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ναυσὶ δ᾽ οὔτε πεζὸς ἰὼν κεν εὕροις
ἐς Ὑπερβορέων ἀγῶνα θαυμαστὰν ὁδόν

(Pind. *Pyth.* 10. 29–30)

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CONSPECTUS

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THE SIXTH-CENTURY SAMIAN FOOT OF 26.25 cm AND EVOLUTION OF THE GREEK LINEAR MEASURES

Deducing a Samian foot of 26.25 cm (for which there is no direct evidence), I rely on the data published by Hermann J. Kienast, who presents the results of the archaeological research of the famous tunnel in Samos which was built in the sixth century by Eupalinus.[1] Herodotus, our main source, reports the measurements of both the tunnel and the canal inside it. Two of his measurements are expressed in terms of feet. He observes that both the height and the width of the tunnel equal 8 feet and that the width of the canal is 3 feet (3. 60. 2).

Kienast informs us that both the height and the width of the tunnel measure 2.10 m. What was then the length of a foot used in constructing Eupalinus' tunnel? Kienast assumes that Herodotus meant either a foot of 34.95 cm (called by him 'Samian') or a foot of 29.5 cm (which he referred to as the 'Attic'), and this makes 2.80 or 2.36 m, respectively. Then Kienast compares the results with the actual dimension, 2.10 m for both the height and width, which allows him the choice in favour of an 'Attic' foot.[2] But this is a strange conclusion. I need not emphasize that the difference of 26 cm nearly amounts to a whole foot. What is essential is that the difference does not constitute a half or any other simple fraction of the chosen unit of measure. For one can construct anything of equal height and width either by applying exactly the same measure, or by applying a common measure the same number of times. Therefore the only reasonable way to obtain the value of a foot used in constructing Eupalinus' tunnel is by dividing 2.10 m by eight, as reported by Herodotus. This yields a foot of 26.25 cm.

Another relevant measurement in terms of feet agrees well with the obtained result. According to Herodotus, the width of the canal is 3 feet, which comes to either 1.05 or 0.89 m on the two options selected by Kienast and 0.79 m on my proposal ($26.25 \times 3 = 78.75$ cm). The true size is 0.80 m.

[1] Kienast 1995.

[2] Kienast 1995, 173 and Pl. 5.

Moreover, our result is consistent with another piece of data concerning Eupalinus' construction. Herodotus (3. 68. 1) says that the tunnel was driven through the base of a mountain one hundred and fifty *orguiai* high. The actual height of the mountain is 237.50 m. According to the classic metrological passage by Herodotus, "the *orguia* measures six feet" (2. 149. 3). One can say, then, that the mountain is nine hundred feet high. Now, 26.25 cm × 900 = 236.25 m, which is very close to the actual height of the mountain.

Furthermore, the measure we recover, a Samian foot of 26.25 cm, is nothing but a half of a well-known Samian cubit. Herodotus equates the Samian cubit with the Egyptian (2. 168. 1), and according to a standard view, based on a number of measurements, the Egyptian (royal) cubit was 52.5 cm.[3] The use of both the Samian cubit and its half is traceable in the architecture of another magnificent construction of six-century Samos, the Heraion.[4] Practically the same cubit of 52.3 cm or so was also established for the Artemision of Ephesus.[5]

Both the cubit in question and its half can be detected at one more glorious construction of the sixth century. Now we turn to Babylon. The excavations of the eastern wall of Nebuchadnezzar II reveal that its towers were erected 52.50 m apart, that is, at the distance equivalent to 100 cubits. The width of these towers is found to have been 8.37 m, while classical authors (who obviously provide the largest dimension, that is, of wall towers) report 32 feet (Strab. 16. 1. 5; Curt. Ruf. 5. 1. 25), and 26.25 cm × 32 = 8.40 m.[6]

The six-century Samian foot of 26.25 cm appears thus as an element of a larger system. There is something to say about this system. First, it is truly body-based since an average foot of a real Greek man would range from

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[3] See Helck 1980. Measurements reveal some variations, yet "the length of the royal cubit (52.5 cm) can only vary between 52.1 and 52.9 cm" (Hirsch 2013, 50). Hirsch 2013, 125 mentions also *Great Span* as "a division of the royal cubit with the length of half a royal cubit (26.25 cm)".

[4] Reuther 1957, 55: "Die Gesamtbreite des Tempels ergibt sich aus den sieben Einzelinterkolumnien mit 52,450 m aus der Verdoppelung des mit mit 26,221 m gemessenen Abstandes der stehenden Säule von der Mitte des Pronaosmittelschiff mit 52,442 m. Eine Messung, die ich mit Scheif im Sommer 1927 durchführte, gab als Resultat 52,446 m". On common assumption that the temple measured 100 cubits, Reuther arrives at 52.446 cm for the length of a Samian cubit (*ibid*., 58).

[5] Bammer 1972, 44 n. 40. Bammer, *ibid*., notes also the use of a half-cubit of 26 cm at Halicarnassus.

[6] I take the dimensions from Unger 1970, 62. Unger offers no metrological interpretation of numbers. Nor did I notice any reflection of this data in otherwise very informative article "Maße und Gewichte" by M. A. Powel 1987–1990, 462–476.

26 to 27 cm.[7] Second, it implies a ratio of 2 : 1 between the cubit and the foot. Third, it employs a foot easily compatible with such a measure unit as the pace: three feet of 26.25 cm make 78.75 cm, which is quite a fair estimate of an average pace. The well-known later system displays none of these features. The pace, so familiar to us from the Roman system of measures, is absent in the standard Greek one.[8] Moreover, Herodotus (2. 149. 3) speaks of "the *orguia* measuring six feet or four cubits"; hence the cubit and the foot are in a ratio of 3 : 2 and not of 2 : 1. Both direct evidence, such as unearthed metrological reliefs, as well as numerous measurements of the remains of Greek temples and stadiums have revealed a number of standard lengths for a Greek foot. They lie within a diapason between 29.4 and 32.8 cm. For instance, the length of the stadium in Olympia was 192.28 m, which means that the Olympic foot was 192.28 m : 600 = 32.047 cm. The Oxford metrological relief (about the middle of the fifth century BC) has a foot of 29.6 cm. The metrological relief from Salamis (about the middle of the fourth century BC) shows a rule corresponding to a foot of 32.2 cm and also a foot of 30.1 cm.[9] It is easy to see that a ratio of 2 : 1 between the cubit and the foot no longer fits with any standard value for a foot as it is known from the fifth century onward (for a cubit over 60 cm is neither body-based nor implied in the sources), that the new standard feet imply man's height of about 192 to 208 cm and that three of such feet would yield an exceedingly long pace. Since the measurement seems to indicate that the monuments of the fifth and subsequent centuries in Asia Minor follow general pattern, we are dealing with two different systems and not just with regional variations.[10]

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[7] Assuming 6.5 : 1 as a standard ratio between man's height and the length of a foot. The data for the average height of Greek males for the period 600–300 BC is neither abundant nor uniform, but sufficient for our purpose. According to the best authorities, it was 170.5 cm (Bisel 1985, 203 and Table 4; Kron 2005, 72). According, however, to more numerous data (though confined to the particular area of the ancient Metapontion), it was between 162 and 165 cm (see Schwartz 2013, 167).

[8] Hultsch 1882, 37: "Von Griechen findet sich der Schritt nirgends als eigentliches Längenmass erwähnt, obgleich es sicher ist, dass bei ihnen die Entfernungen zumeist nur durch Ausschreiten bestimmt worden sind".

[9] Dekoulakou-Sideris 1990.

[10] One more feature of the earlier system can be recovered with some probability: it employed the simple rather than the double pace. Otherwise it would have been easy to retain the pace through equating five feet of the new standards to one double pace (as in the Roman system). It may be characteristic that Heron (3. 9) defines once the *stadion* as 240 paces, that is, simple paces (Hultsch 1864, 186). One may also guess that the *orguia* of the six-century Samian system might have measured 8 rather than 6 feet. For the *orguia* of the Oxford metrological relief is 2.09 m (Fernie 1981), and this value is practically identical with both the height and the width of Eupalinus' tunnel, that is, 2.10 m or 8 feet (according to Herodotus). Samian provenance of the Oxford

David Gilman Romano suggested, based on the measurement of archaic and classical building in Corinth and Isthmia, the foot length of 0.269 m.[11] I have not seen Romano's PhD thesis he refers to. However, I also found a very similar foot of 0.268 m (or 26.75 cm) in archaic Corinth and Isthmia in my own way.

In his meticulous study concerning the length of the foot employed by early Peloponnesian architects, Oscar Broneer conveniently assembled the relevant data within a single table.[12] That table suggests that the stylobate of the archaic temple at Corinth, commonly known as the Temple of Apollo (*ca*. 545 BC), had a length of 168 Olympic feet of 0.3204 m and a length of the cella of 129 Olympic feet and that the same parameters for the Temple of Poseidon II at Isthmia (470–460 BC) appear to be 167 and 116 Olympic feet, respectively. Brooner observes that the stylobate length of the temple of Apollo, measured by several scholars, "varies from 53.82 m (Stillwell), to 53.66 m (Blouet), to about 53.30 m (Dörpfeld); and Stillwell suggests that Blouet's measurement, which was made before the earthquake of 1858, may be more reliable than his own". He further notes that "quite independently of these figures the temple of Poseidon at Isthmia has been restored with a stylobate length of 53.50 m", and then concludes: "Since the calculated stylobate length of the two Temples at Corinth and Isthmia is so nearly the same, it is likely that the later Temple at Isthmia was intended to have the same length as that of the Corinth temple; and it is quite possible that the two had exactly the same length of the stylobate".[13] Such a conclusion is hardly subject to doubt, but I propose that both temples were laid out to have a length of 200 rather than 168 feet.

We saw that the temple of Hera in Samos had a width of 52.446 m, or 100 Samian cubits. Since we detected in Samos that a contemporary foot is equal to a half of such a cubit, we are justified to say that the Temple of Hera was of 200 feet in width. Since 52.446 m is very close to 53.50, the calculated length of the two temples at Corinth and Isthmia, one may suppose that the intended length of the both was also 200 feet. Further, the stylobate of the temple of Zeus in Olympia (*ca*. 470–460 BC) measures 64.08 m,[14] that is, exactly 200 Olympic feet.[15] Moreover, 64.08 m of the

metrological relief because of its implied use of the Samian cubit was supposed by Fernie (*op. cit*.) and much earlier by Michaelis 1883.

[11] Romano 1993, 50 n. 21.

[12] Broneer 1971, 179.

[13] Broneer 1971, 178.

[14] Hennemeyer 2015, 24; Brooner 1971, 179 gives 64.12 m.

[15] Hennemeyer 2015, 23; Sonntagbauer 2015 speaks instead of 196 Pheidonic feet, as he consistently claims that the race-course in Olympia measured 588 (Pheidonic) and not 600 feet, but this is difficult to accept.

Temple of Zeus cannot be said to measure 100 cubits.[16] It seems to follow that an idea of a 200 feet temple was popular. Now, 53.50 m divided by 200 gives 26.75 cm for a foot.[17] As the Samian foot specified above, this Corinthian (or Isthmian) foot is really body-based, easily compatible with such a measure unit as the pace and belongs to a system in which a cubit can be equal to 2 feet. We see again that the six-century Samian foot is not an isolated phenomenon.

There are several other signs that the Greek system of length measures was a matter of change. For instance, Aristoxenus asserts that Pythagoras introduced measures among the Greeks (D. L. 8. 14 = fr. 24 Wehrli). Whatever the precise value of such a surprising testimony from a not very reliable source, it implies an idea of a reform of measures, say, in the late third of the sixth century.

The Greeks were obsessed with athletics. One may suppose that the reconstruction of Greek stadiums in the atmosphere of both growing interest in athletic competitions and economic growth characteristic for the late archaic and early classical epoch caused the change in the system of measures. Stadiums were extended to give place to more spectators, and, since each stadium was 600 feet long by definition (cf. Hdt. 2. 149. 3), the foot was extended accordingly.

There is something to support this guess.

Most excavated stadiums do not essentially differ in length from the Olympic stadium. It seems, however, there was a time when the stadium in Olympia did already acquire the length of 192 m, while other stadiums were significantly shorter. Aulus Gellius (*Noct*. *Att*. 1. 1–2) tells us the story of how Pythagoras determined the height of Heracles. On an assumption that Heracles measured the stadium in Olympia with his own feet, Pythagoras, following the principle of proportionality, concluded that Heracles was as much taller than average man as the stadium in Olympia was longer

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[16] No cubit of the corresponding length, 64 cm, is known (see Hultsch 1882, 45–48). This is not surprising since a body-based cubit, as the distance from the elbow to the tip of the middle finger, would have been about 45–47 cm.

[17] It may seem, however, that Broneer's choice of the Olympic foot is supported by measurements of Isthmian Temple of Poseidon I (700–650 BC). His table gives 40.024 m and 32.084 m for the length of its stylobate and cella, respectively. Expressed in Olympic feet, these figures turn out to be almost exactly 125 (40.05 m) and 100 (= 32.04 m). Yet with a foot of 26.75 cm, we obtain an equally suitable result, that is, of 150 and 120 feet for the corresponding measurements (26.75 cm × 150 = 40.125 m and 26.75 × 120 = 32.10 m). Moreover, these both numbers are multiples of six, and six feet equal one *orguia*. As Brooner notes, a modulus of one *orguia* "would have been of convenient length for architects and masons to use in layout and construction" (Brooner 1971, 180).

than other ones (*tanto fuisse quam aliores procerius, quanto Olympicum stadium longius esset quam cetera*). Indeed, the length of the race-course at the late six-century stadium in Corinth was between 158 and 165 m.[18]

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Bibliography

A. Bammer, *Die Architektur des jüngeren Artemission von Ephesos* (Wiesbaden 1972).

S. C. Bisel, J. L. Angel, "Health and Nutrition in Mycenaean Greece: A Study in Human Skeletal Remains", in: N. Wilkie, W. D. E. Coulson (eds.), *Contributions to Aegean Archaeology: Studies in Honour of William A. MacDonald* (Minneapolis 1985) 197–209.

O. Broneer, *Temple of Poseidon = Isthmia* I (Princeton 1971).

I. Dekoulakou-Sideris, "A Metrological Relief from Salamis", *AJA* 94 (1990) 444–451.

E. Fernie, "The Greek Metrological Relief in Oxford", *The Antiquaries Journal* 61: 2 (1981) 255–263.

A. P. Hirsch, *Ancient Egyptian Cubits – Origin and Evolution*. PhD thesis. University of Toronto (Toronto 2013).

W. Helck, "Masse und Gewichte", in: *Lexikon der Ägyptologie* III (Wiesbaden 1980) 1199 ff.

A. Hennemeyer, "The Temple Architecture and its Modification during the 5th Century BCE", in: A. Patay-Horváth (ed.), *New Approaches to the Temple of Zeus at Olympia. Proceedings of the First Olympia-Seminar 8th–10th May 2014* (Cambridge Scholars Publishing 2015) 16–38.

F. Hultsch, *Griechische und Römische Metrologie* (Berlin ²1882).

F. Hultsch, *Metrologicorum scriptorium reliquae* I (Lipsiae 1864).

H. J. Kienast, *Die Wasserleitung des Eupalinos auf Samos*, Deutsches Archäologisches Institut. Bd. 19 (Bonn 1995).

G. Kron, "Anthropometry, Physical Anthropology, and the Reconstruction of Ancient Health, Nutrition, and Living Standards", *Historia* 54: 1 (2005) 68–83.

A. Michaelis, "The Metrological Relief at Oxford", *JHS* 4 (1883) 335–350.

M. A. Powel "Maße und Gewichte", in: *Reallexikon der Assyriologie* 7 (Berlin – New York 1987–1990) 457 ff.

[18] Romano 1993, 43, 49 f.

O. Reuther, *Der Heratempel von Samos* (Berlin 1957).
D. G. Romano, *Athletics and Mathematics in Archaic Corinth: The Origins of the Greek Stadion* (Philadelphia 1993).
W. Sonntagbauer, "Metrologisches in Olympia", in: A. Patay-Horváth (ed.), *New Approaches to the Temple of Zeus at Olympia. Proceedings of the First Olympia-Seminar 8th–10th May 2014* (Cambridge Scholars Publishing 2015) 56–73.
A. Schwartz, "Large Weapons, Small Greeks: The Practical Limitations of Hoplite Weapons and Equipment", in: D. Kagan, G. F. Viggiano (eds.), *Men of Bronze: Hoplite Warfare in Ancient Greece* (Princeton 2013).
E. Unger, *Babylon. Die heilige Stadt nach der Beschreibung die Babylonier* (Berlin ²1970).

Herodotus (3. 60. 2) notes that both the height and the width of the Eupalinian aqueduct equal 8 feet. Modern measurement gives 2.10 m for both height and width. It follows that the sixth-century Samian foot was 26.25 cm, and there is much to support such a conclusion. However, a standard Greek foot was much longer. We are dealing here with two different systems. In the earlier one, the foot corresponds to the height of an average Greek man, and it measures a half of a cubit and a third of a pace. In the standard system, there is no integer number of feet in one pace, a foot corresponds to the height of exceptionally tall persons and it is in a ratio to a cubit of 2 : 3. The change was probably caused by the growing interest in athletic competitions. The stadiums were extended to accommodate more spectators, and, since each stadium was 600 feet long by definition, the foot was extended accordingly.

Согласно Геродоту (III, 60, 2), у тоннеля, построенного в VI в. до н. э. для водопровода на Самосе, была одинаковая длина и ширина, равная 8 футам. Раскопки показали, что и длина, и ширина тоннеля равны 210 см. Это позволяет точно определить величину фута, бывшего в ходу на Самосе в VI в. до н. э., как равную 26,25 см. Другие данные превосходно согласуются с подобным результатом, который, однако, предстает неожиданным в свете того, что начиная с V в. до н. э. греческий фут был значительно больше и варьировался в диапазоне от 29,4 до 32,8 см. Очевидно, речь идет не о местном своеобразии, но о различии между более ранней и более поздней системами мер. В одной фут соответствует размеру стопы мужчины среднего роста, он образует половину локтя и треть шага. В другой (с V в. и далее) величина фута предполагает людей необычайно высокого роста, фут составляет две трети локтя, и никакое целое число футов не соответствует одному шагу. Такая трансформация была, по-видимому, связана со стремлением строить более вместительные стадионы, тогда как длина их беговых дорожек была по определению равна 600 футам.