

of 16,000 *hasta* was the Indian representative of the Persian *parasang* of 7670·40 metres, = 4·76615606 miles.¹ But, accepting the valuations of the Persian measures and the probability of a common origin, we can only conclude that measures originally identical were not preserved unaltered in the two countries so as to remain exactly commensurate with each other. M. Decourdemanche's value of the long *yōjana* of 32,000 *hasta* is based on an assumption that the ancient Indian cubit was of the same length with the Babylonian mean cubit; namely, 0·4794 metre, = 18·873978 inches. But Āryabhaṭa gave $\frac{1}{4}$ *hasta*, = 96 *āṅgula*, as the height of the Indian man; and Varāhamihira has supplemented his statement by telling us that that was the height of the normal or average man (see p. 232–3 above). The application of the value of the Babylonian mean cubit would give 6 ft. 3·495912 in.,—practically 6 ft. 3½ in.,—as the accepted standard height of the normal Indian man. We cannot endorse such a result as this. For the Indian cubit we cannot admit anything in excess of 18 inches; from which we have 9·09 miles, to be treated practically as 9 miles, as the value of the long *yōjana*, and 4·54 miles, to be treated as 4½ miles, as the value of the short *yōjana*.

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SOME HINDU VALUES OF THE DIMENSIONS OF THE EARTH

The Hindū astronomers were accustomed to state either the diameter of the earth, or the circumference, or both: they had to lay down the diameter for calculating the shadow thrown by the earth in lunar eclipses; and the circumference for determining longitudes, as denoted by

¹ M. Decourdemanche has not mentioned either the short *yōjana* or the ancient original *krōśa* of 4000 *hasta*: he has the later double *krōśa* of 8000 *hasta*. He has called this *parasang* the “*parasange d'étapes*.” He has also a “*parasange (schœne)*” of 6903·36 metres (nine-tenths of the other), = 4·28954045 miles.

distances or by differences of time. They expressed their values in *yōjanas*. And it may be noted that, as they did not know of the flattening of the earth towards the poles, but treated the globe as a perfect sphere, any particular value of the circumference, either stated or to be deduced from a given diameter, represented exactly the meridional as well as the equatorial girth, and also the girth round any other terrestrial great circle.

Āryabhaṭa (wrote in or soon after A.D. 499) gave the diameter as 1050 *yōjana*.¹ His details given in the same place show that he used the *yōjana* of 32,000 *hasta* or cubits, = 9 miles (see p. 236 f. above): and so his value for the diameter was 9450 miles. He had $\pi = \frac{62832}{20000} = 3.1416$,² which gives 3298.68 *yōjana* as the circumference; for which he seems to have taken 3300 *yōjanas*, = 29,700 miles, in round numbers: at any rate, this is the figure stated by his special exponent Lalla, who had the same diameter and the same value of π .³

Brahmagupta (wrote A.D. 628) gave the circumference as 5000 *yōjana*, = 45,000 miles.⁴ From this, with his value $\pi = \sqrt{10} = 3.1623$, we have as the diameter $1581\frac{4037}{31623}$ or say 1581 *yōjana*, = 14,229 miles.

The Sūrya-Siddhānta, 1. 59 (from about A.D. 1000), gives the diameter as 1600 *yōjana*, = 14,400 miles: whence, with its π again = $\sqrt{10}$, we have as the circumference 5059.68 or say 5060 *yōjana*, = 45,540 miles.

As regards the merits of these estimates, we need only note here that it seems customary now to quote 7926 or 7926.6 miles as the mean equatorial diameter;⁵ and

¹ Daśagītikasūtra, verse 5.

² Gaṇitapāda, verse 10.

³ Śiṣhyadhivṛddhida, p. 10, verse 56; for π see p. 28, verse 3.

⁴ Brāhma-Siddhānta, p. 10, verse 36; for π see p. 198, verse 40.

⁵ The latest refinements seem to be those given by Young, from Clarke, in his *General Astronomy* (1904), p. 601:—

equatorial semidiameter,	3963.296 miles;
polar	,, 3949.790 miles.

from these figures, with $\pi = 3.14159$, we have 24,900 or 24,902 miles as the circumference, without fractions.

It might perhaps be thought that, by applying the *yōjana* of 16,000 *hasta* = $4\frac{1}{2}$ miles, we could take the statements of Brahmagupta and the *Sūrya-Siddhānta* as successive improvements on that of Āryabhata, and so could understand them as giving respectively diameters of 7115 and 7200 miles; which would be, for those times, quite respectable approximations to the truth. But, even apart from the point that there is no evidence to show, and nothing to lead us to think, that the Hindūs ever made any independent attempts to determine the dimensions, that possibility is excluded for the following reasons. The author of the *Sūrya-Siddhānta* belonged to the same school with Bhaṭṭōtpala (wrote A.D. 966): and the latter has laid out the *yōjana* of 32,000 *hasta* = 9 miles.¹ And Bhāskarāchārya (wrote A.D. 1150) was a follower of Brahmagupta: he has stated the diameter at 1581 *yōjana*, and the circumference, with a slight refinement of Brahmagupta's value, at 4967 *yōjana*:² and he, too, laid out the *yōjana* of 9 miles.³

So far, indeed, from there having been successive improvements, the reverse was the case; and the explanation seems to be as follows.

If the value of the Greek *stadium* is taken to be 606.75 feet, the *yōjana* of 9 miles works out to $78\frac{258}{89}$ *stadia*. If the *stadium* is taken according to the later valuation at 582.48 feet, the *yōjana* works out to $81\frac{471}{99}$ *stadia*. In either case, we can hardly doubt that the Hindū astronomers would take for convenience, according to their habit, 1 *yōjana* = 80 *stadia* in round numbers: in fact, they would only be doing just what Megasthenes

¹ Commentary on the *Bṛihat-Saṁhitā*, vol. 1, p. 48.

² *Siddhāntaśīromāṇi*, ed. Bapu Deva Sastri, p. 52, verse 1: in verse 52 on p. 261 he has given the diameter more precisely as $1581\frac{1}{4}$.

³ *Līlāvatī*, verses 5, 6: he has referred expressly to this in his statement under *Siddhāntaśīromāṇi*, p. 52, verse 1.

did (see p. 238 above) when he presented 10 *stadia* as the practical equivalent of 1 *krōśa*, = $\frac{1}{8}$ of a long *yōjana*.

Eratosthenes (B.C. 276–196) arrived by experiment and calculation at 250,000 *stadia* for the circumference of the earth; for which, recognizing that his result was only approximate, he substituted 252,000 *stadia*, so as to have a number divisible exactly by 360, giving 1 degree = 700 *stadia*.¹ This value was accepted by Hipparchus

¹ Lewis, *Astronomy of the Ancients* (1862), p. 198; Bunbury, *Ancient Geography* (2nd ed., 1883), vol. 1, p. 623. The equivalent is 28,959 or 27,800 miles, according to the two valuations of the *stadium*. But we are concerned here with the actual figures, not with the values of them.

On the assumption that Eratosthenes had practically the true circumference, proposals have been made on the one side to determine the value of the *stadium* from his figures, and on the other side to decide which one he used out of various *stadia*. But it is reasonable to hold, with Bunbury (p. 624), that, writing for Greeks, he used "the customary Greek stade, the length of which was familiar to them all": and a perusal of details fully justifies the same writer's decision that "his conclusion was erroneous, because his data were inaccurate, and his observations defective." His process was the proper one, of arc-measurement; and we know that similar attempts were made in other countries also in early times: but we have no good reason for believing that any early people could perform the operation with any real approach to accuracy; they could not determine with sufficient exactness either the distance between any two points or the latitudes of them.

Eratosthenes may be treated reasonably thus. According to the two valuations of the *stadium*, his original estimate for the circumference, 250,000 *stadia*, comes to 28,728 or 27,579 miles, and with $\pi = 3.14159$ these give as the diameter 9144 or 8778 miles; all without fractions. These results may be regarded as creditable enough for so early a time, though they were, of course, useless for any really scientific purposes: even the higher of them is not very much more faulty in excess than was, in the opposite direction, the estimate (see farther on) which prevailed in Europe till nearly the end of the seventeenth century.

For an idea of the delicacy and difficulty of the operation of arc-measurement, reference may be made to Airy's *Popular Astronomy*, revised issue of 1891, pp. 50–71. See also Proctor's *Old and New Astronomy* (1892), pp. 87–91.

The modern measurements which have given us the true dimensions began in 1528; see Airy's "Figure of the Earth" in the *Encyclopædia Metropolitana*, vol. 5, Mixed Sciences, vol. 3 (1845), pp. 165–240: I am indebted to Dr. Burgess for drawing my attention to this article. In that year, Fernel found the value of one degree on the north of Paris to be 56,746 toises: with the toise taken at 2.1315 yards, this gives

(B.C. 162–145) and Strabo (? B.C. 54 – A.D. 24).¹ And a story told by Pliny (A.D. 23–79) about a certain Dionysodorus shows that, with the rough value $\pi = 3$, the diameter was taken at 84,000 *stadia*.² This, divided by 80, gives Āryabhaṭa's value of the diameter, 1050 *yōjana*.³

Aristotle (B.C. 384–322) quoted 400,000 *stadia* as the value of the circumference of the earth which had been calculated by mathematicians.⁴ This, divided by 80, gives Brahmagupta's value, 5000 *yōjana*.

It can hardly be doubted that the origin of Āryabhaṭa's value for the diameter of the earth is the rough diameter of Eratosthenes' estimate of the circumference. And it seems also a plain conclusion that Brahmagupta's value for the circumference is simply the Indian equivalent of

1° = 68·724 miles; and from this we should have circumference 24,740 miles and diameter 7875 miles, without fractions. Other measurements were made in or about 1617 and 1637. In 1669, Picard obtained the result of 57,060 toises, = 69·104 miles, as the mean value of one degree between Sourdon and Malvoisine, which would give circumference 24,877 miles and diameter 7912 miles. And this last result, becoming known to Newton, enabled him to establish in 1687 his theory of gravitation, in respect of which he had previously failed in consequence of following the then still usual estimate of 60 miles as the length of a degree, with the result of 21,600 miles circumference and 6875 miles diameter.

¹ Bunbury, op. cit., vol. 2, pp. 9, 228–9.

² *Natural History*, 2. 112. The story was that, after his death, there was found in his tomb a letter from him, stating that he had descended to the lowest part [the centre] of the earth, and that the distance [the radius] was 42,000 *stadia*.

³ His value for the circumference of course works out to more than that of Eratosthenes; because it was the figures for the diameter that he took over, and he applied to them the practically correct value $\pi = 3.1416$, instead of the rough value, 3, by which they had been obtained.

⁴ Bunbury, op. cit., 1. 396. The equivalent is 46,080 or 44,127 miles, according to the valuations of the *stadium*. This value of the circumference perhaps was (but perhaps was not) associated by the mathematicians with the idea of the earth being a flat disc; a view which Aristotle rejected: he held, with the Pythagoreans, that the earth is a sphere. But it does not follow that the idea would reach the Hindūs with the measure: and any circular plan, with dimensions marked on it, would show the earth as a flat surface, even though it was known to be a sphere.

the value reported by Aristotle. It would be interesting if we could ascertain how it was that Brahmagupta, the later in date, went back to a source earlier than that used by his predecessor Āryabhaṭa.¹

Varāhamihira (died A.D. 587) has not stated the diameter of the earth, but has given the circumference as 3200 *yōjana*; apparently from the Original Sūrya-Siddhānta and the Paulīśa.² This seems to be a substitute for Āryabhaṭa's 3300 *yōjana*, with a view to having $\frac{3200}{360} = \frac{80}{9}$, as more easy to manipulate than $\frac{3300}{360} = \frac{11}{6}$, as the value of one degree in *yōjanas* along the equator, a meridian, and any other great circle.

The Sūrya-Siddhānta's value of the diameter, 1600 *yōjana*, seems to be only Brahmagupta's value, 1581 *yōjana*, turned into a round number in the usual fashion. The way in which the Siddhānta states it, is itself indicative of this: the text says that the diameter is 800 *yōjanas*, i.e. the radius, multiplied by 2; and Brahmagupta's radius, 790 or 791 *yōjana*, would suggest the substitution of 800 even more readily than 1581 would suggest the substitution of 1600.

In the case of Brahmagupta there is the curious point that, while he has given 5000 *yōjana* as the circumference in the passage mentioned above, and has stated it with a view to calculating the *dēśāntara* or 'difference of place' (longitude), in another passage he has indicated quite a different value: he there says that the difference

¹ Another Greek value was that of Posidonius (about B.C. 135–51), who reduced the circumference first to 240,000 and then to 180,000 *stadia* Lewis, p. 215; Bunbury, vol. 2, pp. 95, 539. This latter figure, 180,000, was taken over by Marinus of Tyre (second century), and was adopted from him by Ptolemy (A.D. 139 and 161): Bunbury, vol. 2, pp. 539, 564. The equivalent is 20,685 or 19,857 miles. The Hindūs would denote the 180,000 *stadia* by 2250 *yōjana*: but such a value does not seem to be found in their books.

² Pañchasiddhāntikā, trans., p. 71, verse 18; and compare p. 16, verse 14; p. 57, verse 10.

of time on each side of the prime meridian is 1 *nāḍī*, = 24 minutes, for 60 *yōjana*;¹ and this postulates an equatorial circumference of only 3600 *yōjana*, = 32,400 miles. Further, Albērūnī, while mentioning 1581 *yōjana*, each of 8 'miles', i.e. *krōśas* (see p. 239 above), as Brahmagupta's value of the diameter, has represented him as using in his *Khaṇḍakhādyā* still another value for the circumference, namely 4800 *yōjana*.² This I am not able to verify: but it may be a substitute, for some general purposes, for the 4743 which would be deduced from the diameter of 1581 with the value $\pi = 3$, which is mentioned by Brahmagupta as giving the *vyāvahārika* or rough practical circumference.³

Jervis quoted the following other values:⁴—

Laghu-Vāsishṭha-Siddhānta	{	diam. 1581 <i>yōjana</i> .
	{	circ. 4966 „
Siddhāntaśekhara	{	diam. 1581 „
	{	circ. 5000 „
Sārvabhauma-Siddhānta	{	diam. 1600 „
	{	circ. 5026 „
Ārya-Siddhānta		circ. 6625 „

There is no difficulty in recognizing the bases of the statements of the first three works. The fourth work is the Mahā-Siddhānta or Second Ārya-Siddhānta, which says (p. 39, verse 56) that the circumference is 6625 *yōjana* — *ta-yav-āṅgula-mānēna*, “by the measure of the *āṅgula* of six *yava*.” This is only another variety of the same estimate: 6625 *yōjanas* of this kind would be equal to 4968 or 4969 *yōjanas* by the measure of the

¹ Brāhma-Siddhānta, p. 414, verse 10.

² Trans., vol. i, p. 312.

³ Brāhma-Siddhānta, p. 198, verse 40.

⁴ *Primitive Universal Standard of Weights and Measures* (1835), p. 73. It may be noted, as a curiosity, that on p. 53 he made practical use of the long value of π quoted by me in this Journal, 1911. 793, and took the decimal even two places farther, ending with 32384.

angula of eight *yava*. Perhaps some reader of this Journal in the extreme South of India can give us more information about this *angula* of the Second Ārya-Siddhānta and the *yōjana* based on it: I have not as yet found them used anywhere else.

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CREMATION AND BURIAL IN THE RGVEDA

In his elaborate treatise on *The Early Age of Greece*¹ Professor Ridgeway has laid great, and indeed excessive, stress on the importance of the difference between cremation and burial as indicating racial distinctions. Thus he has argued that the practice of burial in Mycenaean² civilization, as contrasted with the practice of cremation, which is decisively Homeric, is to be explained by the fact that on the earlier civilization had been imposed a later structure in the shape of an Achæan inroad, the Achæans being of Celtic stock, and coming from northern lands where cremation had become usual, while the Achæans he sharply distinguished from Dorians,³ who were Illyrians,⁴ by their method of disposal of the dead, the Dorians practising interment and not burning.

Now it is worth noticing that Professor Ridgeway's own evidence from Hallstadt and elsewhere⁵ shows that cremation and burial often existed contemporaneously, and that in some places the rich, in some the poor, were buried, in some places were burned. These facts he

¹ See i, 481-551.

² i, 514.

³ Cf. "Minos the Destroyer" (*Brit. Acad. Proceedings*, iv), p. 28. But we have no real evidence of what the Dorians did for centuries after their entry into Greece, and this argument from their later usages is not cogent.

⁴ "Who were the Dorians?" in *Anthropological Essays presented to E. B. Tylor*, pp. 295 seqq. Murray, *Rise of the Greek Epic*², p. 61, n., suggests that the Dorians were the tribe of the hand (*δαῖρον*), quoting the lambda on their shields. Unhappily for this wild guess, *δαῖρον* does not mean "moving the hand" either in Greek or in Sanskrit.

⁵ i, 429, 439, 495-8.