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33-42 minutes

(*b*. Italy, early first century B.C.; *d*. ca. 25 b.c.),

architecture, architectural history.

Life . For the facts of Vitruvius' life we are dependent almost exclusively on the internal evidence of his only known work, the treatise *De architectura*, In the manuscripts of this work and in references to it by other classical writers he is referred to simply by his family name *(nomen)*, Vitruvius, The attempt by Paul Thielscher to show that his full name was Lucius Vitruvius Mamurra, and to identify him with the Mamurra who served as chief engineer under Julius Caesar, is not generally accepted. There does not, on the other hand, seem to be any good reason to question the evidence of the late third-century writer Faventinus (see below) that his last name (*cognomen*) was Pollio.

The known facts of Vitruvius' career are that he worked in some unspecified capacity for Julius Caesar; that he was subsequently entrusted with the maintenance of siege engines and artillery by Caesar's grandnephew and adopted heir, Octavianus, later the Emperor Augustus; and that on retirement from this post he came under the patronage of Augustus' sister, Octavia (I, praef., 2). It is often suggested, on the evidence of Frontinus (*De aquis urbis Romae*, 25), that book VIII of *De architectura* may have been the fruit of personal experience as a hydraulic engineer during Agrippa's construction of the Aqua Julia in 33 B.C.; but Frontinus is in fact quoting Agrippa and Vitruvius as possible alternative sources for his information, and the relevant passages in Vitruvius contain some surprising technical errors. Vitruvius' only excursion into civil architecture was the building of a basilica at Fanum Fortunae, the modern Fano, on the Adriatic Coast (V, 1, 6–10). This commission, coupled with what appears to be a personal knowledge of many of the Roman cities in the Po valley (for instance, I, 4, 11; II, 9, 16; V, 1, 4), suggests that, like many of those prominent in the culture of Augustan Rome, Vitruvius may have been of north Italian origin. It should be noted that in the first century of the Christian era, a freedman of the same family, Lucius Vitruvius Cerdo, is named as architect of the Arch of the Gavii at Verona.

De architectura . Vitruvius' writings belong to the last period of his life (II, praef., 4). The books were all dedicated to his patron, octavianus, after the latter had achieved undisputed rule of the Roman world by his victory at Actium in 31 B.C. but before the title of Augustus, conferred on him in 27 B.C.,x had passed into general use. The later title is found only once (V, 1, 7), used in reference to a temple of Augustus (*aedes Augusti*) annexed to the basilica at Fano; otherwise he is addressed throughout as Caesar or *Imperator*. Moreover, although Vitruvius makes it clear that his patron was already launched on the great building program that was to change the face of Rome, the buildings specifically cited all belong to that program's earliest years.

De architectura comprises ten books, each with a separate preface. Book I, after a long introductory section defining the nature of architecture and the personality and ideal training of the architect, discusses town planning in very broad terms. Book II covers building materials (brick, sand, lime, stone, timber) and methods. Books III and IV are devoted to religious architecture and to a detailed discussion of the classical orders, and book V to other forms of public architecture, with special emphasis on the theater. Book VI deals with domestic architecture, and book VII with such practical matters as types of flooring, stuccowork, painting, and colors. Book VIII turns to the sources and transport of water, by conduit or aqueduct. After a long excursus on astronomy, book IX describes various forms of clocks and dials; while book X covers mechanics, with particular reference to water engines, a hodometer, and artillery and other forms of military engineering. The illustrations that accompanied the text had already been lost when the earliest surviving manuscripts were transcribed.

To modern readers this may seem a rather curious mixture of subject matter, but antiquity did not recognize the nineteenth-century distinction between architecture and mechanical engineering. The two available sources of architectural training were apprenticeship to an established builder or, as in the case of Vitruvius, service as a military engineer. Thus, the great Roman architect Apollodorus was equally at home building Trajan's Forum in Rome or bridging the Danube for his armies. The scheme of *De architectura* does in fact follow closely the tripartite subdivision of the subject enunciated in the introduction: on building *(aedificatio)* in books I–VII, on the making of timepieces *(gnomonice)* in book IX, and on mechanical devices (*machinatio*) in book X; hydraulics, which included both *aedificatio* and *machinatio*, bridges the transition in book VIII. Whether this classification was derived from some earlier authority, or whether it was Vitruvius' own, designed to embody his special interests, it would not have seemed illogical to a Roman reader.

As defined in book I, Vitruvius' architect is, according to R. Krautheimer. "a strangely ambiguous being… both a practitioner and a theoretician, and in the latter capacity a walking encyclopedia: versed not only in draftsmanship, geometry, and arithmetic but also in history, philosophy, and science, with a good smattering of musical theory, painting and sculpture, medicine, jurisprudence, astronomy and astrology." The theme of architecture as one of the liberal arts is ostentatiously picked up and dropped at intervals throughout the work, but at very few points can it be said seriously to illuminate the main subject matter. *De architectura* illustrates the range of scientific knowledge that might be available to a well-read professional man of Vitruvius' time: and it reflects what other, more critical minds held to be the ideal relationship between (to use a modern distinction) science and the arts. But in the context of a treatise on real architectural practice, it is little more than a pretentious literary exercise.

Any appraisal of the historical significance of Vitruvius' treatise has to begin by recognizing that his writings reflect the two distinct aspects of his architectural personality: the practitioner and the theoretician. The former is well represented, for example. in book II (on materials) and in book VII (on the techniques for laying floors and for finishing and decorating walls), both of which contain a great deal of practical information that would have been part of the stock in trade of any competent working builder. Without such knowledge Vitruvius would have been unable to handle the specifications for his basilica at Fano or to supervise the work on it. The mark of personal experience is revealed in his comments on such matters as the qualities of stone available around Rome and how to use them (II, 7); on the relative merits of the concrete building finishes known as *opus incertum* and *opus reticulation* (II, 8, 1); and, in a section that otherwise relies heavily upon the early Hellenistic writer Theorpharastus, his remarks on the qualities of the north Italian larch tree. At the same time, and very characteristically, Vitruvius shows no awareness of the larger significance of the concrete-vaulted architecture of which both *opus incertum* and *opus reticulatum* were manifestations; and from the list of earlier Italian architects whose opinions he would have valued (VII, praef., 17) he omits Lucius Cornelius, the trusted architect of the censor Quintus Lutatius Catulus, whose building of the Tabularium at Rome in 78 b.c. and whose restoration of the Temple of Jupiter Capitolinus, completed in 69 b.c., were among the most important and forward-looking architectural events of their time. Equally characteristic is his sweeping denunciation of contemporary trends in interior decoration (VII, 5, 5–8), as represented in the wall paintings of the Pompeian Second Style and their equivalents in Rome. His familiarity with contemporary building practice did not entail approval of contemporary architectural taste.

That Vitruvius' tastes were strongly conservative is unquestionable. He makes no attempt to conceal his contempt for the innovations introduced by many of his contemporaries. This fact has, however, led to much misunderstanding of the extent of his influence upon the architecture of his own time. It would seem natural to accept Vitruvius as a spokesman for the traditionalist architects of his day. He was living at a time when the forces of traditionalism and of innovation were still very evenly balanced, the former represented by the established formulas of column, architrave, and timber roof inherited from Greece and quintessentially present in the use of the classical orders, and the latter represented by the new, forward-looking, concretevaulted architecture of late Republican Latium and Campania. In a great many respects the monumental architecture of the Augustan age was a product of the lively creative dialogue between these two forces; and despite his staunch conservatism, Vitruvius could still have been a significant contributor to the great Augustan building program that in so many respects was to remain the touchstone of architectural excellence for centuries to come.

This view does not stand up to critical examination. Books III and IV, discussing temple architecture and the classical orders, are central to Vitruvius' own interests and to his conception of architecture; yet both in his selection and handling of source material it is evident that he is expressing a highly personal —and on many points a positively antihistoric —point of view. In the preface to book VII he quotes a number of earlier writings, almost exclusively in Greek and consisting largely of accounts of individual buildings written by their builders or treatises on particular aspects of architecture, such as proportions and machinery. He was probably right in claiming that no previous writer had tried systematically to encompass the whole field of architectural theory and practice; his own achievement, he claims, was the first really comprehensive study (*corpus architecturae*: II, 1, 8; see IV, praef., 1, *disciplinae corpus*). But in practice Vitruvius was very selective. His own preferred sources were Pythius, architect of the Mausoleum at Halicarnassus (fourth century b.c.) and, above all, Hermog-enes (active *ca*. 200 b.c.); and the models on which he constructed his own system almost exclusively used the Ionic order and were located in Asia Minor. If he had read, for example, Ictinus' account of the Parthenon, he can have had little sympathy with it; and in practice he disregarded it. The great Doric temple architecture of archaic and classical Greece is dismissed (IV, 3, 3) out of hand: "because of this [the difficulty of producing a consistent arrangement of triglyphs and metopes at the outer angles of the frieze] it seems that the ancients avoided the Doric order in their temples." In its place he does, it is true, offer a prescription (IV, 3, 3– 10) for laying out a Doric temple in accordance with his own modular principles —how else could he justify his claim to be presenting a conspectus of the whole of architecture?-but the result is patently an exercise in Vitruvian method, not an objective analysis of the work of the great historical masters.

It is this readiness to define perfection in quantitative terms, and to lay down finite laws governing planning and perfection, that constitutes the essence of Vitruvian method. The history of architecture is to be regarded as that of an evolution based on a series of revelatory discoveries leading to certain definitive achievements (*finitiones*) that it was Vitruvius' task to expound. In this view he was following a line of late Hellenistic thinking to which many educated Romans of his day would have subscribed. But whereas, for example, Cicero in *Deoratore* could see the possibility of a diversity of manifestations of perfection, Vitruvius' approach lacked any such flexibility. By imposing a system of strict numerical analysis upon his models, he contrived to reduce temple planning to a series of rules based on the "correct" dimensions of each constituent element relative to a constant module. There is no hint of awareness that this modular formulation of the laws governing the proportions of the orders is no more than a convenient device for classifying the infinite variety of real architectural practice. Modular planning was already a familiar concept, but there is nothing in the monuments to suggest that the precise forms propounded by Vitruvius were those actually used by contemporary architects. Many Augustan temples were pycnostyle, in the generalized sense that they had close-set columns (III, 3, 1-2); but none of those preserved was laid out in strict accordance with the Vitruvian formula. Again, many Augustan architects, like Vitruvius, were looking back to Greek models; but many of these models, among them the Erechtheum, were quite different from those preferred by Vitruvius. Even on his chosen ground Vitruvius was not in the mainstream of conservative trends in contemporary architectural thinking.

Vitruvius the theorist left little mark on the official Roman architecture of his time. To us this aspect of his writing is a valuable source of information about current intellectual attitudes toward the arts and sciences, and about many aspects of Hellenistic and late Republican architectural history; but his influence on subsequent Roman architecture seems to have been limited almost entirely to those parts of his work in which Vitruvius the architect and builder was speaking from personal experience. The best evidence for this lies in the works of two late Roman writers, Marcus Cetius Faventinus (*ca*. a.d. 300[?]), who wrote and annotated an abbreviated compendium of parts of *De architectura*, and the somewhat later Palladius, a wealthy landowner who made liberal use of Faventinus' compendium in compiling his own treatise on the management of a typical late Roman estate. Both of these authors were writing manuals for practical use, and both clearly regarded Vitruvius' work as the natural point of departure for their own. Their subject matter tells its own story. Apart from a ritual gesture to culture in Faventinus' introduction, what mattered to them were such things as finding and exploiting a water supply, the siting of domestic buildings, the best use of materials, the techniques of vaulting, and the method of constructing a set square or a simple timepiece. Traditional columnar architecture and the classical orders did not concern them. Such matters were past history.

During the Middle Ages very little of *De architectura* was relevant, but manuscripts of it continued to be copied in monastic scriptoria (the earliest one surviving was produced at Jarrow in the ninth century). In the fifteenth century, classical architecture suddenly became a matter of direct and lively concern to architects and humanists alike. Gian Francesco Poggio Bracciolini's "rediscovery" in 1414 of two manuscripts of *De architectura* was a major event. There was no printed edition until 1486, but there are more than twenty fifteenth-century manuscript copies, made for circulation among humanist scholars, architects, and artists. To the extent that the architecture of the Quattrocento represented a deliberate return to the models of antiquity, *De architecture*, the only surviving ancient treatise on the subject, was bound to become the ultimate authority for true doctrine. When Leone Alberti, between 1452 and 1467, wrote the first great Renaissance treatise on architecture, his debt extended even to the title used, *De re aedificatoria*, and to the work's subdivision into ten books; he wrote in Latin (a self-consciously "purer" Latin than the Hellenized Latin of Vitruvius); he cited Vitruvius frequently and borrowed from him even more frequently. Not that he always agreed with him: there are a great many criticisms, both expressed and implied, of principle and of detail. But for matters of historical fact, for such technical details as the making of bricks or the laying of pavements, for the classical orders, and for the description of a number of classical building types (such as palaestrae, theaters, and forums) about which the Quattrocento had little direct information, he drew heavily on Vitruvius.

Even so, Alberti's debt was often more one of formal presentation and of detail than of real substance. The genuine wish to use Vitruvius as a guide to building in the antique manner came up against formidable difficulties, among them the obscurities of Vitruvius' style, the loss of his illustrations, and the lack of surviving models. On many topics, Krautheimer states, "his book remained sealed, its terminology unintelligible, its references to building types and extant monuments obscure." Moreover, the shifts of intellectual attitude were often too great to be bridged by direct borrowing. However much *De re aedificatoria* may have set out to reshape *De architectura* for contempoary needs, it found itself turning more and more to the monuments of antiquity and to contemporary building practice. To be serviceable, the works of antiquity, monuments and writings alike, had to be interpreted, reconstructed, and, where necessary, improved, in accordance with the Quattrocento vision of antiquity.

In all of this Alberti, the great architectural theorist, was speaking also for the practicing architects of his day. Whatever its ultimate inspiration, Renaissance architecture had to chart a course of its own. Vitruvius continued to be a quarry of detailed information for would-be classical purists, but it was only among scholars that his authority as the source of pure doctrine remained virtually unchallenged. Because of his manifest admiration for Greek architecture, his reputation survived the shock of the subsequent rediscovery of Greece and of the great monuments of Greek classical architecture: indeed, the advent of systematic archaeological research in Italy, which might have supplied a corrective, seemed only to confirm the established opinion that the history of Roman imperial architecture was one of decadence and steady decline from the models of Greek perfection. Where the monuments did not fit the Vitruvius formulas — and few of them did —it was the monuments that were out of step, not Vitruvius. It is only during the twentieth century that a growing appreciation of the true qualities and significance of Roman imperial architecture has enforced a critical reevaluation of his reputation.

BIBLIOGRAPHY

I. Original Works. Critical editions of *De architectura* are V. Rose, ed. (Leipzig, 1899), the Teubner ed.; F. Granger, ed., with English trans., 2 vols. (Cambridge, Mass., 1945–1970), the Loeb Classical Library ed.; and C. Fensterbuch, ed. (Darmstadt, 1964). The Collection Guillaume Budé, with French trans, and full commentary, will run to 10 vols. and be published at Paris. Already issued are vol. VIII, L. Callebat, ed. (1973), and vol. IX, J. Soubiran, ed. (1969). In preparation are vol. II, A. Balland, ed.; vols. III and IV, P. Gros, ed.; vol. VII, P. Liore, ed.; and vol. X. L. Callebat, ed.

II. Secondary Literature. On Vitruvius' life and work in relation to the architecture of classical antiquity, the fundamental bibliographical article is P. Thielscher, in Pauly-Wissowa, *Realenzyklopädie*, 2nd ser., IX, A (1961). 427–489. This article must, however, be used with great caution to the extent that it identifies Vitruvius with Mamurra —a very questionable hypothesis. Other important works on the subject are F. E. Brown, "Vitruvius and the Liberal Art of Architecture," in *Bucknell Review*, **11** (1963), 99 ff.; P. Gros. "Hermodoros et Vitruve," in *Mélanges de l'École française à Rome: l'antiquité*. **85** (1973), 173 (ff.; and "Structures et limites de la compilation vitruvienne dans les livres III et IV du *De architectura,"* in *Latomus*, **34** (1975), 986– 1009; F. Pellati, "La basilica di Fano e la formazione del trattato di Vitruvio," in *Rendiconti della Pontificia Accademia romana di archeologia*, **23—24** (1947–1949), 153–174; H. Plommer, *Vitruvius and Later Roman Buildina Manuals* (London, 1973); H. Riemann, "Vitruv und der griechische Tempel," in *Archäologischer Anzeiger* (1952), cols. 2–38; and F. W Schlikker, *Hellenistischer Vorstellungen von der Schöheit des Bauwerks nach Vitruv* (Münster, 1940).

Vitruvius' reputation and influence on postclassical architecture are treated in W. B. Dinsmoor, "The Literary Remains of S. Serlio," in *Art Bulletin*, **24** (1942), 55 ff., esp. 55–61; R. Krautheimer, "Alberti and Vitruvius," in *The Renaissance and Mannerism*, II (Princeton, 1963), 42–52; H. Millon, "The Architectural Theory of Francesco di Giorgio," in *Art Bulletin*, **40** (1958), 257–261; H. Saalman, "Early Renaissance Theory and Practice in Antonio Filarete's Trattato," *ibid*., **41** (1959), 89–106; and R. Wittkower, *Architectural Principles in the Age of Humanism* (London, 1949; New York, 1965).

Jhon Ward-Perkins

Machines and Scientific Instruments . Although *De architectura* is widely cited as one of the very few classical texts that describes interesting machines and scientific instruments in any detail, and although the text also includes some astronomical material, the reader must be warned that the contents are not necessarily typical of the science and technology of the period. These matters are included either incidentally or as addenda to the main treatise on architecture, and constitute embellishments rather than a systematic account. Furthermore, there is some reason to suppose, from the few other texts (such as Hero) and from the artifacts that have survived, that Vitruvius knew only the practitioner arts of his day rather than the more sophisticated mathematics and theoretical astronomy. Even with the water clocks and sundials he may be reporting only a selection of the simpler devices. It should also be noted by historians of science and technology that in the sixteenth and seventeenth centuries Vitruvius was regarded as a living handbook rather than a historical text, and that early editions of the text include pictures of the machines and instruments reconstructed —and thereby popularized in the idiom and technical paraphernalia of the period rather than those of the time of Vitruvius.

At several places throughout the first eight books, Vitruvius draws upon standard Greek physical theory to provide a basis for the properties of materials, the nature of the elements and of climates, and the mathematical proportions governing harmony and pleasing design. The most important passage in these earlier books is, however, an account of the Tower of the Winds constructed in the Roman agora of Athens by Andronicus of Cyrrhus either very shortly before the time of Vitruvius or during his youth. The tower still stands with its frieze of the eight winds, its nine elaborate sundials, and the reservoir and other remains of the astronomical water clock within, the wind vane above, and an element theory symbolism as architectural design and internal furnishing.[1] Vitruvius introduces a description in the context of a discussion of the winds and their effect in the siting and orientation of buildings, and tells us that the octagonal tower was constructed as an exemplum of the eight-wind theory of Andronicus.

Book IX opens with discursive accounts of the Pythagorean theorem, the anecdotal bathtub discovery by Archimedes, and the Delian problem of the duplication of the cube, all used as illustrations of the cumulative power of ancient authors. In this light, Vitruvius says, he proceeds to an important exposition of gnomonics, the science of sundials. First, however, there is a section on the periods of the planets, the waxing and waning of the moon, and the constellations of the fixed stars.[2] The text then proceeds with the important first discussion of the principle of the analemma, which is used as a basis for much of later mathematical dialing. This geometrical construction has been analyzed and commented on by O. Neugebauer,[3] who also sets it in its context of the development of stereographic projection and its application to the anaphoric clock and then to the astrolabe.

In a much-quoted passage at the beginning of chapter 8, Vitruvius describes the chief varieties of sundials and names their inventors. This list has been matched against known and extant varieties of portable sundials by E. Buchner and by D. de S. Price, although still with some uncertainty.[4] The case for the fixed masonry sundials has become more certain since the publication of the corpus of such surviving dials by S. L. Gibbs.[5] Next follows an account of the water clocks of Ctesibius of Alexandria, in which an inflow pipe of gold or gemstone fills a cylinder with a float that can rise, working *parerga* and/or turning a dial through the action of a rack and pinion. Vitruvius discusses devices for controlling the water flow by wedgelike stopcocks or by using a sort of analemma to raise and lower the level of the output hole. He also considers the anaphoric clock, in which the seasonal variations in the length of day and night are exhibited by using an astrolabic (stereographic) projection of the heavens and the ecliptic that is turned by the water clock at a uniform rate.

The mechanical details of these water clocks have been discussed with admirable competence and thoroughness by A. G. Drachmann,[6] who also supplies the best commentary on the machines discussed in book X. Again, it must be noted that the older reconstructions and diagrams showing these machines and instruments are highly unreliable and should no longer be repeated. The book on machines opens with a discussion of simple and compound pulleys and on cranes using them in building construction, then treats levers in similar fashion. Next discussed are water-raising wheels, mill wheels, the Archimedean-screw water raiser, and the pump of Ctesibius. Chapter 8 describes the water organ, an example of which, somewhat dubiously reconstructed, has survived at Aquincum, near Budapest. Chapter 9 deals with the hodometer devices also described by Hero and considered by most modern commentators to be so unrealistic in their technical descriptions as to be fanciful and" theoretical "rather than accounts of actual working devices. This point is, however, no longer of the essence as evidence for the use of gear trains at this period of classical antiquity, since the evidence of the Antikythera[7] mechanism shows that much more complex gearing systems were known and utilized at this date.

The remaining chapters of *De architectura* deal in good technical detail with such military architectural machinery as catapults, ballistae, battering rams and other siege engines, and a pair of devices called" tortoises "for filling and digging ditches. In all of these the detailed criticism and reconstructions due to Drachmann may be regarded as authoritative, and supersede much of the earlier evaluations. For an account of the most recent studies, see the review by B. S. Hall of the books of E. W. Marsden.[8]

NOTES

1. D.de S. Price, "The Water Clock in the Tower of Winds," in *American Journal of Archaeology*, **72** (1968), 345–355, written with J. V. Noble. For an account of the symbolism, sec my chapter, "Clockwork Before the Clock and Timekeepers Before Timekeeping," in J. T. Fraser and N. Lawrence, eds., *The Study of Time, Proceedings of the Second Conference of the International Society for the Study of Time, Japan* (New York, 1975), 367–380; also in *Bulletin of the National Association of Watch and Clock Collectors*, **18** , no. 5 (Oct 1976). 398–409.

2. The astronomical sections are splendidly analyzed in O. Neugenauer, *A History of Ancient Mathematical Astronomy*, pt. 2 (New York-Heidelberg-Berlin, 1975).

3.*Ibid*., 843–845.

4. E. Buchner, “Antike Reiseuhren,” in *Chiron*, **1** (1971), 457–482; and “Römische Medaillons als Sonnenuhren,” *ibid*., **6** (1976), 329–348; and D. de S. Price. “Portable Sundials in Antiquity, Including an Account of a New Example From Aphrodisias,” in *Centaurus*, **14** , no. 1 (1969), 242–266.

5. S. L. Gibbs, *Greek and Roman Sundials* (New Haven London, 1976).

6. A. G. Drachmann, *The Mechanical Technology of Greek and Roman Antiquity* (Copenhagen-Madison, Wis.-London, 1963); *Ktesibios, Philon and Heron* (Copenhagen, 1948); and “Ktesibios’s Waterclock and Heron’s Adjustable Siphon,” in *Centaurus*, **20** , no. 1 (1976), 1–10.

7. D. de S. Price, “Gears From the Greeks, the Antikythera Mechanism—a Calendar Computer From ca. 80 b.c.,” *Transactions of the American Philosophical Society*, n.s. **64** , pt. 7 (1974); also published separately (New York, 1975).

8. B. S. Hall, “Crossbows and Crosswords,” in *Isis*, **64** (1973), 527–533

Derek de Solla Price

Sundials . Book IX ostensibly is concerned with the construction of sundials and clocks, which fell within the province of the architect in antiquity. However, in accordance with his claim that the complete architect must be familiar with astronomy (**I** , 1, 3 and 10), Vitruvius devotes a long section (**IX** , 1–6) to theoretical astronomy. Although the book would have been useless to a contemporary as a practical guide to the construction of time-measuring instruments (so muddled and incomplete is Vitruvius’ account, even when we allow for the corruption of the manuscript tradition), for us it provides much valuable historical information, particularly since no work on the theory of sundials has survived from antiquity. It also throws some light on the obscure area of pre-Ptolemaic astronomy.

After recounting some edifying anecdotes illustrating the importance of mathematical discoveries, Vitruvius attempts to describe the structure of the universe as conceived by astronomers of his time. The chief points of interest in his confused account are a possible reference to the theory that Mercury and Venus revolve about the sun (IX, 1, 6), some fairly accurate figures for the sidereal periods of the outer planets (IX, 1, 10), and a possible example of the notion that the absolute speed of all planets is the same. Vitruvius also retails some curiously primitive notions about the physical reasons for the phases of the moon and the retrogradations of the planets, and provides (IX, 3–5) a detailed but nonnumerical description of the relative positions of the chief constellations. A historical notice on the origin and progress of astrology precedes the real matter of the book, gnomonics and timekeeping.

The only practical information Vitruvius provides for the construction of sundials is his description of the analemma (IX, 7), a graphic method of determining the hour lines and day curves in a plane sundial with vertical gnomon. We have a treatise on the analemma by Ptolemy (*ca*. a.d. 150); but the invention of the method is due to Diodorus of Alexandria (first century b.c.), and Vitruvius’ description, although sadly incomplete, is a most valuable aid to reconstructing the original form of the theory, In Figure 1, *AB* represents the gnomon and *BC* the equinoctial shadow at a given place. The circle with center and radius *AB* represents the meridian, *DE* the celestial equator, and *LO* the local horizon. *BJ*

and *BK*, the lengths of the shadow at summer and winter solstices, are found by marking off the arcs *DF* and *DH* equal to ϵ, the obliquity of the ecliptic (Vitruvius takes ϵ as 1/15 of the circle, or 24°), and drawing *HAJ* and *FAK*. If these lines intersect the meridian circle in *G* and *R* respectively, then chords *FG* and *HR* (parallel to the equator *DE*) are the traces of the day circles of the sun at summer and winter solstice respectively. Half of these circles are drawn and rotated into the plane of the meridian, as *FPG* and *HQR*. The perpendiculars from the intersections of day circle and horizon, *NP* and *MQ*, cut off the arcs *FP* and

HQ, which represent half the length of daylight on the longest and shortest days respectively. The “civil hours” (1/12 the length of daylight) used in antiquity are determined by dividing these arcs into six equal parts. The day circle and civil hour length for any given date are found by means of an auxiliary circle *RSG*, on diameter *RG* (see Figure 2). Vitruvius explains how to construct this circle but not how to use it. If the sun’s longitude on the given date is λ, mark off the arc *ST* equal to λ on circle *RST*. and draw *TUXV* parallel to *DA*, intersecting the meridian in *U* and *V* and the horizon in *X*. The semicircle on diameter *UV* represents the sun’s path on the day in question, and *XW*, the perpcndicularfrom *X*, cuts off the half-day arc *VW;*[1] the civil hour lengths are again obtained by dividing this arc into six. The hour lines and day curves for a horizontal sundial

can then be derived graphically, although Vitruvius omits all explanation of the method.[2]

Vitruvius ends his discussion of sundials with a list of the types of sundial and their inventors. The historical value of this, although considerable, is diminished by his failure to describe any of the sundials named. However, comparison of the meaning of the names with preserved ancient sundials has permitted tentative identification of many types. All the inventors who can be identified belong to the Hellenistic period, with the exception of Eudoxus.

Vitruvius ends the book with an account of what he calls “winter clocks” (*horologia hiberna*), which tell time without the sun, or water clocks. His occasionally obscure description of the water clock of Ctesibius (third century b.c.), with its ingenious methods of ensuring a constant flow of water and of indicating the seasonal hours, is sufficiently detailed to allow modern reconstructions. He also describes the anaphoric water clock, which employed a dial rotating once daily on which the constellations were represented by stereographic projection, and in front of which was fixed a “spider” of wires forming the civil hour curves, also constructed by stereographic projection.[3] His description is useful in reconstructing the two examples of such a clock which have survived, fragmentarily, from antiquity.

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10. For a proof, see Neugebauer. 844–845.

11. For a modern explanation, see Drccker, 3-4.

12. This is exactly analogous to the astrolabe, except that the roles of “spider” (rete) and dial are reversed in the astrolabe. Vitruvius provides the earliest unambiguous evidence for the use of stereographic projection, the basic principle of the astrolabe.

BIBLIOGRAPHY

Jean Soubiran, ed., *Vitruve, De l’architecture, Livre IX* (Paris, 1969), provides a text and translation; the extensive commentary is useful but should be read with caution, since it contains some technical and many historical errors. On theoretical astronomy in Vitruvius, see Otto Neugebauer, *A History of Ancient Mathematical Astronomy* (New York-Heidelberg-Berlin, 1975), 782–784, and index; on the analemma, *ibid*., 839–857, esp. 843–845; and Joseph Drecker, *Die Theorie der Sonnenuhren* (Berlin-Leipzig, 1925), 1–11; and, on Ptoiemy’s version, P. Luckey, “Das Analemma von Ptolemäus,” in *Astronomische Nachrichten*, **230** (1927), 17–46. The only fully informed modern attempt to identify the sundials listed by Vitruvius is Sharon L. Gibbs, *Greek and Roman Sundials* (New Haven-London, 1976), 59–65, with full reference to preserved dials and descriptions of all known ancient sundials.

The best older discussion is Hermann Diels, *Antike Technik,* 3rd ed. (Leipzig-Berlin, 1924), 155– 192. For the identification of portable sundials named by Vitruvius, see D. de S. Price, “Portable Sundials in Antiquity,” in *Certaurus,*, **14** , no.1 (1969), 242-266. Reconstructions of the water clocks described by

Vitruvius are in Diels, 204-219; D, de S. Price, “Precision Instruments to 1500,” in Charles Singer, ed., *A History of Technology,* III (London, 1957), 601-605; and esp. A. G. Drachmann,*Ktesibios. Philon and Heron* (Copenhagen, 1948), 16–36. On the anaphoric clock in particular, see also Neugebauer, 869–870, with references (870, n. 5) to the literature on the fragments of clocks found at Salzburg and Grand (Vosges), France.

G. J. Toomer