CULTURAL INTERCHANGE OVER A WATER-CLOCK

IT once seemed almost self-evident that the extraordinary progress of Greek astronomy and mathematics in the Hellenistic age were, at least in part, the result of contact with Babylonian and Egyptian culture. But, whatever they may have owed to Babylonia in the exact sciences, there is now a growing consensus that even as early as Eudoxus the Greeks had advanced beyond the point where they might have profited from Egyptian help,[1] and it is not easy to find a solid basis for the widespread Greek belief in the superior wisdom of the Egyptian hierarchy. Yet the preface to the famous Calendar for the Saite nome, P. Hibeh 27,[2] provides circumstantial evidence that one Greek, at least, in the fourth or early third century B.C., found in Egypt an instrument for measuring the time at night which was new to him and which he may well have found impressive in its accuracy.

This evidence has no doubt escaped notice because the introduction to the Saite calendar appears at first sight to be merely so much jam round the repellently technical matter of the almanac. On palaeographic grounds the papyrus is dated to the early third century B.C.; the calendar itself, assuming that the observations on which it was based were reasonably accurate, suits the years between 313 and 298. The introduction (frg. a) begins thus: . . . *ἐ]ν Σάι πάνυ ἀνὴρ σοφὸς καὶ ἡμῶν χρείαν ἔχων. ἔχομεν γὰρ τὸν Σαίτην νομὸν ἔτη πέντε. πᾶσαν οὖν τὴν ἀλήθει[αν] ἡμῖν ἐξετίθει καὶ ἐπὶ τοῦ ἔργου ἐδείκνυεν ἐ[κ το]ῦ ὅλμου τοῦ λιθίνου [ὃς ἐκ]αλεῖτο Ἑλληνιστὶ [γν]ώμων.* There follows a summary of the Saite astronomer's system, which includes some coincidences with the Paris papyrus known as the *Ars Eudoxi* (Pack[2] 369), which, however, probably preserves only a miserable remnant of the genuine work of Eudoxus. Grenfell and Hunt inferred that the Saite astronomer was a pupil of Eudoxus. If so, the emphasis on his long-standing acquaintance with the author seems a shade odd; there is a suggestion of a certain mystique, of information not to be lightly imparted, which one would not expect to find in connection with the doctrines of a scientist whose writings enjoyed a wide diffusion. Wilcken (*A.P.F.* iv [1908], 108 f.) was surely right to see here an Egyptian astronomer;[3] as he realized, this suits the curiously awkward way in which the apparatus

[1] Cf. Neugebauer, *The Exact Sciences in Antiquity*[2]. p. 151.

[2] Pack[2] 2011 (but the entry contains an error: there is no reason to think this a school text). The continuous numeration of fragments and columns is slightly misleading, as the calendar itself is written in a different hand from the introductory matter of frg. a; it is not absolutely certain that both come from a single work, though there seems no doubt that all the fragments concerned belong to the same roll.

[3] 'Ich möchte eher an den typischen ägyptischen "Weisen" denken, wie er häufig als Lehrer von griechischen Gelehrten in der Tradition begegnet.' This perhaps needs some qualification, since 'typical Egyptian sages' have a long, and not altogether creditable, literary history, both in antiquity and in modern times: the alleged *Überlieferungsgeschichte* of the Book of Mormon is a familiar instance of this appeal to the authoritative wisdom of Egypt to commend esoteric doctrines. However, the convenience of an observational device and the accuracy of the information obtained with it are things which the interested reader might be expected to verify for himself; there is no point in investing either with a bogus Oriental glamour. The wise man of Sais surely represents a genuine Egyptian source.

used is named: 'so beschränkt sich der Grieche hier zwar auf den griechischen Namen, aber seine Worte lassen doch durchscheinen, dass der Weise ihm den Gnomon auch *Αἰγυπτιστί* genannt hatte.'

γνώμων in Greek is not much more specific than 'gauge', 'indicator', or 'marker' in English;[1] Grenfell and Hunt translated the phrase 'the stone dial which is called in Greek a "gnomon" ', but this is not quite right, as is clear from two other papyri concerned with astronomical topics. P. Oslo 73 (Pack² 2021), of the late first or early second century, describes a method for determining the apparent diameter of the sun by the use of a water-clock,[2] which should be constructed thus: *κατα[σκευά]σαντες δὲ καὶ ἀγγεῖον ὅλμωι [παραπλήʃσιον καὶ τούτου τρήσαντες* κτλ. P. Oxy. 470 (Pack² 2044), of the third century A.D., gives a detailed account of the procedure for making such a vessel: *τὸν δὲ τῶ[ν ὡ]ρολογίων ἀριθμὸν τῆς [κα]τασκευῆς οὕτως ἀ[πο]διδόασιν, τὸ μὲν ἄνω ὁλμίσκου δακτύλων [κδ] ποιοῦντες, τὸν δὲ πυθμέν[α] ιβ δακτύλων, τὸ βάθος δ[α]κτύλων ιη.* The calculations become more complex, but the result would be the shape of a bucket or plant-pot; the ancient theory evidently was that in a vessel constructed according to these proportions the water-level sank equal heights in equal times (which is not in fact true). This latter text also preserves an astronomical explanation of an Egyptian board-game,[3] and it is hard to imagine what link any Greek could have seen between these two items unless both emanate from an Egyptian source and illustrate the methods of Egyptian astronomy. Such, one might suppose, were *τὰ ἀστρολογούμενα τῶν Ἑρμοῦ βιβλίων* mentioned in Clement's description of Egyptian priests in procession (*Strom.* 6. 4);[4] Plutarch (*de Iside* 61) in fact cites 'the so-called books of Hermes' in terms which suggest a translation had been made.

[1] The entry in L.S.J. obscures the generality of the term with a multitude of separate categories giving interpretations for particular contexts (though an omnium gatherum-sense of 'index, mark' (II. 5) is included). Certainly there is no evidence that before the Hellenistic period *γνώμων* without further qualification could be used to refer specifically to the gnomon of a sundial.

[2] For a similar experiment *διὰ τῶν ὑδρολογίων*, cf. Cleomedes 2. 1. 75 (p. 136 Ziegler); he concludes *λέγεται δὲ ἡ τοιαύτη ἔφοδος ὑπὸ πρώτων τῶν Αἰγυπτίων ἐπινοηθῆναι.* Similarly Macrobius (*Comm. in Somn. Scip.* i. 21. 12 ff.) explains how the Egyptians used the water-clock to divide the zodiac into twelve equal parts.

[3] Cf. Pieper, *Zeitschr. f. Äg. Sprache*, lxvi (1931), 16 ff., Gwyn Griffiths on Plut. *de Iside* 12. Odd though such exegesis may seem at first sight, this is not an isolated case. Pieper describes another Egyptian interpretation of (almost certainly) the same game in terms of a journey through the underworld; an astral interpretation of the game of *τάβλα* is found in several Byzantine writers: see Lamer, s.v. *lusoria tabula*, *R.E.* xiii, col. 1904, where similar (perhaps related) Arabic interpretations of the game of *nard* are also mentioned. This was not a peculiarly Levantine mode of thought: for a tenth-century British attempt to find a scriptural sense in the popular Germanic game of *hnefatafl* see H. J. R. Murray, *A History of Board Games other than Chess* (1952), pp. 61 ff.

[4] *μετὰ δὲ τὸν ᾠδὸν ὁ ὡροσκόπος, ὡρολόγιόν τε μετὰ χεῖρα καὶ φοίνικα ἀστρολογίας ἔχων σύμβολα, πρόεισιν. τοῦτον τὰ ἀστρολογούμενα τῶν Ἑρμοῦ βιβλίων τέσσαρα ὄντα τὸν ἀριθμὸν ἀεὶ διὰ στόματος ἔχειν χρή, ὧν τὸ μέν ἐστι περὶ τοῦ διακόσμου τῶν ἀπλανῶν φαινομένων ἄστρων, τὸ δὲ περὶ τῆς τάξεως τοῦ ἡλίου καὶ τῆς σελήνης καὶ περὶ τῶν πέντε πλανωμένων, τὸ δὲ περὶ τῶν συνόδων καὶ φωτισμῶν ἡλίου καὶ σελήνης, τὸ δὲ λοιπὸν περὶ τῶν ἀνατολῶν.* The *ὡρολόγιον* carried by the 'observer of hours' was surely a water-clock, not a portable sundial; though the word can denote either, the latter is not much use to an astronomer. The other *σύμβολον* of his craft is presumably functional too: a straight palmrib with a V-shaped slot cut in the wider end was used by the Egyptians as a sighting instrument, and known as *bay* (*en imy unut*), 'palm-rib (of the observer of hours)'. This is conveniently illustrated in I. E. S. Edwards, *The Pyramids of Egypt*² (1961), p. 259, fig. 54.

The *γνώμων* of P. Hibeh 27 is, then, a water-clock. Theophrastus too used the word in this sense (fr. 109, ap. Ath. 2. 42 b, from a discussion of the peculiarities of water in various places): *συστέλλει δὲ αὐτὸ καὶ πυκνοῖ μᾶλλον τὸ ψῦχος. διὸ καὶ ἐν τοῖς γνώμοσι ῥέον οὐκ ἀναδίδωσι τὰς ὥρας ἐν τῷ χειμῶνι, ἀλλὰ περιττεύει βραδυτέρας οὔσης τῆς ἐκροῆς διὰ τὸ πάχος. καὶ ταὐτὰ περὶ Αἰγύπτου φησίν, ὅπου μαλακώτερος ὁ ἀήρ.*[1]

Yet the *κλεψύδρα* is one of the most memorable features of fifth-century social life: what was so new about a water-clock? The Athenian *κλεψύδρα*, first attested in Aristophanes (*Ach.* 692, *V.* 93),[2] was a relatively simple device no more subtle than an egg-timer, mainly used as an inducement to concision in the law-courts (cf. Arist. *Ath.* 67). A bucket-like vessel discovered in the agora, in an undisturbed well-deposit of *c.* 400 B.C., has been identified as a *clepsydra*: see Young, *Hesperia* viii (1939), 274–84; it was found to discharge its contents in six minutes. A reference in Aeneas Tacticus (22. 24), who recommends the use of *clepsydrae* to ensure the fair distribution of watches among the troops, implies a rather larger vessel, but the principle is still that of the simple timer, not of a clock. He suggests adjusting it to the shorter nights of summer by coating the inside with wax, which may be gradually removed as the nights grow longer; this ingenious modification surely implies that he did not know of any more advanced device for measuring the time.[3] But in Egypt water-clocks designed to mark the hours of the night at any season had been in use for centuries: the earliest example is a splendid alabaster vessel from Karnak, dated to the reign of Amenhotep III (early fourteenth century), which has often been reproduced.[4] We even have the autobiographical grave inscription of Amenemhet, court astronomer to Amenhotep I, who, with justifiable pride, claims to have invented the device;[5] mythologically the credit went to Thoth. Unlike other types of Egyptian clock, shadow-clocks and astral clocks, this could be constructed on independent principles and does not presuppose the existence of some other means of measuring the time. The system of marking the hours (an hour being simply a twelfth part of the night, not a unit of fixed length) assumed a constant rate of increase and decrease

[1] On Theophrastus' visit to Egypt, see Capelle, 'Theophrast in Ägypten', *W.S.* lxix (1956), 173 ff.

[2] The word itself occurs earlier, in Empedocles (fr. 100, 9), where, however, it means an instrument like a pipette. The sense of 'water-clock' sounds as if it originates in slang and the orators obviously prefer expressions with *ὕδωρ* when they have to refer to it. The word *κλεψύδρα* is also conspicuous by its absence from an inscription of Iasos (Hicks, *J.H.S.* viii [1887], 103), dated to the early third century B.C., which gives a detailed specification for the construction of such a device.

It should incidentally be noted that the Babylonians too used an instrument of this type; it is attested in certain problems of the kind which modern arithmetic books, with a distracting lack of verisimilitude, express in terms of wild extravagance with bath-water: see Thureau-Dangin, *Revue d'assyriologie*, xxix (1932), 133 ff. But again, this seems fairly primitive. There is no reason to suppose that the Greeks owed their *clepsydra* to the Babylonians (unless that was what Herodotus meant by *γνώμων* at 2. 109).

[3] A water-clock of a sort is ascribed to Plato according to Aristocles *περὶ χορῶν* ap. Ath. 174 c: *λέγεται δὲ Πλάτωνα μικράν τινα ἔννοιαν δοῦναι τοῦ κατασκευάσματος νυκτερινὸν ποιήσαντα ὡρολόγιον ἐοικὸς τῷ ὑδραυλικῷ οἷον κλεψύδραν μεγάλην λίαν.* It does not sound very sophisticated. I owe this reference to an anonymous referee.

[4] See, for instance, Sloley, *J.E.A.* xvii (1931), Plates xix, xx, xxi, *Ancient Egypt* (1924), p. 43; Borchardt, *Altägyptische Zeitrechnung*, Taf. 1; Neugebauer and Parker, *Egyptian Astronomical Texts* iii (1969), Plate 2.

[5] See Sloley, *Ancient Egypt* (1924), p. 45, Borchardt, op. cit., pp. 60 ff.

from month to month, an approximation which we still find in the Calendar of P. Hibeh 27 (though the latter expresses the varying lengths of day and night in terms of equinoctial hours).

The inscription of Amenemhet uses the word *merkhet* for this device. *Merkhet*, literally 'instrument of knowing', was a fairly general term, applied to all three kinds of clock, even though they each had individual names;[1] it corresponds to γνώμων very neatly.

I would not suggest that the tutorial at Sais described in P. Hibeh 27 marks a decisive point in the development of Greek horology; in an age before patents and scientific journals some Greeks will have known about these things before others, and there is, in any case, a great difference between knowing how to use such a gadget and understanding the principles involved in constructing one: for any given model there would, after 120 years, be a discrepancy of a month between the month names engraved on the rim and the scales of the clock which give the time, and though this can be easily repaired, it means that simple reproduction, without a knowledge of the basic theory, would only bring short-term profit. No doubt if Hero's περὶ ὑδρίων ὡροσκοπείων had survived, we should have a clearer picture of the way in which progress was achieved. But it seems undeniable that the Greeks of the age of Eudoxus, and perhaps for some generations subsequently, could have improved their techniques for measuring the passage of time under Egyptian instruction, and that from the Hellenistic age more satisfactory clocks (both sundials and water-clocks) are well attested. The Greeks took over the Egyptian calendar; it looks as if they owed something to Egypt in the measurement of smaller units of time too. Though such gadgetry may seem relatively humble to the historian of science, it is not surprising if the Greeks of the fourth century were impressed by it.

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[1] Cf. Edwards, op. cit., pp. 257 f., Z. Žába, *L'Orientation astronomique dans l'ancienne Égypte et la précession de l'axe du monde* (Prague, 1953), 56.