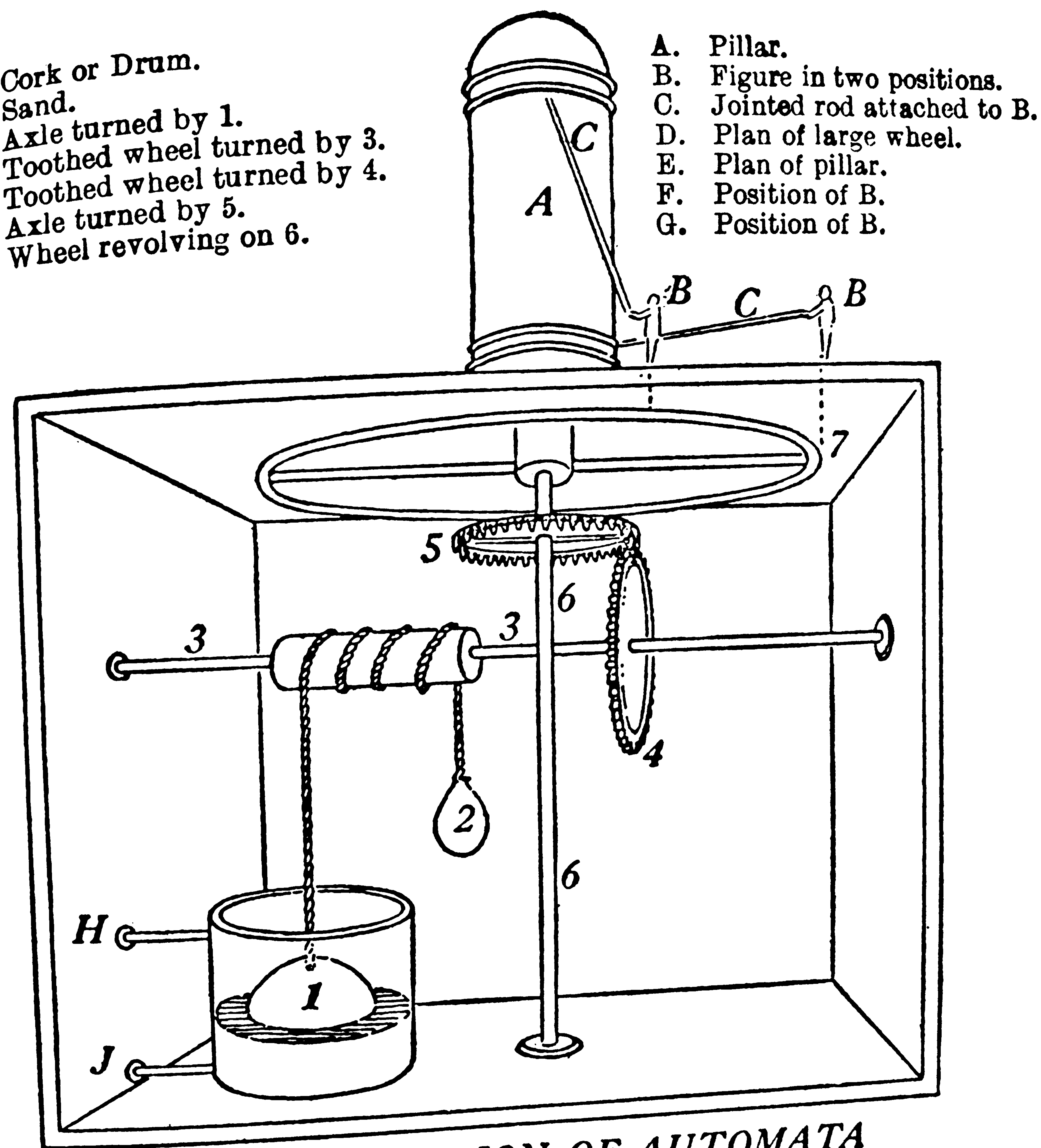
ANALEMMA: LATITUDE OF ROME

Book IX. vii. 1 ff.

AB. Gnomon.
BC. Shadow.
EI. Horizon.

CFAN. Equinoctial Ray.
GAK. Winter Solstice.
HAL. Summer Solstice.

1. Cork or Drum.
2. Sand.
3. Axle turned by 1.
4. Toothed wheel turned by 3.
5. Toothed wheel turned by 4.
6. Axle turned by 5.
7. Wheel revolving on 6.

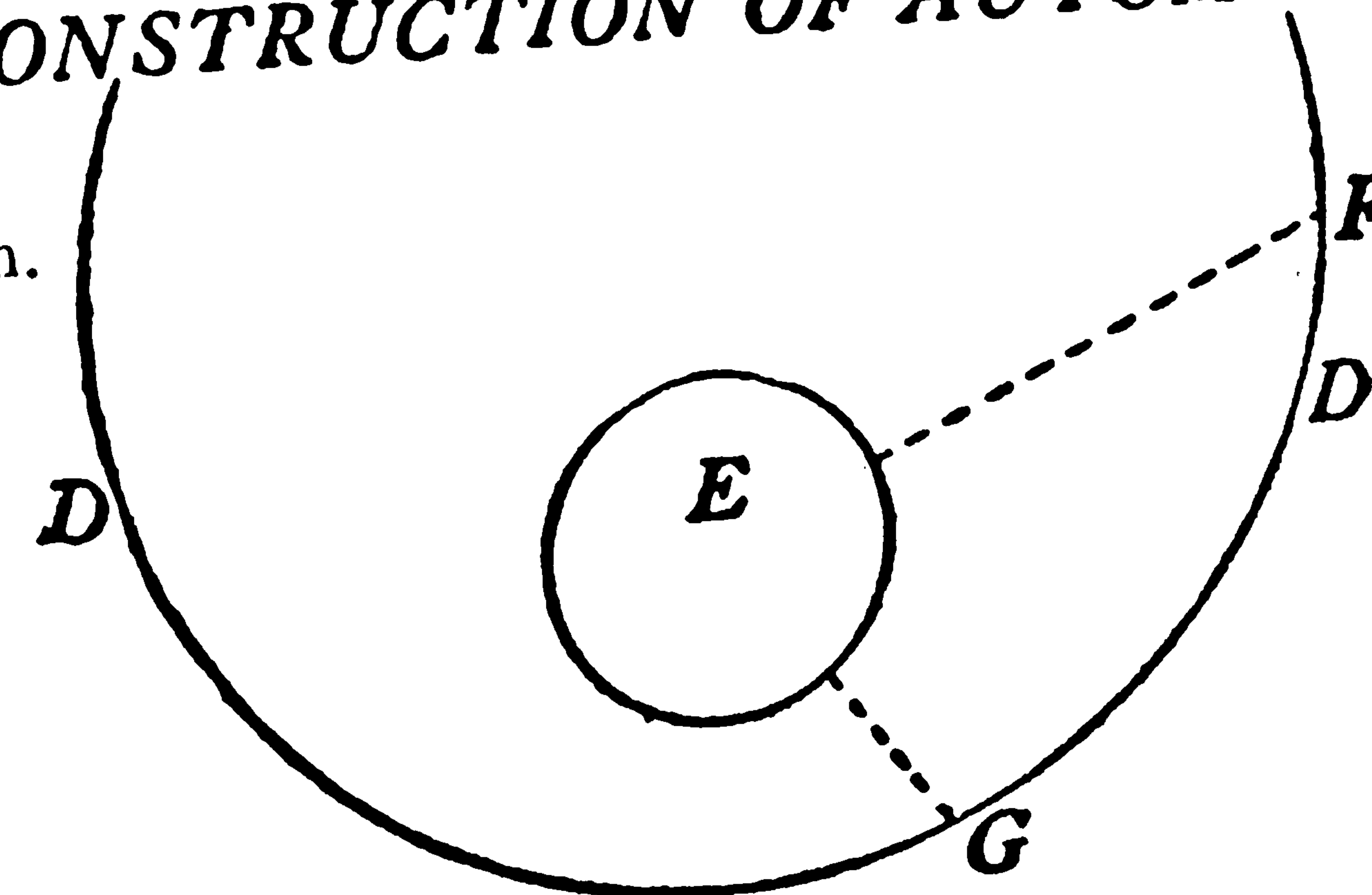


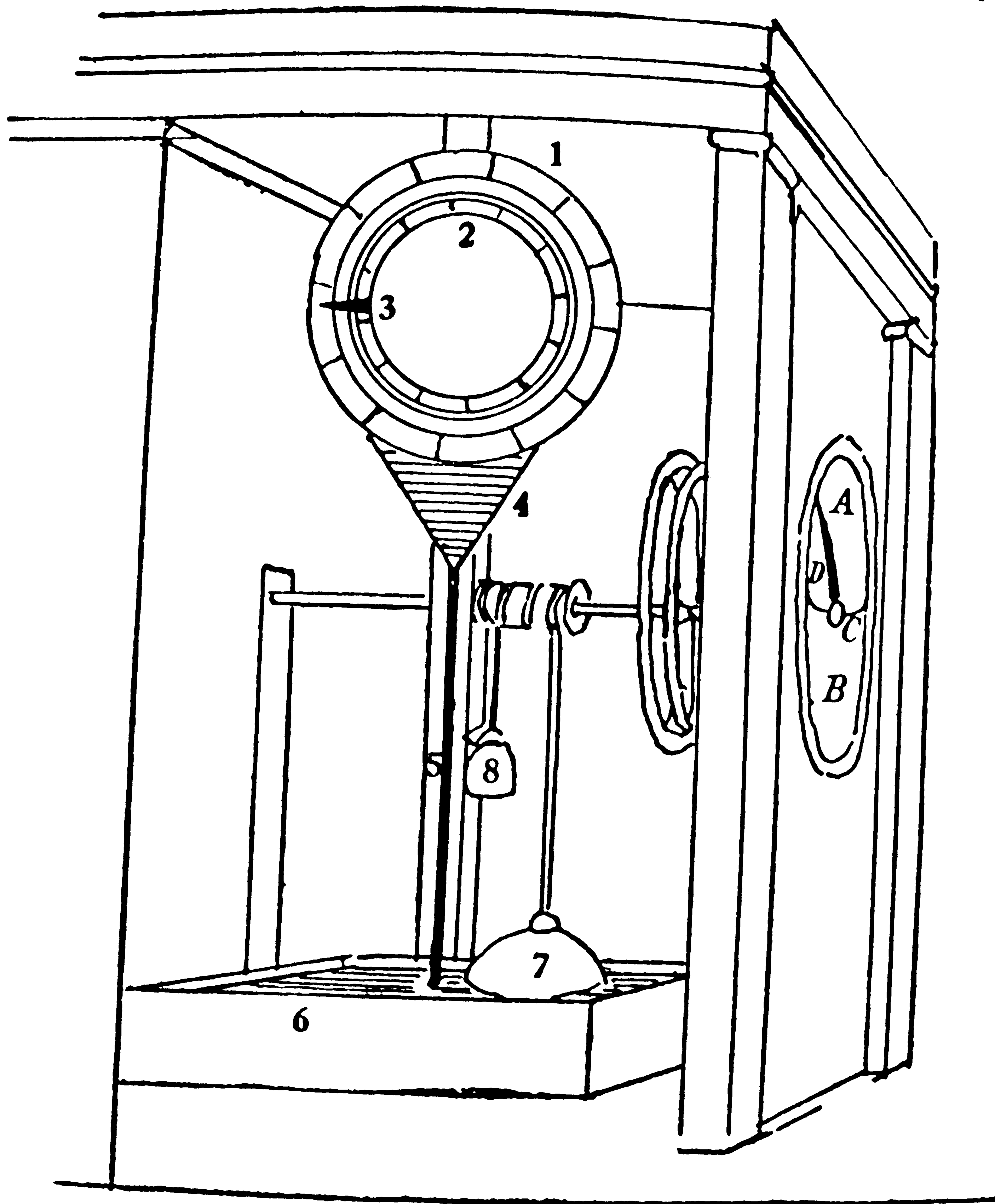
- A. Pillar.
- B. Figure in two positions.
- C. Jointed rod attached to B.
- D. Plan of large wheel.
- E. Plan of pillar.
- F. Position of B.
- G. Position of B.

CONSTRUCTION OF AUTOMATA

Book IX. viii. 5.

- H. Inlet to cistern.
- J. Outlet.



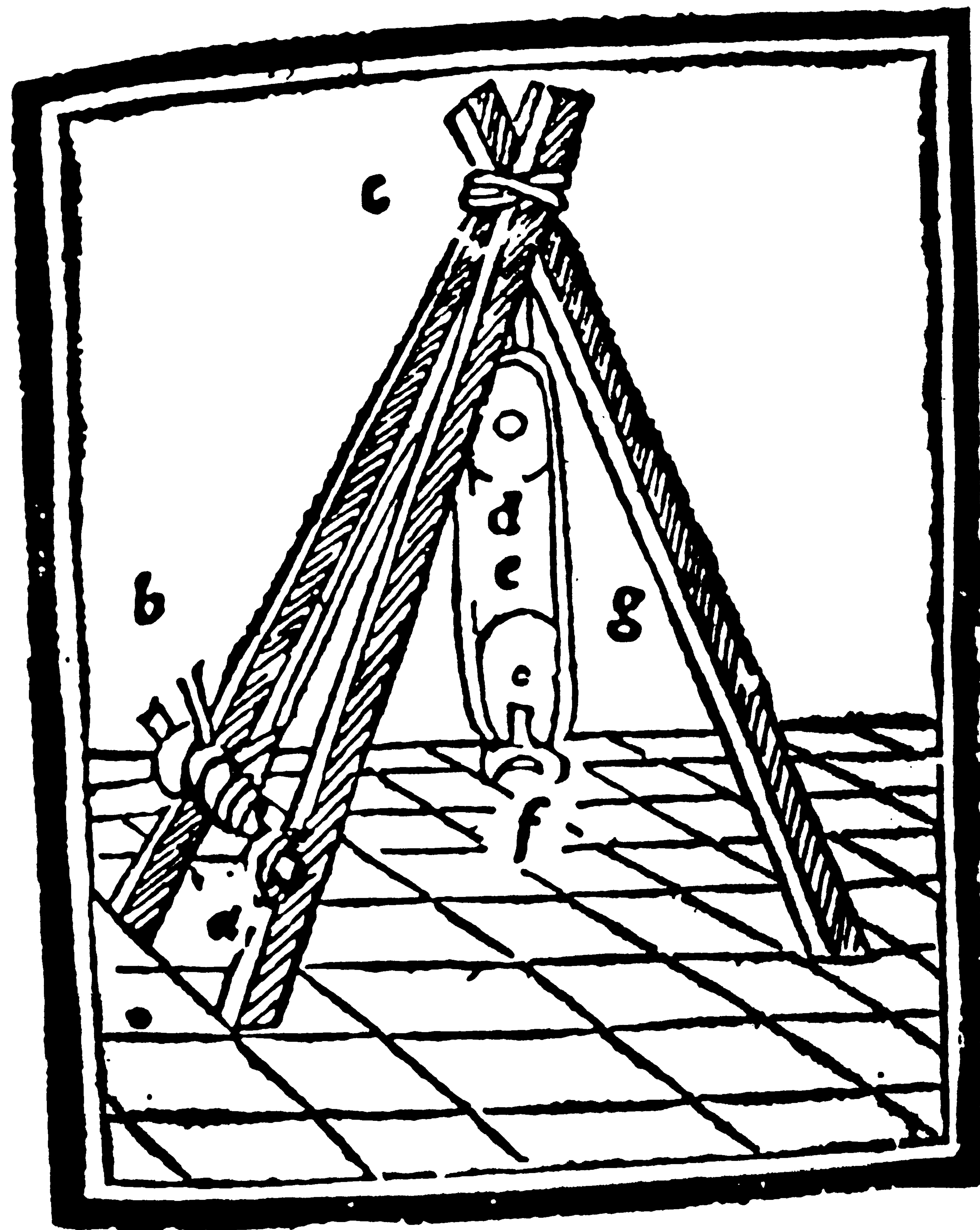


WATER-CLOCK OF CTESIBIUS

Book IX. viii. 8.

1. Outer fixed circle of signs.
2. Inner movable circle of months.
3. Point moving with inner circle.
4. Cistern receiving water from rotary valves of 2.
5. Pipe delivering into 6.
6. Main cistern.

7. "Oork" or drum.
8. Sand.
- A. Hours of daylight.
- B. Night hours.
- C. Dividing line.
- D. Finger of clock.

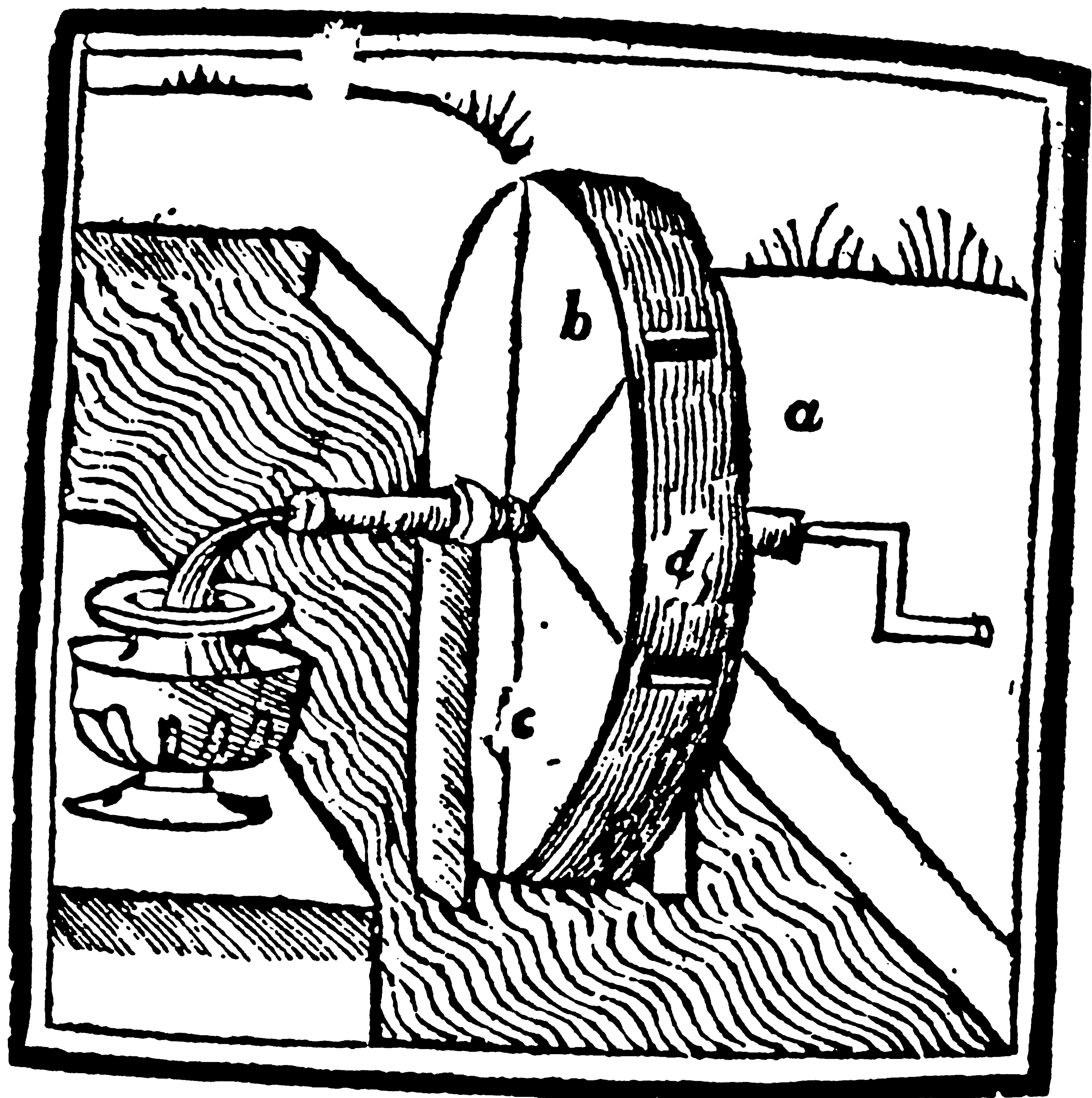


PULLEY.

Book X. ii. 1 ff.

- a. Windlass.
- b. Socket of windlass.
- c. Brace.

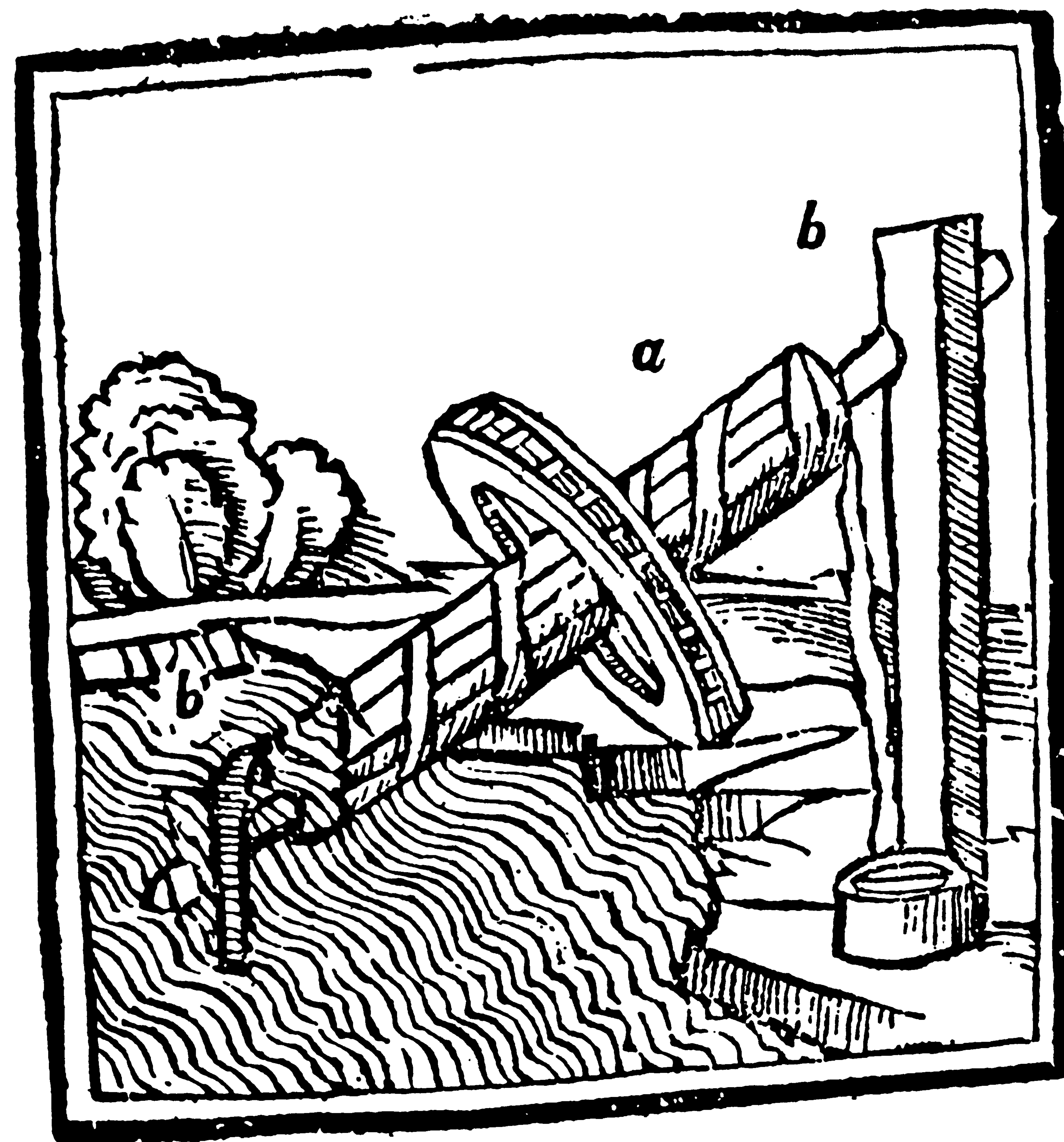
- d. Upper block.
 - e. Lower block.
- Pincers.



TYMPANUM

Book X. iv.

- a. Axle.
- b. Tympanum.
- c. Upright.
- d. Opening.

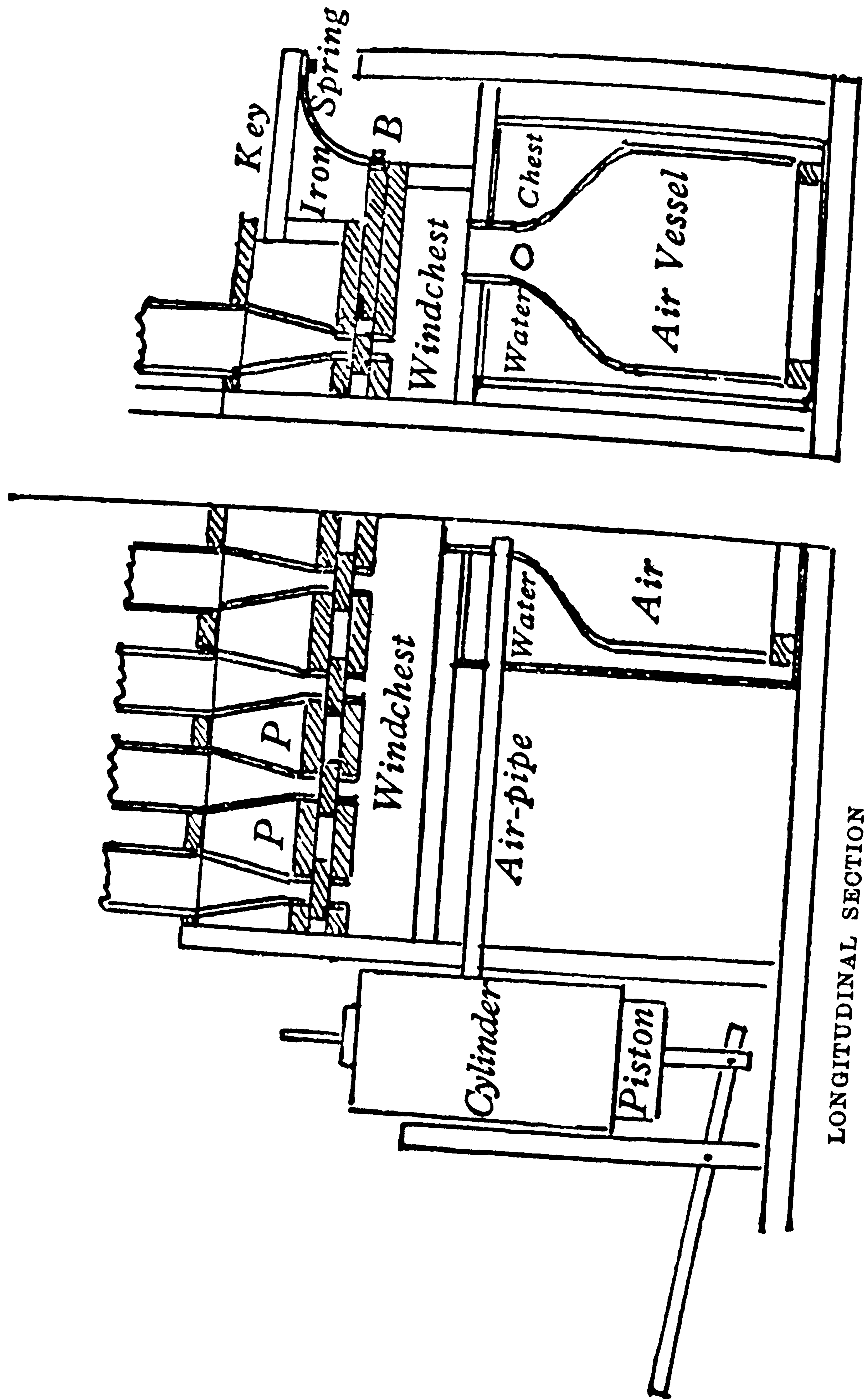


WATER-SOREW

Book X. vi.

- a. Screw.
- b. Upright in which screw turns.

PLATE R.



LONGITUDINAL SECTION

CROSS SECTION

WATER-ORGAN

P. Top Board.
 B. Sliding bar.
 Book X. viii.

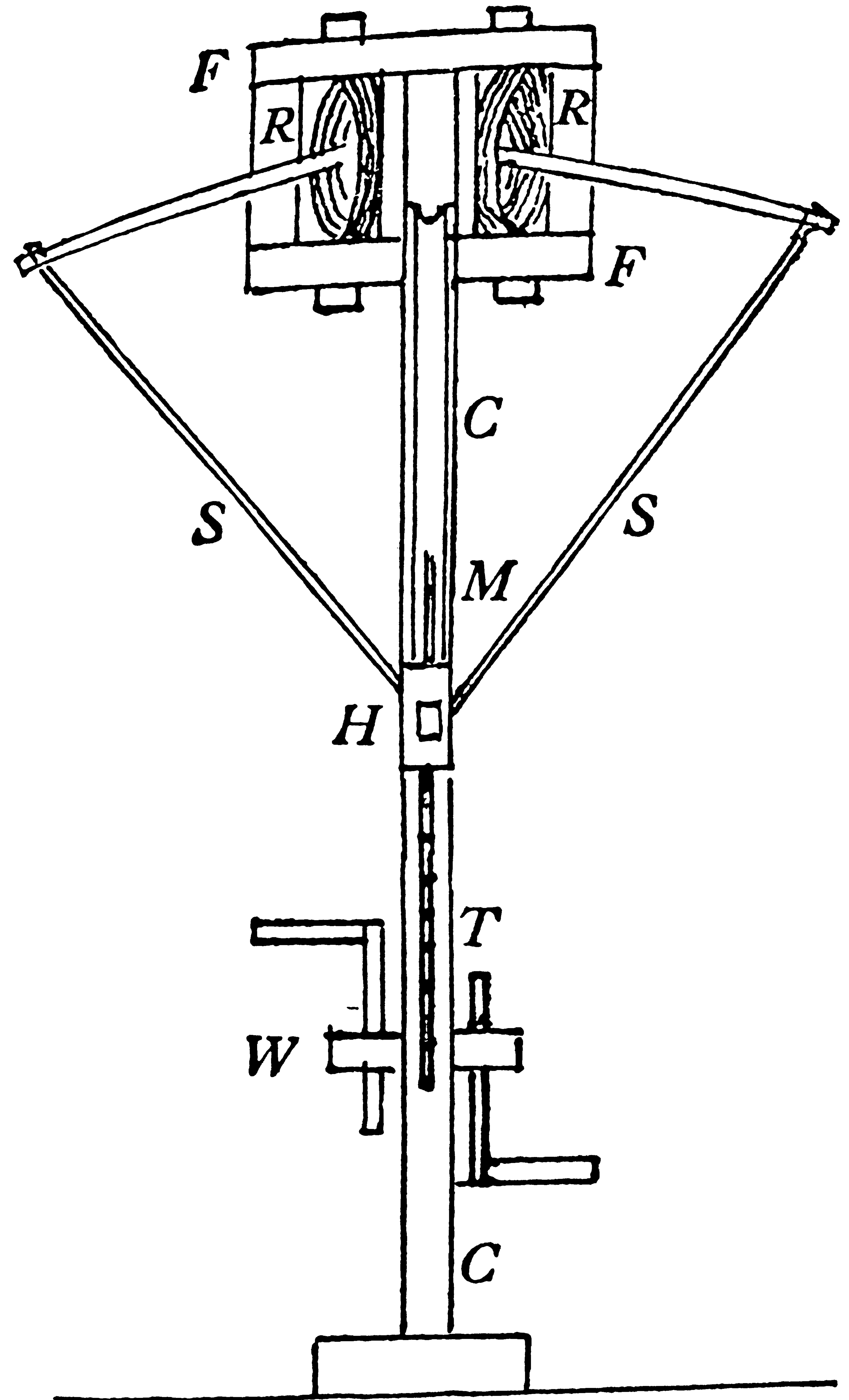


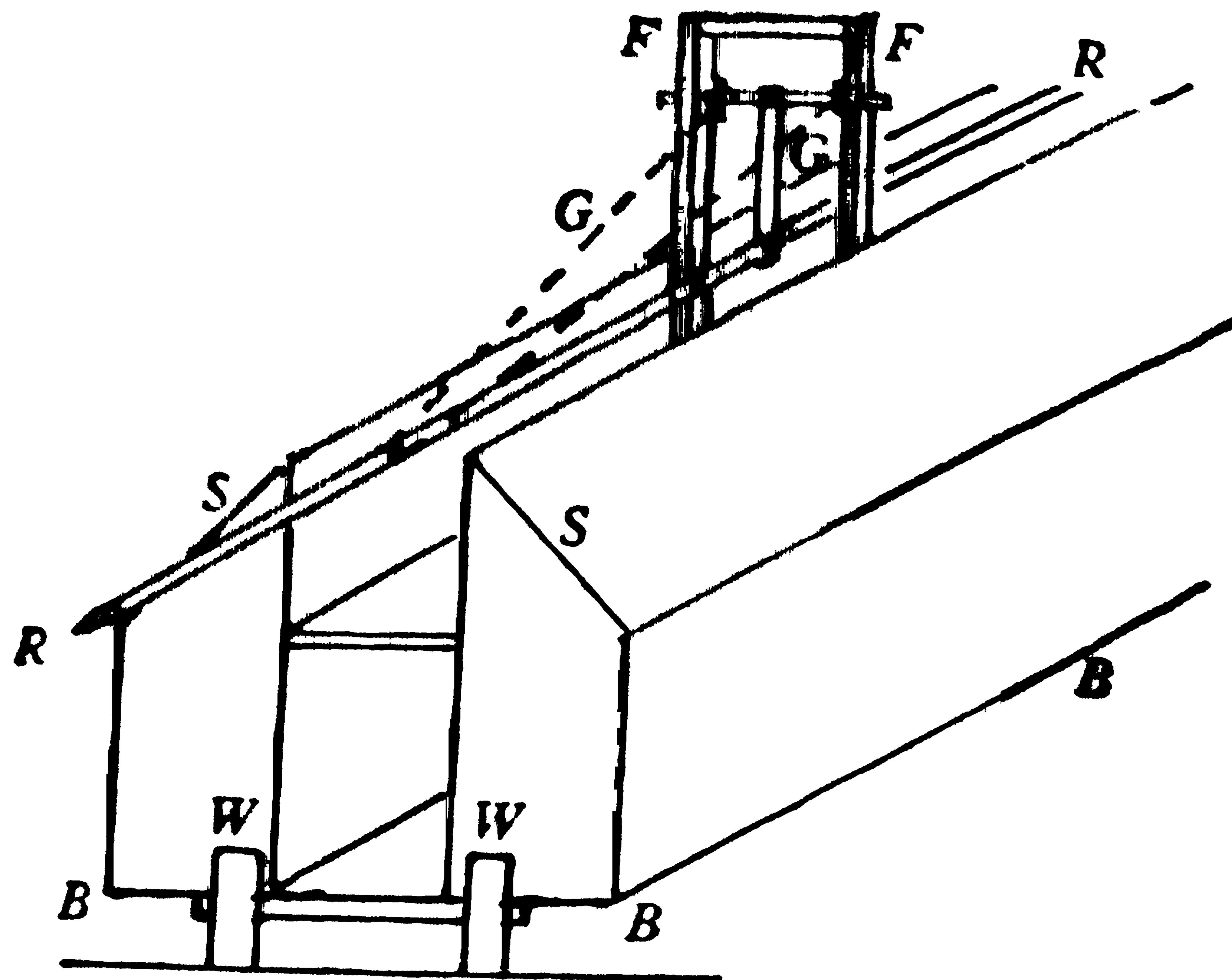
DIAGRAM OF BALISTA: BACK ELEVATION

BALISTA

Book X. xi.

- O. Channel inclined 45°.
- F. Frame.
- R. Ropes in tension.
- W. Windlass.
- S. Bowstring.
- M. Missile.
- H. Hook to release bowstring.
- T. Rope tightened by windlass.

PLATE T



FRONT ELEVATION AND ISOMETRIC PROJECTION

TORTOISE OF HAGETOR

Book X. xv.

F. Frame.
G. Guiding ropes.
R. Ram.

B. Base.
W. Wheels.
S. Sloping roof.

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