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ARCHIMEDES' *CATTLE PROBLEM*

Below is the Greek text of Archimedes' *Cattle Problem* (henceforth *CP*) and the anonymous prose introduction which provides the context of its composition, a translation and a delineation of the equations represented algebraically.[15]

πρόβλημα ὅπερ Ἀρχιμήδης ἐν ἐπιγράμμασιν εὑρὼν τοῖς ἐν Ἀλεξανδρείαι περὶ ταῦτα πραγματευομένοις ζητεῖν ἀπέστειλεν ἐν τῆι πρὸς Ἐρατοσθένην τὸν Κυρηναῖον ἐπιστολῆι.

πληθὺν Ἠελίοιο βοῶν, ὦ ξεῖνε, μέτρησον
  φροντίδ' ἐπιστήσας, εἰ μετέχεις σοφίης,
πόσση ἄρ' ἐν πεδίοις Σικελῆς ποτε βόσκετο νήσου
  Θρινακίης τετραχῇ στίφεα δασσαμένη
χροιὴν ἀλλάσσοντα· τὸ μὲν λευκοῖο γάλακτος,   5
  κυανέῳ δ' ἕτερον χρώματι λαμπόμενον,
ἄλλο γε μὲν ξανθόν, τὸ δὲ ποικίλον· ἐν δὲ ἑκάστῳ
  στίφει ἔσαν ταῦροι πλήθεσι βριθόμενοι
συμμετρίης τοιῆσδε τετευχότες· ἀργότριχας μὲν
  κυανέων ταύρων ἡμίσει ἠδὲ τρίτῳ   10
καὶ ξανθοῖς σύμπασιν ἴσους, ὦ ξεινε, νόησον,
  αὐτὰρ κυανέους τῷ τετράτῳ τε μέρει
μικτοχρόων καὶ πέμπτῳ, ἔτι ξανθοῖσί τε πᾶσιν.
  τοὺς δ' ὑπολειπομένους ποικιλόχρωτας ἄθρει
ἀργεννῶν ταύρων ἕκτῳ μέρει ἑβδομάτῳ τε   15
  καὶ ξανθοῖς αὐτοὺς πᾶσιν ἰσαζομένους.
θηλείαισι δὲ βουσὶ τάδ' ἔπλετο· λευκότριχες μὲν
  ἦσαν συμπάσης κυανέης ἀγέλης
τῷ τριτάτῳ τε μέρει καὶ τετράτῳ ἀτρεκὲς ἴσαι·
  αὐτὰρ κυάνεαι τῷ τετράτῳ τε πάλιν   20
μικτοχρόων καὶ πέμπτῳ ὁμοῦ μέρει ἰσάζοντο
  σὺν ταύροις πάσαις εἰς νομὸν ἐρχομέναις.
ξανθοτρίχων δ' ἀγέλης πέμπτῳ μέρει ἠδὲ καὶ ἕκτῳ
  ποικίλαι ἰσάριθμον πλῆθος ἔχον τετραχῇ.

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[15] This chapter develops and substantially expands arguments first put forth in Leventhal (2015).

ξανθαὶ δ' ἠριθμεῦντο μέρους τρίτου ἡμίσει ἷσαι   25
  ἀργεννῆς ἀγέλης ἑβδομάτῳ τε μέρει.
ξεῖνε, σὺ δ' Ἠελίοιο βόες πόσαι ἀτρεκὲς εἰπών,
  χωρὶς μὲν ταύρων ζατρεφέων ἀριθμόν,
χωρὶς δ' αὖ θήλειαι ὅσαι κατὰ †χροιὰν ἕκασται,
  οὐκ ἄϊδρίς κε λέγοι' οὐδ' ἀριθμῶν ἀδαής,   30
οὐ μήν πώ γε σοφοῖς ἐναρίθμιος. ἀλλ' ἴθι φράζευ
  καὶ τάδε πάντα βοῶν Ἠελίοιο πάθη.
ἀργότριχες ταῦροι μὲν ἐπεὶ μιξαίατο πληθὺν
  κυανέοις, ἵσταντ' ἔμπεδον ἰσόμετροι
εἰς βάθος εἰς εὖρός τε, τὰ δ' αὖ περιμήκεα πάντη   35
  πίμπλαντο πλίνθου Θρινακίης πεδία.
ξανθοὶ δ' αὖτ' εἰς ἓν καὶ ποικίλοι ἀθροισθέντες
  ἵσταντ' ἀμβολάδην ἐξ ἑνὸς ἀρχόμενοι
σχῆμα τελειοῦντες τὸ τρικράσπεδον οὔτε προσόντων
  ἀλλοχρόων ταύρων οὔτ' ἐπιλειπομένων.   40
ταῦτα συνεξευρὼν καὶ ἐνὶ πραπίδεσσιν ἀθροίσας
  καὶ πληθέων ἀποδούς, ξεῖνε, τὰ πάντα μέτρα
ἔρχεο κυδιόων νικηφόρος ἴσθι τε πάντως
  κεκριμένος ταύτῃ γ' ὄμπνιος ἐν σοφίῃ.[16]

(Archimedes *Cattle Problem SH* 201)

A problem Archimedes devised in epigrams that he sent in a letter to Eratosthenes of Cyrene, to those in Alexandria attempting to work out such things.

    The multitude of the Cattle of the Sun calculate, O stranger, and set your mind to it, if you have a share in wisdom, as many as once grazed the plains of Sicilian Thrinakia's island, divided four-ways into groups of differing colours: one milky white, another shining with black hue, while yet another brown, the last dappled. In each herd were bulls strong in number formed in the following proportions. Consider, O stranger, that the white-haired equal a half and third of the black bulls together with the brown bulls, but that the black equals a quarter share and fifth of the dappled and the whole of the brown besides. Observe how the remaining dappled bulls equal a sixth and a seventh share of the white bulls and the whole of the brown. With the cows, it was the following: the white-haired were exactly equal to a third and a quarter share of the whole of the black herd: but the black cows again equalled a quarter of the dappled and a fifth share together, when with all the bulls they went to pasture. The dappled quartered have an equal number to a fifth and sixth of the brown-haired herd. The brown cows numbered equal to a half of a third share of the white herd and a seventh share.

    If, O stranger, you accurately tell how many Cattle of the Sun there are, telling separately the number of well-fed bulls and separately again the number of each

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[16] This text follows Lloyd-Jones and Parsons (1983) 77–8.

herd of cows according to colour, you would not be called unskilled or ignorant of numbers; nor yet, though, would you be numbered among the wise.

But come, consider all these conditions of the Cattle of the Sun. When the white-haired bulls mix their multitude with the black they stand firmly together, their length and breadth of equal measure, stretching far and wide the plains of Thrinakia were filled with their masses. Again, when the brown and dappled bulls were herded together they stood, beginning with one, increasing in number resulting in a three-bordered shape, neither any other coloured bulls among them, nor with any left out.

If, O stranger, having completely worked out in your mind these things, collating and giving an account of every dimension you may go, a victor, and carry yourself proud, knowing that wholly you have been judged *opmnios* (perhaps 'well-fed') in this species of wisdom.[17]

White Bulls = $\frac{5}{6}$ Black Bulls + Brown Bulls
Black Bulls = $\frac{9}{20}$ Dappled Bulls + Brown Bulls
Dappled Bulls = $\frac{13}{42}$ White Bulls + Brown Bulls
White Cows = $\frac{7}{12}$ (Black Bulls + Black Cows)
Black Cows = $\frac{9}{10}$ (Dappled Bulls + Dappled Cows)
Dappled Cows = $\frac{11}{30}$ (Brown Bulls + Brown Cows)
Brown Cows = $\frac{13}{42}$ (White Bulls + White Cows)
White Bulls + Black Bulls = A square number
Brown Bulls + Dappled Bulls = A triangular number

These twenty-two couplets capitalise on Homer's depiction of the Cattle of the Sun in *Odyssey* 12 and its numerical aspect, where Circe explains to Odysseus that on Thrinakia, 'there many cows and stout sheep of Helios graze, seven herds of cows and just as many fine flocks of sheep and fifty in each' (*Od.* 12.127–30). The description in the *CP* of the related proportions of black, white, brown and dappled herds of cattle, which are then configured geometrically on Sicily, creates a strikingly colourful image. Just as striking is the author's decision to respond to Homer's scene with a poem that fills the verses almost exclusively with the ratios of cattle. Reading through the work it becomes clear that the mathematics is more complex than that of Homer's *Odyssey*.

Since the work's discovery, scholars have essayed solutions to Archimedes' mathematical complexity.[18] It was only in 1965 that

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[17] The translation is adapted from Thomas (1941) 202–5.
[18] According to Hermann (1831) 230, C. F. Gauss was reported to have worked on the problem, although Krumbiegel (1880) 123 doubts Gauss' involvement. The key advance towards a solution is found in Wurm (1830), later developed in Nesselmann

the smallest solution was able to be written out in full (a number whose digits filled forty-two sheets of paper).[19] What makes the problem particularly fiendish is the addition of the further parameters. The poem first outlines a series of ratios which in modern notation can be written as a series of simultaneous equations. The problem is interesting in that, since there are seven equations and eight unknowns (again this is a modern way of phrasing the problem), one cannot find a single solution, but instead infinitely many solutions.[20] It is the subsequent stipulation that the white bulls and black bulls together form a square number and that the brown bulls and dappled bulls form a triangular number that makes the (infinitely many) solutions to the problem become truly astronomical in size. Unsurprisingly, attention has largely been paid to the mathematics, with historians of mathematics keen to highlight how the *CP* attests to an ancient awareness of complex arithmetic and of its limitations.[21] Approaches that have eschewed the mathematics inevitably do so only to discuss authenticity, a thorny riddle as unsolvable as the equations.[22]

The obsession with solving the mathematics and the question of authenticity has meant that the importance of the *CP*'s medium has been understudied and undervalued. Discussions of the text have failed to appreciate the *CP* as a poem and to understand the cultural and literary context which engendered it. Most, if not all, readers have been left bewildered by the mathematical

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(1842) 484 and finalised in the form given by Amthor (1880). It was he who found a method for calculating the solution's large size, expressing only the first four significant digits of a number containing hundreds of thousands of digits.

[19] That is to say, the number was fully expressed. See Williams et al. (1965) and, in a more manageable form, Nelson (1981).

[20] Solutions are of the following form, with n as any arbitrary positive integer: White Bulls = 10,366,482n; Black Bulls = 7,460,514n; Brown Bulls = 4,149,387n; Dappled Bulls = 7,358,060n; White Cows = 7,206,360n; Black Cows = 4,893,246n; Brown Cows = 5,439,213n; Dappled Cows = 3,515,820n.

[21] See e.g. Heath (1921) II, 14.

[22] The poem is mentioned in Hero's *Definitions* – on which it is clear that the *scholium* to *Charmides* (see above) depends – and Cicero mentions a πρόβλημα Ἀρχιμήδειον (*Att.* 12.4, 13.28). I take Cicero to refer to the *CP* since no other work of Archimedes', as far as I know, is called a problem and although he does talk of problems in his treatises, this is too unmarked a use to develop into something as marked as a title for a poem. I think the most likely explanation is that this is the text to which the ancient sources refer. For further discussions see Struve and Struve (1821); Nesselmann (1842) 481–2; Krumbiegel (1880) 125. A balanced approach can be found in Fraser (1972) I, 407.

124

demands of Archimedes' prescribed proportions and configurations and read no deeper. Certainly, the confrontation of Homeric epic and mathematics is central to the work, yet its importance lies not in the complex calculations alone, but in how the mathematics is co-opted to manipulate a readership. It seems clear, given the time and effort modern scholars have put into solving Archimedes' ratios, that his recipient, Eratosthenes, would have been unable to solve the arithmetical challenge.[23] A more productive approach is to accept that the problem would have been arithmetically unsolvable and then to analyse Archimedes' unique intersection of arithmetic and Homeric reception.

In that respect, it is important to observe that in other surviving treatises Archimedes shows himself to be a versatile and erudite author in his writing up of mathematics. In the *Sand Reckoner*, he engages with that most poetic trope, counting the number of the sands (e.g. *Il.* 2.800, 9.385; Pind. *Ol.* 2.98–100), and attempts to calculate the number of grains of sand that would be required to fill the universe. The treatise is dedicated to Gelon II, the ruler of Syracuse, and localised in relation to Sicily: Archimedes specifies that some people think the number of sands is infinite, the number 'not only around Syracuse and the rest of Sicily, but in every region, both inhabited and uninhabited' (2.134.1–6 Mugler). It stands apart from other, more typical mathematical texts in that it is not characterised by a pared-down, impersonal style focused on geometric proof, but 'is ruled throughout by Archimedes speaking in his own voice, occasionally breaking his speech so as to give room for mathematical proof'.[24] Similarly, in his *Stomachion* – which will be treated in more detail in the next

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[23] It is still unclear how ancient mathematicians would begin to think about solving the problem, nor is it known if the creator of the mathematical problem knew the quantities beforehand, although Archimedes' *Sand Reckoner* does develop a system for coping with large numbers; see Vardi (1998) 318. The Press' anonymous reader further notes that the Greek is unclear in places. At verse 14 τοὺς ὑπολειπομένους should mean not the dappled bulls in their entirety but the dappled bulls not mentioned in the previous ratio delineation. The third equation above should thus perhaps be $^{11}\!/_{20}$ Dappled Bulls = $^{13}\!/_{42}$ White Bulls + Brown Bulls. There are similar problems with the interpretation of line 24, which raises the possibility that the sixth equation may not be correct either. These might be further reasons for thinking that the problem was indecipherable.

[24] Netz (2009) 105.

chapter – he discusses the Greek game called στομάχιον ('Belly-teaser'), in which a square cut into fourteen shapes can be rearranged into many other figures. From what survives of the text, his first aim was to compute the total number of different ways that the pieces could be combined to produce a square, the answer being 17,152. How the treatise then proceeded is unclear, but it is probable that it introduced further parameters which result in a solution for the number of different combinations being so large that it can only be approximated.[25] In a not dissimilar vein to the *Sand Reckoner*, Archimedes takes an idea within Greek culture as a springboard for mathematical demonstration and as an opportunity for creating what Reviel Netz has called a 'carnival of calculation'.[26] In addition to this showmanship, there is the far more personal work of Archimedes' *Method*, also addressed to Eratosthenes, which describes a mechanical method for calculating the volume of certain solids.[27] He reminds Eratosthenes of geometrical problems he had sent him previously (4.82.1–8 Mugler) and praises his pedagogical commitment and mathematical enquiries (4.83.18–24 Mugler), before launching into an account of his discovery of the method which is strikingly biographical (4.84.10–25). My intention here is thus to situate the *CP* within the Archimedean corpus as equally sophisticated and literary, both capable of dazzling the reader with mathematical display and forged by his long-standing dialogue with Eratosthenes.

In what follows, then, I make three interrelated arguments. First, I show that the poem is a refined composition which resembles in form and content many other works produced in the Hellenistic era. In terms of the poet's allusiveness, I suggest that the narrative of the *Odyssey* is not just a useful image with which to encode the mathematics, but that it is at the heart of the poem, and in particular, that epic's concern with the location and name of Sicily. These aspects gain further significance when it is appreciated that the *CP*

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[25] Netz (2009) 36. [26] Netz (2009) 17–21.
[27] The *Method* allows for the calculation of volumes of 'solids of revolution', those solids that are formed by the rotation of a two-dimensional figure about an axis to create a three-dimensional volume. For example, a rectangle set upon the axis and rotated about it will form a cylinder.

126

is sent between two scholar-poets in different Hellenistic kingdoms. In the following section, I show in detail that a further key intertext of the *CP* is the Catalogue of Ships in *Iliad* 2 and the surrounding scenes, including the Invocation to the Muses. Appreciating this intertext allows one to observe how Archimedes conceives of, and presents to the reader, the very project of providing calculations in verse. By appealing to this foundational context in which the Homeric poet deals with numbers and must call on the help of the Muses, he addresses the issue of mathematical knowledge and its limits. In Section 3, I combine the geopolitical reading of the *CP* proposed in the first section with the focus on poetic catalogues developed in the second section. I draw on a range of catalogic scenes from Archaic and Hellenistic poetry in order to demonstrate that an abiding association in these passages is enumeration as geographical possession: whoever is able to make a symbolic census – be it of cities, crops or livestock – has a claim to the control and ownership of the land. In offering the reader the opportunity to calculate the Cattle of the Sun, I argue, Archimedes makes a political point about the (im)possibility of possessing Sicily by means of arithmetic. This arithmetical poem, in short, advances a very particular aesthetic which not only characterises the competitive context of the challenge posed, but also probes precisely what it means to simultaneously compose poetry and produce arithmetic.

3.1 Archimedes' Art

Archimedes was a great mathematician, but how good was his poetry? In this section I examine the literary aspects of the *CP*, its generic positioning and its allusions to earlier poetry. Whereas the focus has traditionally been on the complex enumeration encoded in the *CP*, here I provide a description of Archimedes the poet, a figure as erudite with words as he is sophisticated with mathematics. What will emerge, importantly, is not simply a scientific writer who draws on a Hellenistic education in order to 'versify' a series of equations, but a scientific writer able to handle a range of genres and generic expectations as well as to produce a poem full of intertexts and playful allusions to earlier works. Just like his

127

correspondent Eratosthenes, Archimedes deserves to be ranked alongside the great Hellenistic poets as well as the greatest mathematicians.

To begin: the *CP* offers a number of different reading frameworks in its opening. The epistolary prose introduction frames the recipient as Eratosthenes and Archimedes as the sender. But is this Archimedes' voice in the poem? The phrase ἐν ἐπιγράμμασιν εὑρών is ambiguous: it could mean he discovered the poem 'among some epigrams' or that he devised it 'in elegiac couplets'.[28] It is not inconceivable that he would have found the poem in a pre-existing collection, but given the complexity of the mathematics I think it is more likely that Archimedes himself composed the poem. In any case, it is an intentional communicative gesture to Eratosthenes on his part. If the poem were read without assuming the context of the prose introduction, a reader would probably consider themselves to be the addressee and the speaker to be the author of the poem. In characterising the relationship between the speaker and the addressee, one can also look towards the generic history of epigram. For public inscriptions and literary epigrams, the address to a παροδίτης ('passer-by', 'traveller'), ὁδοιπόρος ('wayfarer', 'traveller') or ξένος/ξεῖνος ('stranger', 'wanderer') is a competitive manoeuvre intended to catch the reader's eye, on busy public thoroughfares or on the scroll.[29] φροντίδ' ἐπιστήσας (2) could be taken not only as 'set one's mind to' but also 'halt one's mind', converting the traditional call to a passer-by to physically stop into a request for one to halt mentally. This aspect, as is often noted, is fruitfully exploited by epigrammatists of the Classical and Hellenistic period.[30] As

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[28] ἐν ἐπιγράμμασιν in some cases appears to designate a generic form, as at Antig. *Mir.* 19.24, but it is a matter of interpretation. For example, in the case of references to Callimachus' epigrams, ἐπιγράμμασιν is found both with the definite article (Diog. Laert. 2.111, Ath. 7.284c) and without (Ath. 7.327a), and so it is unclear whether a collection of his is meant or the verse form is being defined. Athenaeus (3.125c) has Myrtilus call a poem by Simonides an epigram although modern commentators take it to be a fragment of an elegy; see Sider (2020) 315–16. The line is thus seemingly blurred also in antiquity.

[29] This appears to be the default position, although, as Sourvinou-Inwood (1996) 279–80 admits, it is often unstated. See also Tueller (2008) 59–60.

[30] The ideas of playfulness, generic awareness and supplementation have been a fruitful area of research in recent years. See Bing (1995); Bing (1998); Selden (1998) 307–19;

Michael Tueller has shown, depending on whether the epigram is sepulchral, dedicatory or amatory, the relationship between speaker and addressee differs.[31] Archimedes' ξεῖνε hints towards the genre, though it is unclear into which subgenre the *CP* fits. In the present case, a subsequent, probably purposeful, ambiguity arises as to whether Eratosthenes is a 'foreigner' (ξεῖνος) or a 'guest-friend' (ξεῖνος).

The *CP* is also indebted to the language in the *Odyssey* where Circe addresses Odysseus.

Θρινακίαν δ' ἐς νῆσον ἀφίξεαι· ἔνθα δὲ πολλαὶ
βόσκοντ' Ἠελίοιο βόες καὶ ἴφια μῆλα,
ἑπτὰ βοῶν ἀγέλαι, τόσα δ' οἰῶν πώεα καλά,
πεντήκοντα δ' ἕκαστα.

(Homer *Odyssey* 12.127–30)

Then you will come to the Thrinakian island: there many cows and stout sheep of Helios graze, seven herds of cows and just as many fine flocks of sheep and fifty in each.

An alert reader may infer a similar dynamic in the *CP*: Odysseus as the addressee and Circe the speaker. Indeed, Odysseus as a ξεῖνος is a key theme in the *Odyssey*, and its use in the epigram is a possible exegetical signpost.[32] Is this Odysseus quite literally (or textually?) in disguise? Without any clear indication to whom these Circean words are directed, the reader may well place themselves as the Odyssean addressee. If the reader has before them the prose introduction, they could also imagine that Archimedes has taken on the role of Circe and therefore that Eratosthenes has been made to play the role of Odysseus. In either case, the addressee's characterisation as Odysseus presents them as the cunning, wily figure who is skilled in speech, according to Calypso (*Od*. 5.182–3) and Alcinous (*Od*. 11.367–8). The challenge as the poem proceeds is whether they can match up to that archetypal figure of intelligence and solve the mathematical puzzle.

Gutzwiller (2002); Fantuzzi and Hunter (2004) 291–306. For more on supplementation in the context of arithmetical poetry see Chapter 4, Section 2.

[31] Tueller (2008) 66–94.

[32] Stewart (1976) chapter 2 and Murnaghan (1987) chapter 3 still offer the best discussions of disguise, recognition and guest-friendship in the *Odyssey*.

Moreover, the opening line and address taken together point towards a further generic form:

πληθὺν Ἠελίοιο βοῶν, ὦ ξεῖνε, μέτρησον
  φροντίδ᾽ ἐπιστήσας, εἰ μετέχεις σοφίης

(*Cattle Problem* 1–2)

The multitude of the Cattle of the Sun calculate, O stranger, and set your mind to it, if you have a share in wisdom.

In the initial hexameter line there is an invocation (ὦ ξεῖνε), a command (μέτρησον) and a topic (πληθύν) modified by an extended description (Ἠελίοιο βοῶν). It structurally recalls the opening lines of many hexameter poems, including the *Iliad* and the *Odyssey*.[33]

ἄνδρα μοι ἔννεπε, Μοῦσα, πολύτροπον, ὅς . . .

(Homer *Odyssey* 1.1)

Tell me, o Muse, of the man of many ways, who . . .

μῆνιν ἄειδε, θεά, Πηληϊάδεω Ἀχιλῆος

(Homer *Iliad* 1.1)

Sing, o Goddess, of the anger of Achilles, son of Peleus

They too open with their subject, an invocation, a command and often a polysyllabic adjective. Epic invocations are employed to request information from the poet's goddess or Muse: they, and not the poet, have true knowledge and information.[34]

The verse-initial use of πληθύν ('multitude') is uncommon in Homer (cf. *Il.* 9.641, 11.305, 11.405 and 15.295), and by far the most well-known usage is in the Invocation to the Muses in *Iliad* 2. This word, I argue in Section 2, provides a connection to the Invocation prior to the Catalogue of Ships and its positioning of the poet's knowledge in relation to the Muses'. What can be said here is that the *CP*'s epic invocation is instead addressed to the reader and solver; will you be as successful as the omniscient Muses of epic in solving the problem? In one sense, the idea of knowing the number of the Cattle of the Sun parallels the knowledge of the Muses. Teiresias' underworld explanation of Odysseus' future stop on Thrinakia and encounter with the livestock represents the Sun in

[33] See also, for example, *Thebaid* fr. 1.
[34] The clearest discussion of this is still Lenz (1980) 21–41.

130

terms similar to the Muses. The description of the Sun who 'looks over everything and hears everything' (πάντ᾽ ἐφορᾷ καὶ πάντ᾽ ἐπακούει, *Od.* 11.109) is reminiscent of the Muses as described in the Invocation, who 'are gods and are present and know everything' (θεαί ἐστε πάρεστέ τε ἴστέ τε πάντα, *Il.* 2.485). The Cattle of the Sun are not a subject that the Muses dealt with directly, but the purview of the Sun allows for the possibility of their number being a matter of divine, superhuman and Muse-like knowledge nevertheless: an epic invocation in a Sicilian mode.

Equally, there is the influence of archaic elegy. Geoffrey Benson has argued that the stanzaic structure, the key terms of wisdom (σοφία) and measure or proportion (μέτρον) and the address to a ξεῖνε mean that 'the main motifs imitate archaic elegy'.[35] Wisdom and a sense of proportion appear in both archaic elegy and the *CP*, although the use of those terms in an emphatically mathematical context complicates the association; Archimedes enters into a dialogue with, but does not necessarily imitate, elegy. As Benson further notes, moreover, elegy continued to be composed in the Hellenistic period, and in particular it is the form used for some longer catalogue poems.[36] So while the prose introduction suggests that the poem ought to be read as a long epigram, the *CP*'s metrical form together with its listing of ratios rather places it in the tradition of Hellenistic catalogues. Generically speaking, then, the *CP* positions itself at the intersection of a number of poetic forms; both epigram and elegy are in play, and the period attests amply to how both genres reinterpret and rework Homeric material. Echoing archaic elegy, for example, no doubt lent an air of intellectual superiority and didactic wisdom to the imagined speaker. The disjunction between a lengthy catalogue and the short, compact works of epigram will return more pointedly in the following section.

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[35] Benson (2014) 180–2, with the quotation from 182.
[36] His analysis of the structural similarities is strong. Antimachus, Hermesianax and Callimachus all employ elegy in catalogue form, and this may well have influenced Archimedes. His argument – Benson (2014) 183–6 – that something like the tradition of the Seven Sages is meant at line 31 does not persuade. I present my own interpretation of lines 30–1 below.

131

Besides generic dexterity, Archimedes shows himself to be in touch with contemporary literary scholarship, and the prose introduction suggests some sort of dialogue with those working in Alexandria specifically.

πρόβλημα ὅπερ Ἀρχιμήδης ἐν ἐπιγράμμασιν εὑρὼν τοῖς ἐν Ἀλεξανδρείαι περὶ ταῦτα πραγματευομένοις ζητεῖν (*Cattle Problem*, Introduction)

A problem which Archimedes devised in epigrams for those in Alexandria attempting to work out such things: ...[37]

As the *scholia* to the *Odyssey* suggest, the number of the Cattle of the Sun was a subject of enquiry; ζητεῖν picks up the common term in the *scholia* for describing scholarly research.[38] The *scholia* present the seven herds of fifty cows and seven of fifty sheep as representing the days and nights of the year, and the sun the whole year. According to one *scholium*, it is a claim made by anonymous thinkers: ἥλιον ἐνταῦθα τὸν χρόνον λέγουσιν εἶναι, βόας καὶ μῆλα τὰς ἡμέρας ('they say that here the sun is time and the cows and sheep the days', B-*scholia* on *Odyssey* 12.128). A further *scholium* specifies that Aristotle had considered the meaning of the Cattle of the Sun: Ἀριστοτέλης φυσικῶς τὰς κατὰ σελήνην ἡμέρας αὐτὸν λέγειν φησὶ τν΄ οὔσας ('Aristotle explains in the manner of natural enquiry that he [Homer] says that the days under the moon are 350', B-*scholia* on *Odyssey* 12.129). It thus appears that this passage created a 'Homeric problem' as early as the fourth century.[39] Reincorporating scholarly cruces into new compositions is a hallmark of the early Hellenistic poets. Here Archimedes goes one step further and makes a Homeric *zêtêma* the subject of an entire poem.

Archimedes is no less scholarly in his vocabulary; his lexical choices suggest a keen awareness of Homeric language. As the reader proceeds through the poem, Archimedes plays with the idea of the reader as being Odysseus-like in their progress. After a gap

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[37] The referent of ταῦτα is probably the number of cattle; verse 41 of the poem refers to the cattle in this way.

[38] Nünlist (2009) 11.

[39] See now Mayhew (2019) 188–90, who persuasively argues that this is not Aristotle's reading, but Aristotle's attempt to describe what gave rise to the myth.

132

of twenty-two lines, in which Archimedes elucidates the ratios of the herds of the Cattle of the Sun, he addresses the reader.

ξεῖνε, σὺ δ᾽, Ἠελίοιο βόες πόσαι ἀτρεκὲς εἰπών,
  χωρὶς μὲν ταύρων ζατρεφέων ἀριθμόν,
χωρὶς δ᾽ αὖ θήλειαι ὅσαι κατὰ †χροιὰν ἔκασται,
  οὐκ ἄϊδρίς κε λέγοι᾽ οὐδ᾽ ἀριθμῶν ἀδαής,
οὐ μήν πώ γε σοφοῖς ἐναρίθμιος.

<div align="right">(Cattle Problem 27–31)</div>

If, O stranger, you accurately tell how many Cattle of the Sun there are, telling separately the number of well-fed bulls and separately again the number of each herd of cows according to colour, you would not be called unskilled or ignorant of numbers; nor yet, though, would you be numbered among the wise.

This signpost is not for the unlettered. It is an allusive reference underscoring the work's scholarly nature and its ludic application of Homeric philology. The adjective describing the addressee, ἄϊδρις ('unskilled'), occurs twice in Homer, once in the *Iliad* and once in the *Odyssey*. In the *Iliad*, Antenor describes Odysseus feigning foolishness while on an embassy to Troy as ἄϊδρις (*Il.* 3.219). In the *Odyssey*, after he has arrived on Aeaea and his crew have been transfigured into pigs, Hermes halts Odysseus and provides him with the protective moly before confronting Circe.

πῆι δὴ αὖτ᾽, ὦ δύστηνε, δι᾽ ἄκριας ἔρχεαι οἶος
χώρου ἄϊδρις ἐών;

<div align="right">(Homer Odyssey 10.281–2)</div>

To where are you heading this time, poor man, along the hilltops, knowing nothing of the country?

This is not the sly Odysseus of the *Iliad*, but of the *Odyssey*, constantly wandering and wondering to which land he has been blown, guided by the divine assistance of Athena.[40] Similarly, the related noun ἀϊδρείη ('ignorance') is twice applied to Odysseus' men who 'with ignorance' entered Circe's palace: οἱ δ᾽ ἅμα πάντες ἀϊδρείησιν ἕποντο ('they all at the same time entered with ignorance', *Od.* 10.231 = 10.257). Superficially, this adjective seems to be a congratulatory compliment to the reader and hopeful solver. What might the attentive reader infer about Archimedes' allusive

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[40] E.g. *Odyssey* 6.191, 7.193, 8.301.

description of them and another possible reference to Odysseus literally and textually disguised before them?

The Odyssean passage is emphatically geographical: Odysseus has no knowledge of *where* he is. How does this square with the *CP*? Broadly, the reader's halted progress parallels Odysseus' movement along the hilltops – δι' ἄκριας ἔρχεαι – intercepted by Hermes.[41] A problem that arises, however, is the transposition from Aeaea in the *Odyssey*, to Thrinakia in the *CP*. A claim of oversight on Archimedes' part is a possibility, but this does not really explain why such a specific textual allusion would lead to a readerly 'dead end'. Rather, I suggest, for the reader recognising both their adopted Odyssean role and the incongruity of the Homeric intertext, they best Odysseus by orienting themselves in line with Homeric geography, textually and figuratively. Thus, Archimedes' line could be reread as 'you will not be called unskilled (as Odysseus was, *geographically speaking*)'. In geographic terms, the allusion asks the reader if they can locate Odysseus. For Eratosthenes, questions of Odyssean geography are highly contentious. Broadly speaking, Homeric scholars had two positions on Odysseus' wanderings. Some located the wanderings within the Mediterranean, so Strabo records, such as himself and Callimachus (Strabo 1.2.37),[42] while others pinpointed them beyond the Pillars of Hercules, including Apollodorus of Athens and Eratosthenes (Strabo 7.3.6–7).[43] Sicily was identified as an especially likely candidate for the mythical island, and by the Hellenistic period the association was common. This was no doubt bolstered by Thucydides' folk etymology: Θρινακίη (Thrinakia), or as it was also known, Τρινακρία (Trinakria), a back-formation based on Sicily's three capes, τρεῖς-ἄκρας (lit. 'three points', Thuc. 6.2.2).[44] However, employing mythology to elucidate contemporary geography was found by some scholars to be methodologically dubious.

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[41] On the literal and figurative movements of reading epigrams see Höschele (2007).

[42] For Strabo's positive view of Homer see most recently Kim (2010) chapter 3.

[43] The particular naming and concretisation of this theory as 'ἐξωκεανισμός', however, comes only later with Crates of Mallos; cf. Crates frr. 44 and 77 Broggiato with Walbank (1979) 586–7 and Roller (2010) 120–3.

[44] See Gomme et al. (1970) 211.

134

Eratosthenes was a particularly vocal opponent. As a scientist and philosopher, as well as a literary critic and poet, he argued that although he was not against Homer's poetry per se, Homer's *Odyssey* had no place in the burgeoning discipline of geography.[45]

Yet prior to this proposed 'geographical' intertext, Archimedes had already signalled for the reader his intellectual allegiances.

πόσση ἄρ' ἐν πεδίοις Σικελῆς ποτε βόσκετο νήσου
  Θρινακίης τετραχῇ στίφεα δασσαμένη

(*Cattle Problem* 3–4)

As many as once grazed the plains of Sicilian Thrinakia's island, divided four-ways . . .

Archimedes' account of Sicily as Thrinakia signals no debate: the suggested geographical equivalence becomes fact. The association would pose no problem for the average reader, used to the mythical heritage of the island: cultural terra firma. For Eratosthenes, however, the equation of Sicily as Thrinakia is an impossibility. From the beginning, Eratosthenes' acceptance of the mathematical challenge and the readerly journey would jar. The Odyssean allusion, then, advances Archimedes' strategy. To decode Archimedes' allusion, the reader must take on the Odyssean role, journeying through a text and a myth firmly located on Thrinakia, a Thrinakia that is in fact Sicily. The allusion sets the reader at the interstices of Homeric geography and Homeric philology. Yet Eratosthenes, whom one would expect to notice this allusion, interprets the *Odyssey* in a way which does not allow Archimedes' (playful) geography and philology to intersect. The characterisation of the reader as οὐκ ἄϊδρις in a geographical sense gains piquancy when it is imagined to be aimed at Eratosthenes. Praise about knowing *where* one is, is a pointed compliment for Eratosthenes the revolutionary geographer. But the setting of Archimedes' poem and the Odyssean allusion which would constitute this praising set such a compliment on the precipice of ridicule. Eratosthenes may know where he is in this poem through textual allusions, but as a geographer, does he *really* know Homeric

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[45] Eratosthenes encapsulated this thinking, so Strabo reports, with the quip, 'one would find the location of Odysseus' wanderings when one finds the cobbler who sewed up the bag of winds' (ἂν εὑρεῖν τινα ποῦ Ὀδυσσεὺς πεπλάνηται, ὅταν εὕρῃ τὸν σκυτέα τὸν συρράψαντα τὸν τῶν ἀνέμων ἀσκόν, 1.2.15).

135

geography? Archimedes displays a sophisticated literary strategy, not only testing the reader's educated status, but offering a view of the literary challenge he sets up for Eratosthenes.

The final lines of the *CP* express a conditional tone, and again the possibility of a solution seems to be undercut by the literary references. Archimedes employs language reminiscent of Greek epinician poetry.

ταῦτα συνεξευρὼν καὶ ἐνὶ πραπίδεσσιν ἀθροίσας
   καὶ πληθέων ἀποδούς, ξεῖνε, τὰ πάντα μέτρα
ἔρχεο κυδιόων νικηφόρος ἴσθι τε πάντως
   κεκριμένος ταύτῃ γ᾽ ὄμπνιος ἐν σοφίῃ.

<div align="right">(Cattle Problem 41–4)</div>

If, O stranger, having completely worked out in your mind these things, collating and giving an account of every dimension you may go, a victor, and carry yourself proud, knowing that wholly you have been judged *ompnios* in this species of wisdom.

Proceeding as one who is κυδιόων νικηφόρος, the reader proudly carries off their victory. In the context of this intellectual contest, ἔρχεο is as much a sphinx-like 'you may pass' – having solved the problem – as it is a secondary epigrammatic command to go forth, having contemplated an inscription. The initial conditionality of the challenge – εἰ μετέχεις σοφίης (2) – is here resolved in a neat ring composition. Having completed these calculations, you have been judged wise; not only is it no longer a case of 'if', but the successful solver is 'rich' in a species of wisdom. The νικηφόρος so reminiscent of Pindaric epinician should also make one read an agonistic context in κεκριμένος – 'having been judged *in contest*' (cf. Pind. *Isthm.* 1.22; *Nem.* 3.67; *Ol.* 2.5, 13.14). This novelty should not be overlooked. The challenge exchanged between the two scholars, a battle of learning and culture, offers a noticeably different view of competing individuals and *poleis* in the Greek world. Success is not gained through sporting prowess, but in giving an account of mathematical dimensions and aspects of Homeric poetry.

Through his use of allusion Archimedes points to both the geographical and intellectual stakes of his problem: it is concerned with Sicily and with the parameters of human knowledge and the limits of the wise. Before exploring how these two issues are dealt

with on the scale of the poem as a whole and its catalogic form, I want to consider further the integration, confrontation and elision of various epigrammatic forms. The dense, allusive reworking of Homeric material positions the *CP* within the genre of epigrammatic riddles. The differing levels of assumed knowledge on the part of the reader have something to say about the *CP*'s context of production and reception.

To what extent is this allusion to Odyssean geography in the *CP* to be noticed by an astute reader? An epigram by Philetas of Cos underscores how Hellenistic riddle epigrams engage with Homeric material in intricate ways, employing both philology and a broader cultural knowledge.

οὐ μέ τις ἐξ ὀρέων ἀποφώλιος ἀγριώτης
    αἱρήσει κλήθρην, αἰρόμενος μακέλην·
ἀλλ' ἐπέων εἰδὼς κόσμον καὶ πολλὰ μογήσας,
    μύθων παντοίων οἶμον ἐπιστάμενος.

(Philetas fr. 8 Lightfoot)

No lumbering rustic from the mountains shall bear me, snatching up a hoe – me, an alder tree; but one who knows the marshalling of words, who toils, who knows the pathways of all sorts of speech.[46]

Peter Bing, rejecting variant views of the alder tree as a poet or a woman, suggested that it refers to a writing tablet.[47] More recently though, Jan Kwapisz highlights how the noun κλήθρη refers to the alder tree out of which Odysseus constructs his raft on Calypso's island.[48] The noun is a Homeric *dis legomenon*, only appearing in the scene where Odysseus builds the raft (*Od.* 5.64, 239), and it is the key for decipherment. If the pronoun μέ refers to the alder, then the 'alder-slayer' who knows 'the marshalling of words' and 'toils' is Odysseus, traits formulaically ascribed to him. Much as in the *CP*, the character of Odysseus is revealed to us through a philological signpost. How convincing is this reading? Philetas' epigram balances the reader's broad cultural exposure to Odyssean material with a textual allusion. Retrospectively, the reader might congratulate themselves for having noticed the unique κλήθρην. It is possible

[46] Translation adapted from Lightfoot (2009) 43. [47] Bing (1986) 224.
[48] Kwapisz (2013b) 156, developing Cerri (2005).

137

that an ancient reader would have deciphered the epigram simply from the references to a man who is good with speech, has struggled, but nevertheless knows many ways.[49] These are, after all, Odysseus' characteristic traits. This is crucial when considering literary riddles. Within a riddle, the information supplied is never itself erroneous; rather, it is obscurely expressed. With Philetas, as with Archimedes, their language describing Odysseus employs both philological specificities and ingrained cultural formularity. Not only does Archimedes repeatedly address the reader as a ξεῖνος ('stranger', 'guest') – Odysseus being the archetypal ξεῖνος – but the very situation is uniquely Odyssean. The novelty of this type of riddling epigram, it seems to me, lies in the ability to observe the author at work covering up the identity of a figure in Greek culture, mentioning but not mentioning the great Homeric hero. For the astute reader, a philological allusion is a further sign of the poet's skill in pointing to, but not explicating, the well-known subject.

The following riddle functions similarly, leaving its subject, a key Homeric figure, initially hidden from the reader.

ἄνδρ᾽ ἐμὸν ἔκταν᾽ ἑκυρός, ἑκυρὸν δ᾽ ἔκτανεν ἀνήρ,
    καὶ δαὴρ ἑκυρὸν καὶ ἑκυρὸς γενέτην.

<div align="right">(AP 14.9)</div>

My father-in-law slew my husband, my husband slew my father-in-law, my brother-in-law slew my father-in-law, and my father-in-law my father.

The epigram's features are not outwardly Homeric, nor are there any philological pointers; rather, a certain level of knowledge of Homer's epics is required. To solve this riddle and identify the figure as Andromache, one must know that her first husband Hector was killed by Achilles, who became her father-in-law when she married Neoptolemus, who had killed her first father-in-law Priam, and that Andromache's brother-in-law Paris killed her father-in-law Achilles, who had killed her father Eetion. The epigram presents a set of propositions concerning certain members of an unknown person's family which are relatively straightforward. The repetitious language compounding the four interrelations,

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[49] Bing (2009) chapter 8 considers insightfully the difference between general and specific allusions to Odysseus.

138

however, spawns complexity. With Philetas the identity of Odysseus is a textual matter; this Homeric epigram weaves a knot of interconnection around Andromache out of the broader cultural currency of epic. Archimedes operates in like fashion. There is a certain superficial simplicity in offering up the ratios of herds of cattle. When considered thoroughly, though, it becomes obvious that things are more complicated. Both epigrams underscore how difficult it can be to untangle the mass of culture that is the Homeric tradition. The denouement of the epigram on Andromache is successful because it offers the reader resolution; there are simple answers to knotty cultural interrelations.

In these riddles, the workings of cultural capital can be seen at play. Hellenistic literate education and knowledge of Homer in particular could create a shared identity uniting the educated Greek elite, but it is also the means through which individuals could gain intellectual distinction by demonstrating the extent and depth of their learning.[50] The agonistic intellectualism of the Andromache epigram seems clear, for Philetas this is probable, and in the case of the *CP*, the epistolary header is highly suggestive. Clearly, a philological note demands deeper knowledge than heroic genealogies. Nonetheless, literary reference and popular knowledge are not mutually exclusive, and this is part of the craft of the riddle. In the *CP*, there is no enunciation of Odysseus. Yet his character and his narrative are never far from the reader's mind. A reader of the *CP*, picking up the Odyssean cues, could congratulate themselves. Those who notice the philological intertext of ἄϊδρις will feel 'intellectual' and may additionally reflect whether Eratosthenes too noticed the intertext. Archimedes' poem allows the reader to observe intellectual agonism 'in action', and the literary riddle is the ideal form through which to underscore this competitive interaction.

3.2 Cattle and Catalogues

Archimedes' allusive art in the *CP* sets his poetic skills on a par with Hellenistic poets more traditionally viewed as scholarly

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[50] See Morgan (1998) 74–89 with Thompson (1994) 67–8 and Cribiore (2001) 225–30.

and recondite. By redeploying key Homeric words, he alludes to the exclusive nature of being σοφός ('wise') and reconfigures Odyssean geography. This would have had a clear effect for a poem exchanged between himself and Eratosthenes, revolutionary geographer and curator of the largest Greek library ever seen. In addition to the allusive language, however, the catalogic form of the poem – its listing of the ratios of cattle – has a deep history in Homeric poetry. My interest in this section is the connection between the *CP* and Homer's Invocation prior to the Catalogue of Ships. I argue that Archimedes frames the possibility of solving the ratios through a series of allusions to that passage and to *Iliad* 2 more broadly. My focus in particular will be on what this intertext implies about handling large numbers in verse and the possibility of the reader solving the ratios. Subsequently, I ask how this perspective is modified by the appeal to elegiac traditions that occur in the first pentameter. If the Iliadic Catalogue is signalled as an intertext in the opening hexameter, how does this picture change when it becomes clear that this is an elegiac catalogue of cattle? I ultimately want to argue that Archimedes actively strains generic forms that might be ascribed to the *CP* in order to highlight the limits of human knowledge. The series of allusions to *Iliad* 2 together with the programmatic opening couplet, in other words, explores the similarities between mathematical and poetic knowledge and the difficult compromises which arise when they interact.

Before turning to the first word of the *CP*, it is worth pointing out that Archimedes' subject matter fits closely with the broader context of the Catalogue in *Iliad* 2. Immediately preceding the Invocation to the Muses for support in accounting for all the Achaeans at Troy, Homer describes the gathering host in a series of seven similes. They are likened first to a fire ravaging a forest (2.455–8), then to birds flocking on to a meadow (2.459–66), to the number of leaves in a meadow (2.467–8) and flies swarming round a milk pail (2.469–73). Following these four similes characterising the host, the poet turns to characterise their organisation.

140

τοὺς δ᾽, ὥς τ᾽ αἰπόλια πλατέ᾽ αἰγῶν αἰπόλοι ἄνδρες
ῥεῖα διακρίνωσιν, ἐπεί κε νομῷ μιγέωσιν,
ὣς τοὺς ἡγεμόνες διεκόσμεον ἔνθα καὶ ἔνθα
ὑσμίνηνδ᾽ ἰέναι

<div align="right">(Homer Iliad 2.474–7)</div>

Just as when goatherds easily divide up the broad herd of goats when they mix in the field, so did the leaders order them [the troops] here and there to go into battle.

The organisation of the troops is likened to goat-herding. The leaders who διεκόσμεον ('ordered') the troops recall Agamemnon's notable numerical language earlier in the book, where he imagines both the Trojans and Achaeans being 'counted up' (ἀριθμηθήμεναι, *Il.* 2.125) and the Achaeans being 'ordered into tens' (ἐς δεκάδας διακοσμηθεῖμεν, *Il.* 2.127), in order to highlight that the Trojans are outnumbered. The counting of troops in this later scene is now a pastoral activity. Archimedes' poem looks to a highly numerical passage regarding cattle in the *Odyssey* but, given its opening allusion to the Invocation prior to the Catalogue, also connects this with the herding imagery which immediately precedes the Invocation. In asking the reader to calculate the πληθύς ('multitude') of cattle, Archimedes realises the vehicle of the Homeric simile and transforms it into the actual subject of a calculation.

Now to the opening word itself: πληθύν. Primarily, it signifies a 'multitude'. It also recalls Homer's Invocation before the Catalogue. That passage's popularity as a stand-alone section of the *Iliad* in Greek society, evidenced by papyri, affords the opportunity to take πληθύν seriously as a salient intertext and ask how this might affect a reading of the *CP*.[51] Here is the passage again.

ἔσπετε νῦν μοι, Μοῦσαι Ὀλύμπια δώματ᾽ ἔχουσαι –
ὑμεῖς γὰρ θεαί ἐστε πάρεστέ τε ἴστέ τε πάντα,
ἡμεῖς δὲ κλέος οἶον ἀκούομεν οὐδέ τι ἴδμεν –
οἵ τινες ἡγεμόνες Δαναῶν καὶ κοίρανοι ἦσαν.
πληθὺν δ᾽ οὐκ ἂν ἐγὼ μυθήσομαι οὐδ᾽ ὀνομήνω,
οὐδ᾽ εἴ μοι δέκα μὲν γλῶσσαι, δέκα δὲ στόματ᾽ εἶεν,
φωνὴ δ᾽ ἄρρηκτος, χάλκεον δέ μοι ἦτορ ἐνείη,
εἰ μὴ Ὀλυμπιάδες Μοῦσαι, Διὸς αἰγιόχοιο
θυγατέρες, μνησαίαθ᾽ ὅσσοι ὑπὸ Ἴλιον ἦλθον·
ἀρχοὺς αὖ νηῶν ἐρέω νῆάς τε προπάσας.

<div align="right">(Homer Iliad 2.484–93)</div>

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[51] Cribiore (1994) 4–5; Cribiore (1996); Cribiore (2001) 194.

Tell me now, you Muses who have dwellings on Olympus – for you are goddesses and are present and know all things, but we hear only a rumour and know nothing – who were the leaders and lords of the Danaans. But the multitude I could not tell or name, not even if ten tongues were mine and ten mouths and a voice unwearying, and the heart within me were of bronze, unless the Muses of Olympus, daughters of Zeus who bears the aegis, call to my mind all those who came beneath Ilion. Now I shall tell the leaders of the ships and all the ships.

With the prospect of (re)counting all the men at Troy the poet reaffirms his relationship to the Muses. The poet's inability to deal with a large number of people contrasts with the Muses' omniscience. This progression of thought raises interpretative issues. The poet's lack of knowledge in comparison to the Muses and the inability to recall the entire πληθύς given his human limitations and mortal frame are traditional elements of catalogues.[52] The further conditional, however, could be interpreted as implying that the Muses can help the poet overcome those mortal deficiencies which he had outlined.[53] I would follow Tilman Krischer and see this as being resolved by taking ὅσοι (*Il.* 2.492) to be an indirect interrogative and not a relative pronoun.[54] The Muses, that is, can support the poet to recall the number of the πληθύς and select narratives, but nothing more: recalling the narratives of the entire πληθύς would demand a superhuman ability.[55] His final resolution to speak about the leaders of the ships and the ships allows him to balance both demands.

How the passage in the *Iliad* might have been understood later in antiquity affects the sense that can be ascribed to the echo of πληθύς in the *CP*. On the broadest level, the opening use of πληθύς brings to mind the difficulty of dealing with large numbers that arose in *Iliad* 2 and raises the question whether the reader of the *CP* will be able to manage these large numbers too. In *Iliad* 2, the

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[52] See Sammons (2010) 148–53, with further bibliography.

[53] See Brügger et al. (2003) 143–4.

[54] Krischer (1965) 4–5. Sammons (2010) 154–5 points to some problems with this interpretation, especially the fact that the indirect interrogative follows on from a clause which is more to do with naming than counting. However, I take counting here to be a prerequisite for recalling: one could not possibly recall the entire (narrative history of the) multitude without first establishing how many there are.

[55] This distinction between naming and counting finds support in one of the *scholia* to the Catalogue, which specifies that it is the act of recalling and naming which requires divine aid and so, it might be thought, divine *abilities* (bT-*schol. Il.* 2.488).

Invocation could be interpreted as signalling that the poet has divine support in giving the audience an account of the gathered troops, or it could be understood that his account based only on the leaders and the ships instead constituted the poet recounting the troops without divine aid. If Homer were understood not to have the support of the Muses in giving his enumerative catalogue, this may make more tangible the reader's expectation that the catalogue of ratios is manageable and the πληθύς enumerable: Homer did this without the Muses, so might I. In my estimation, though, the condition of the Muses' support in recalling how many went to Ilion (492) is what enables the poet to account for (to say nothing of naming) the πληθύς in the form of a catalogue. With *Iliad* 2 in mind, the Muses' absence from Archimedes' poem suggests that, just like the poet on his own, the reader will be unable to give the total number of Cattle of the Sun. This picks up a further aspect of the Catalogue and its calculations, namely that Homer never gives a final answer nor explicitly puts a number to the πληθύς of the troops. Even with the Muses' help, the poet is only able to give a catalogue that counts the number of troops per ship and ships per leader, and fails to provide the numerical total. Since Archimedes' ratios would have been irresolvable, his poem too remains a catalogue of numbers that does not yield a final numerical answer for the πληθύς.

Computing the ratios of the Cattle of the Sun thus becomes akin to attempting to count up all the heroes who went to Troy, but this connection extends well beyond the allusive opening word. Archimedes further draws from the deliberative scenes in *Iliad* 2 in order to characterise the potential solver of the problem. Consider again Archimedes' apostrophe to the reader.

ξεῖνε, σὺ δ᾽, Ἠελίοιο βόες πόσαι ἀτρεκὲς εἰπών,
  χωρὶς μὲν ταύρων ζατρεφέων ἀριθμόν,
χωρὶς δ᾽ αὖ θήλειαι ὅσαι κατὰ †χροιὰν ἕκασται,
  οὐκ ἄϊδρίς κε λέγοι᾽ οὐδ᾽ ἀριθμῶν ἀδαής,
οὐ μήν πώ γε σοφοῖς ἐναρίθμιος.

(*Cattle Problem* 27–31)

If, O stranger, you accurately tell how many Cattle of the Sun there are, telling separately the number of well-fed bulls and separately again the number of each

143

herd of cows according to colour, you would not be called unskilled or ignorant of numbers; nor yet, though, would you be numbered among the wise.

Verse 31 looks forward to the additional parameters which Archimedes will provide, but also continues to allude to Homer and to Odysseus. The *Iliad* and the *Odyssey* each contain a single occurrence of ἐναρίθμιος ('numbered among'). Most pertinent is the Iliadic context where Odysseus seeks to persuade the Achaeans not to flee following Agamemnon's test of the troops and false promise of return.[56]

δαιμόνι᾽ ἀτρέμας ἧσο καὶ ἄλλων μῦθον ἄκουε,
οἳ σέο φέρτεροί εἰσι, σὺ δ᾽ ἀπτόλεμος καὶ ἄναλκις,
οὔτέ ποτ᾽ ἐν πολέμῳ ἐναρίθμιος οὔτ᾽ ἐνὶ βουλῇ.

(Homer *Iliad* 2.200–2)

Good man, sit still and listen to the words of others, who are better than you, while you are weak and unwarlike, nor are you ever to be counted in war or in council.

Odysseus attempts to subtly talk over the other leaders among the Greeks, but he addresses those of the masses with harsher words. Here, being ἐναρίθμιος designates inclusion within a group, and a group that is marked out by its power and elite position within Homeric society. Odysseus' denigration of the masses as not being ἐναρίθμιος within this group is offset by the Catalogue of Ships. If Odysseus uses the language of counting to define the lower social position of the average soldier, Homer nevertheless ensures that they are given some renown by being meticulously counted among those who went to Troy. The adjective's Iliadic usage raises the possibility of the reader of the *CP* being counted among the wise in the same way that the leaders at Troy are promoted above the mere mass of soldiers.

Archimedes concludes his representation of the reader in the final lines of the *CP* and continues to draw on *Iliad* 2 in characterising the successful solver.

ταῦτα συνεξευρὼν καὶ ἐνὶ πραπίδεσσιν ἀθροίσας
  καὶ πληθέων ἀποδούς, ξεῖνε, τὰ πάντα μέτρα

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[56] Its use in the *Odyssey* scene (12.62–6) may also be pertinent for the *CP* given that the passage is spoken by Circe, who later in her speech will describe the Cattle of the Sun.

ἔρχεο κυδιόων νικηφόρος ἴσθι τε πάντως
  κεκριμένος ταύτῃ γ᾽ ὄμπνιος ἐν σοφίῃ.

<div align="right">(Cattle Problem 41–4)</div>

If, O stranger, having completely worked out in your mind these things, collating and giving an account of every dimension you may go, a victor, and carry yourself proud, knowing that wholly you have been judged *ompnios* in this species of wisdom.

Important for my purposes, first, is that the participle κυδιόων ('carrying oneself proudly') is used to describe Agamemnon in his entry within the Catalogue.[57]

ἐν δ᾽ αὐτὸς ἐδύσετο νώροπα χαλκὸν
κυδιόων, πᾶσιν δὲ μετέπρεπεν ἡρώεσσιν,
οὕνεκ᾽ ἄριστος ἔην, πολὺ δὲ πλείστους ἄγε λαούς.

<div align="right">(Homer Iliad 2.578–80)</div>

And among them he himself wearing flashing bronze, exulting, standing out among all the heroes, very much the best because of his many people.

Even in a catalogue of heroes and their troops, Agamemnon nevertheless stands above them all in his pre-eminence. Identifying the figure of Agamemnon behind Archimedes' representation of the reader in the final lines highlights the arithmetic progress being implied. The rhetorical movement in the *CP* from the solver as one who is ἐναρίθμιος to one who is like Agamemnon models Odysseus' address to the soldiers. Following his denigration of the soldiers as not even ἐναρίθμιος in war or council he then calls for them to unite under Agamemnon – εἷς κοίρανος ἔστω | εἷς βασιλεύς ('let there be one ruler, one king', *Il.* 2.204–5). Characterising the solver now not simply as one of those who is counted among the generals of the troops as opposed to the mass of soldiers, but as the leader of the whole contingent, figures them as unique in their abilities. Agamemnon had already displayed his ability to make calculations regarding the troops earlier in the book (*Il.* 2.123–33), and he stands even above the other leaders ordering their troops in the simile before the Invocation and Catalogue (474–5, see above), both of which suggest his ability to handle and order numbers on a greater scale than the other leaders. At the

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[57] It is used in the nominative plural in reference to the gods at *Il.* 21.519.

<div align="right">145</div>

end of the *CP*, Archimedes' use of κυδιόων in a poem already recalling the Invocation and Catalogue raises the possibility that the reader will have full mastery over the number of cattle just as Agamemnon had control over the troops.

Equally, though, the conclusion can be read as hinting at the impossibility of the arithmetical task. The participle κυδιόων also appears in two almost identical similes comparing the heroes Paris and Hector to horses that have bolted the stable and enjoy their freedom glorying in their splendour (*Iliad* 6.506–11 = 15.263–8). With Paris, the image of a horse that delights too much in his appearance reflects Paris' underlying nature, whereas Apollo, rousing Hector from his feeling of defeat, brings out in him the exulting confident defender of Troy. It is this onslaught, this final rallying against the Achaeans with Apollo's aid, that leads to the death of Patroclus at Hector's hands, and thus seals his fate at Achilles' hands.[58] Moreover, in the Homeric *scholia* both Paris and Hector are taken as paradigms of 'boastfulness' (ἀλαζονεία).[59] To read echoes of either narrative is thus to hear a note of caution about believing in one's own abilities.[60] There may well be further irony, too. The adjective νικηφόρος plainly refers to the solver as a victor, but in Pindaric epinician poetry it can also be applied to horses (e.g. *Ol.* 2.5). Likewise, while the meaning of ὄμπνιος remains unclear, it seems that it was connected by a number of authors with nourishment, agricultural produce and grain.[61] The solver may well be 'victorious' and 'well-fed' or 'nourished', but like an overly proud horse; after all, Homer appeals to the Muses to

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[58] On both similes see most recently Graziosi and Haubold (2010) 226–7.

[59] On Paris see bT-*schol. Il.* 3.439–40a and on Hector see bT-*schol. Il.* 7.29 and A-*schol. Il.* 17.201b.

[60] The account of Agamemnon as κυδιόων in the Catalogue also recalls his earlier description in the run of similes before the Invocation. There in the same metrical *sedes* he is likened to a bull 'standing out among the gathered herds' (βόεσσι μεταπρέπει ἀγρομένῃσι, 481) and the simile is made explicit two lines later when Homer describes how Zeus makes Agamemnon 'stand out from the many and pre-eminent among heroes' (ἐκπρεπέ᾽ ἐν πολλοῖσι καὶ ἔξοχον ἡρώεσσιν, 483). If Agamemnon is seen as the leader of all the troops, it does not mean from a divine perspective that he is not still one of the herd.

[61] See LSJ *s.v.* ὄμπνιος with further discussion at Dettori (2000) 21 and 122–3, Lightfoot (2009) 79 and Leventhal (2015) 209. A *scholium* to Apollonius Rhodius offers the phrase στάχυν ὄμπνιον ('an *ompnios* ear of corn') and records that Philetas of Cos defined it as corn that is εὔχολον καὶ τρόφιμον ('succulent and nourishing'), *Schol.* on Ap. Rhod. 4.989i Wendel = fr. 46 Lightfoot.

account for horses, as well as for men, in his Catalogue (cf. *Il.* 2.760–2). Archimedes thus employs Homeric terms in order to create the expectation of a solution as well as to undercut it. Halfway through the *CP*, the reader is promised that they might become more than one of the masses and ἐναρίθμιος among the Greek leaders if they can solve the mathematics, and the conclusion elevates this to the possibility that they might be an Agamemnon having control over all the troops. Yet it is a decidedly ambiguous representation of the solver in the final lines. These allusions to *Iliad* 2 raise but do not confirm the possibility that the reader can compute the number of cattle in the same way that the poet counted the troops in his Catalogue after they had been herded by the leaders, in the imagery of Homer's simile.

It is equally important to observe that the question of how easy it might be to grasp such a large amount is not only posed by the Iliadic intertexts. It also extends across the first couplet as a whole and particularly in the move from the opening hexameter to the following pentameter. In explaining the interrelation of the hexameter and pentameter, I consider to be instructive the one surviving fragment of the fifth-century Carian poet Pigres. This brother (*Suda s.v.* Πίγρης 1551) or son (Plut. *Mor.* 873f) of Artemisia, the ruler of Halicarnassus and ally of Xerxes, composed an *Iliad* in elegiacs, inserting after each of Homer's hexameters a further pentameter. His modification to *Il.* 1.1 is as follows:

μῆνιν ἄειδε θεὰ Πηληϊάδεω Ἀχιλῆος
 Μοῦσα· σὺ γὰρ πάσης πείρατ᾽ ἔχεις σοφίης.

(Pigres fr. 1 *IEG*)

Sing, goddess Muse, of the wrath of Achilles son of Peleus: for you hold the limits of all wisdom.

Pigres plugs Homer's own concerns with the limits of mortal knowledge in the Invocation in *Iliad* 2 back into the opening invocation of the *Iliad*. He also reworks the proem into an elegiac couplet and introduces a notably elegiac theme. The term σοφία is common in Theognis' articulation of wisdom in his sympotic elegies (563–6, 790, 876, 1074 *IEG*), and it is an attribute associated specifically with poets by Solon in his Elegy for the

147

Muses: ἄλλος Ὀλυμπιάδων Μουσέων πάρα δῶρα διδαχθείς | ἱμερτῆς σοφίης μέτρον ἐπιστάμενος ('Another, taught with gifts from the Olympian Muses, knowing the measure of lovely wisdom', fr. 13.51–2 *IEG*). Similarly, μέτρον ('measure') is common in earlier elegiac poetry, denoting self-control in sobriety and desire.[62] In both Solon and Pigres, these terms sit in the pentameter, the line which differentiates the genre from epic hexameter. In Solon's elegy, the pentameter negotiates the distinctiveness of elegy as a genre – with ἱμερτή suggesting a more erotic mode (cf. Theognis 1063–8 *IEG*) – and focalises the agency of the poet and his ability to know. Whereas Solon intimates the bounded nature of poetic knowledge per se through his use of μέτρον, Pigres' pentameter emphasises how epic and elegiac poets differ in their claims to wisdom and authority. Rather than expanding the request for knowledge from the goddess across a series of lines, specifying the remit of the present song as was typical in early incipits, Pigres' rewriting both curtails this request and emphasises the Muse's supreme control over knowledge. His couplet does not position the elegiac poet as in control of *sophia*, but rather the Muse; it (re)asserts the authority of the Iliadic – and so, epic – Muse by means of an elegiac strategy. Moreover, despite Pigres doubling the length of the *Iliad* through pentameters, it is the Muse who retains 'mastery' over Homeric material. Archimedes likewise addresses the question of human and divine knowledge through the addition of the pentameter. There, he commands that the reader measure the multitude 'if they have a share in wisdom' (εἰ μετέχεις σοφίης, 2). Unlike Pigres, Archimedes does not make it immediately explicit who it is that possesses wisdom. He offers up to the reader the hope that they may gain wisdom but, given the irresolvable ratios, the *CP* demonstrates the exclusive and elusive nature of wisdom, something that Pigres' elegiac addition had simply stated. That is, the pentameter supports the language and allusion of the hexameter in setting up another expectation for the hopeful solver that is destined to be unfulfilled.

The move from the hexameter to the pentameter hints at the potential impossibility of measuring the multitude in poetry in

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[62] On μέτρον cf. Solon fr. 16 *IEG* and Theognis 876 *IEG* with Prier (1976).

148

another manner, too. πληθύν in *Iliad* 2 signalled the opening of a hexameter catalogue. Similarly in the *CP*, the reader's expectations are fulfilled when Archimedes provides his exposition of the ratios of the cattle, a catalogue of cattle responding to Homer's imagery in *Iliad* 2. A catalogue in elegiac couplets, or epigram as the prose introduction has it,[63] however, strains the concept of the generic form. Epigram is a traditionally compressed genre that would seem to be poles apart from the extended narratives of epic. A later Greek epigrammatist attempts to lay down the law when it comes to poetic length and its generic association, quipping in a single couplet that 'a two-line epigram is very fine; but if you exceed three couplets, you are rhapsodising and are not saying an epigram' (πάγκαλόν ἐστ' ἐπίγραμμα τὸ δίστιχον· ἢν δὲ παρέλθῃς | τοὺς τρεῖς, ῥαψῳδεῖς κοὐκ ἐπίγραμμα λέγεις, *AP* 9.369).[64] At a total of twenty-two couplets, the *CP* would rank as one of the longest extant epigrams. It could perhaps be compared to the equally ambitious Hellenistic inscription found at Salamacis on the history of Halicarnassus.[65] By the same token, the blurred line between epigram and elegy that I noted in Section 1 reinforces the sense of strained generic forms; the recent advent of catalogue elegy represents a generic compromise between the concision of epigram and the expanse of epic.[66] In an analogous vein, Archimedes combines a move into elegiacs with textual extension: his versified catalogue of the Cattle of the Sun is over ten times longer than Homer's original (forty-four lines vs four lines). Yet, in Pigres' case, doubling the length of the *Iliad* did not counteract the fact that the Muse is the one who possesses wisdom. The very meaning of his first inserted pentameter underscores this. The *CP* likewise offers the hope of wisdom in the pentameter but never in fact confers it upon the reader. In other words, length does not directly translate into more wisdom or knowledge contained within the poem. In that

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[63] The phrase ἐν ἐπιγράμμασιν refers to epigram rather than elegy; cf. p. 128 n.28 above. As I have noted, however, Archimedes appears to be influenced by, and plays with, epigrammatic and elegiac forms.

[64] For all that is known about the poet Cyrillus and his possible dates, see Page (1981) 115.

[65] See Isager (1998) and discussion in Gagné (2006) and Sider (2017).

[66] On which see Asquith (2005).

149

respect, too, the extension of the *CP* into a form of catalogue epigram or elegy simulates Homer's own expansive catalogue of numbers and figures which for all its length does not in the end explicitly supply the total amount of the πληθύς for the audience. The opening couplet of the *CP*, then, introduces the challenge to the reader but also draws on language redolent of the quintessential epic catalogue, as well as of elegiac concerns about wisdom, precisely in order to suggest that such a feat might not be within the bounds of mortal knowledge.

On my reading, these Iliadic intertexts set up the expectation that calculating the number of cattle, and especially without the help of the Muses, will not be a success. This is subsequently supported with the pentameter's turn to questions of wisdom and its attainability. Archimedes has set his sights on the question of human knowledge and its limits. This would have been a potent and political issue for Eratosthenes at the Library of Alexandria. In this respect, I want to tentatively suggest that the use of μέτρησον at the end of the opening hexameter is pointed. The verb μετρέω and its cognates are connected to measurement of all kinds from the earliest times, but it sees increasing use in the Hellenistic period in contexts which highlight not just a manipulation of, but a control over, Greek culture and its Homeric aspects. In the case of the Tabulae Iliacae, Michael Squire has demonstrated that the ability to circumscribe, condense and schematise Homeric narratives is constructed as a wondrous feat and an expression of mastery and wisdom (σοφία) by those who claim to have done so.[67] Archimedes' opening hexameter, flanked by πληθύν and μέτρησον, offers a similar possibility to the reader and to Eratosthenes, that they might succeed by employing the concrete tools of mathematics and have some grasp of one aspect of the Homeric tradition. There is an irony, moreover, in addressing the challenge to Eratosthenes in the library where Homer's epics were most famously edited, ordered and commented upon in a way that sought mastery and control over the Homeric texts.[68] How easily will this servant of the Muses calculate the πληθύς without the

[67] Squire (2011) 102–10, 247–83.   [68] See Erskine (1995) 42–6.

Muses' explicit support? Even before the irresolvable ratios, Archimedes' epic intertext and elegiac turn in the pentameter suggest that this is far from guaranteed. The opening couplet questions the possibility of measuring the multitude in poetry, a tension that additionally raises the possibility of, but also resists, the circumscribing of Homeric subject matter more widely.

3.3 Calculating Cattle and Cultural Competition

The *CP* represents itself as operating in line with Homer's poetics of calculation in *Iliad* 2, but its metrical form also hints at the strain of composing a catalogue of calculations in verse. My argument in this section is that this tension that arises when one attempts to compress such a large amount of mathematical material into a poem has a specific cultural-political motivation. Here, I examine cataloguing and calculating in contemporary and earlier poetry. The calculations in these texts do not compare to the complexity of Archimedes' ratios; they are for the most part displays of simple addition. The difference in the mathematical operation exhibited notwithstanding, I demonstrate that an abiding aspect of these passages is the enacting or performing of calculation as a form of geographical possession. This poetics of census-taking seems to have a particular aim in the context of the *CP*'s geographically focused claim to a Homeric Sicily. My proposal is that the very form of Archimedes' calculating catalogue articulates a politics of space and identity in order to circumscribe the possibility of Sicily's (metaphorical) possession.

I begin with perhaps the clearest contemporary instance of a poetics of census-taking. Theocritus, Archimedes' older contemporary and fellow Syracusan, demonstrates the politics of a counting catalogue in his *Encomium to Ptolemy* (*Idyll* 17), where the fertility and productivity of Egypt are described.

ἀλλ' οὔτις τόσα φύει ὅσα χθαμαλὰ Αἴγυπτος,
Νεῖλος ἀναβλύζων διερὰν ὅτε βώλακα θρύπτει,
οὐδέ τις ἄστεα τόσσα βροτῶν ἔχει ἔργα δαέντων.
τρεῖς μέν οἱ πολίων ἑκατοντάδες ἐνδέδμηνται,
τρεῖς δ' ἄρα χιλιάδες τρισσαῖς ἐπὶ μυριάδεσσι,
δοιαὶ δὲ τριάδες, μετὰ δέ σφισιν ἐννεάδες τρεῖς·

151

τῶν πάντων Πτολεμαῖος ἀγήνωρ ἐμβασιλεύει.[69]

(Theocritus *Idylls* 17.79–85)
(300 + 3,000 + 30,000 + 6 + 27 = 33,333)

But none [other tribes] brings forth so much as low-lying Egypt, when the Nile gushing breaks the wet soil, nor has any [other country] so many towns of men skilled in work. Three hundred cities have been built there, and three thousand upon thirty thousand, and two times three and three times nine in addition to them; great Ptolemy rules over all of them.

As with Archimedes' poem, the explanation of a number through calculation emphasises multiplicity, although of course Theocritus aims at nothing so complex. Both exhibit a similar means of connecting fertility and calculation. Just as the Nile's fertile bubbling up (ἀναβλύζων, 80) is paralleled in the ensuing count of the many cities, so too do Archimedes' cattle when ordered in a triangular formation 'begin bubbling up from a single one' (ἀμβολάδην ἐξ ἑνὸς ἀρχόμενοι, 38): numerical growth simulates natural and economic growth. Given that the passage concludes by stating that Ptolemy rules over this large number, however, its evocation of 'the Egyptian and Ptolemaic passion for counting and census-making' has the serious function of characterising political control through a control of numbers.[70] The ability to express such a large number within just three lines further simulates this Ptolemaic control: the great number of cities in Egypt are still accountable to Ptolemy, and so their number is countable for a Ptolemaic poet.

A similar claim to land through enumeration can be seen in Lycophron's *Alexandra*, a 1,474-line Hellenistic iambic poem which gives Cassandra's final prophecy during the sack of Troy, which spans all the way from the time of the Trojan War through mythic history and down to the Hellenistic period itself. It describes Aeneas' founding of Lavinium after fulfilling Helenus' prophecy, in a narrative familiar from the *Aeneid* (3.390–2).

κτίσει δὲ χώραν ἐν τόποις Βορειγόνων
ὑπὲρ Λατίνους Δαυνίους τ' ᾠκισμένην,
πύργους τριάκοντ', ἐξαριθμήσας γονὰς
συὸς κελαινῆς, ἣν ἀπ' Ἰδαίων λόφων

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[69] The Greek text follows Gow (1952); my translation adapts Hunter (2003) *ad loc.*
[70] Hunter (2003) 158.

152

καὶ Δαρδανείων ἐκ τόπων ναυσθλώσεται,
ἰσηρίθμων θρέπτειραν ἐν τόκοις κάπρων·

<div align="right">(Lycophron Alexandra 1253–8)</div>

He [Aeneas] will found a place among the areas of the Aborigines, beyond the settlements of the Latins and Daunians, and thirty towers, having numbered up the offspring of the dark sow, which he will have brought by ship from the peaks of Ida and the Dardanian regions, the nurse of those equal-numbering piglets in the litter.[71]

It is emphatically Aeneas' enumeration here that leads to his founding of Lavinium and determines its number of towers. The *Alexandra*, although once considered to be early third-century, is most likely a product of the mid-second century.[72] This passage from the so-called Roman section is relatively early evidence for the development of Roman foundation myths, especially in a wider Greek context.[73] While the prophecy on the enumeration of the sows is alluded to here first in poetry, as a myth it predates the *Alexandra* having been recorded by Fabius Pictor in the late third century (*FGrH* 809 F 2).[74] In a less mythical – but no less fantastic – vein, the *Alexander Romance* (1.33.11) reports a numerical conundrum posed to Alexander in a dream by a god, who delineates a series of numbers (200-1-100-1-80-10-200) which reveals their nature when converted into letters (σ-α-ρ-α-π-ι-ς, Σάραπις, 'Sarapis').[75] Certainly, this is a different form of mathematical challenge. Still, its appearance in the context of recognising the god so as to legitimate and support Alexander's foundation of Alexandria highlights a further example of the

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[71] The Greek follows Mascialino (1964) and the translation is an adaptation of Hornblower (2015) *ad loc.*

[72] For a welcome corrective and full explanation of the down-dating, see Hornblower (2015) 36–9; Hornblower (2018) 3–10.

[73] For Roman myths in a Greek context and the importance of Troy, see Erskine (2001).

[74] A version of the Mopsus and Calchas contest (see below) is about the number of offspring in a sow's womb (Apollod. *Epit.* 6.3–4). Both a boar (σῦς) and figs (συκέα) appear at *Od.* 24.330–46 in a similarly enumerative context (see below); the two traditions of enumeration may thus have their roots in subsequent (mis)interpretations of the one scene.

[75] The text as it stands is corrupt – see Kroll (1926) *ad loc.* and Stoneman (2007) 74 with commentary at 544–5 – and the date of the *Alexander Romance* itself ranges from the beginning of the Hellenistic to the Late Imperial period; see the discussion of Stoneman (2007) xxv–xxxiv. Nevertheless, since the Ptolemies encouraged the Sarapis cult, this section is generally thought to be a later echo of that earlier, Hellenistic Ptolemaic propaganda.

intersection of counting and foundation. It is important to underscore in these examples that at the time Archimedes was composing the *CP*, scenes of enumeration were a productive means of staging (re)imaginations of political geography.

A further passage that has not been discussed in relation to the *CP* is Odysseus' reunion with his father, Laertes. Having reunited with Penelope, Odysseus heads to the farm where his father lives and labours. Meeting him alone in the vineyard, he at first pretends to be someone else who had met Odysseus on his travels; only when Laertes breaks down in sorrow does Odysseus reveal himself to his father.[76] In order to prove his identity, he offers the following tokens as evidence.

τὸν δ' ἀπαμειβόμενος προσέφη πολύμητις Ὀδυσσεύς·
"οὐλὴν μὲν πρῶτον τήνδε φράσαι ὀφθαλμοῖσι,
τὴν ἐν Παρνησῷ μ' ἔλασεν σῦς λευκῷ ὀδόντι
οἰχόμενον· σὺ δέ με προΐεις καὶ πότνια μήτηρ
ἐς πατέρ' Αὐτόλυκον μητρὸς φίλον, ὄφρ' ἂν ἑλοίμην
δῶρα, τὰ δεῦρο μολών μοι ὑπέσχετο καὶ κατένευσεν.
εἰ δ' ἄγε τοι καὶ δένδρε' ἐϋκτιμένην κατ' ἀλωὴν
εἴπω, ἅ μοί ποτ' ἔδωκας, ἐγὼ δ' ᾔτεόν σε ἕκαστα
παιδνὸς ἐών, κατὰ κῆπον ἐπισπόμενος· διὰ δ' αὐτῶν
ἱκνεύμεσθα, σὺ δ' ὠνόμασας καὶ ἔειπες ἕκαστα.
ὄγχνας μοι δῶκας τρισκαίδεκα καὶ δέκα μηλέας,
συκέας τεσσαράκοντ'· ὄρχους δέ μοι ὧδ' ὀνόμηνας
δώσειν πεντήκοντα, διατρύγιος δὲ ἕκαστος
ἦην — ἔνθα δ' ἀνὰ σταφυλαὶ παντοῖαι ἔασιν —
ὁππότε δὴ Διὸς ὧραι ἐπιβρίσειαν ὕπερθεν."
ὣς φάτο, τοῦ δ' αὐτοῦ λύτο γούνατα καὶ φίλον ἦτορ,
σήματ' ἀναγνόντος τά οἱ ἔμπεδα πέφραδ' Ὀδυσσεύς·

(Homer *Odyssey* 24.330–46)

And resourceful Odysseus answered him and said: 'This scar, first, let your eyes take note of, which a boar gave me with his white tusk on Parnassus when I went there. It was you who sent me, you and my honoured mother, to Autolycus, my mother's father, so that I might get the gifts which, when he came here, he promised and agreed to give me. And come, I will tell you also the trees which

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[76] This scene, since it appears in Book 24, has been thought spurious following the statement in the *scholia* that Aristarchus and Aristophanes of Byzantium set the end of the *Odyssey* at 23.296. Many have debated the authenticity of all or part of Book 24; for discussion see Moulton (1974); Wender (1978) 45–62; Russo et al. (1992) 353–5. Whatever the case, its authenticity does not affect my argument for a reception in the Hellenistic period.

154

you once gave me in our well-ordered garden, and I, who was only a child, was following you through the garden, and asking you for this and that. It was through these very trees that we passed, and you named them and told me of each one. Thirteen pear trees you gave me, and ten apple trees, and forty fig trees. And rows of vines, too, you promised to give me, even as I say, fifty of them, which ripened one by one at separate times – and upon them are clusters of all sorts – whenever the seasons of Zeus weighed them down.' So he spoke, and his father's knees were loosened where he stood, and his heart melted, as he recognised the firm tokens which Odysseus showed him.

Odysseus gives two forms of evidence: the physical scar on his body and his mental recollection of the gifts that Laertes had promised to give him. Homer, through a variety of intermediaries, has already presented the scar and the narrative which accompanies it (cf. *Od*. 19.391, 393, 464, 507; 21.221; 23.74). The recounting of the trees, however, appears only here. The description of the trees and their count responds to the over-exposed sign of the scar; it represents not heroic deeds or the revealing and naming of the hero, but the naming of home (ὠνόμασας/ὀνόμηνας), its fixedness (τά … ἔμπεδα) and fecundity (the *hapax* διατρύγιος). As Odysseus reaches the heart of Ithaca at the end of the *Odyssey*, he reconnects with his roots and points to the one sign of belonging that he was unable to take with him but took account of nevertheless. For John Henderson, the enumeration is only one part of a wider rehearsal between father and son; Odysseus' miming of 'bodily commitment', 'his insistent deixis' and his 'remembered walk in the wake of his father across the very scene of utterance' constitute a performance of sameness between father and son, a 'monological evidentiality, a self-identical prestation'.[77] I would emphasise in addition that within this recollection and rehearsal, the count of the trees figures Odysseus' Ithacan inheritance at large: the variety of trees, their continual bearing of fruit throughout the seasons represents not just this plot of land, but also the fertility of Ithaca *tout court*. He has regained his son, his wife, his halls, and now he must recover the land. The passage from Lycophron's *Alexandra* showed how the challenge of enumeration was employed to explain and legitimate claims over land following the Trojan war, and Odysseus' enumeration at the end of the

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[77] Henderson (1997) 105–6.

Odyssey is in a sense a prototype of the later Aeneas, although he is seeking to *re*claim his Ithacan inheritance. As I have argued, the *CP* engages intricately with Odyssean geography; the tradition of claiming the land through counting also has an Odyssean lineage. Archimedes offers the possibility of another Odyssean 'accounting', and so the possibility of another claiming of land, only this time of a different island. He has taken one Odyssean claim to the possession of space and has transferred it to the equally Odyssean *and* equally numerical context of the Cattle of the Sun which had more significance for him as a Sicilian.

Odysseus' and Aeneas' travels and subsequent census-taking most likely arose in response to the Greek colonisation of the archaic period and to the need for myths to explain the foundation of new colonies. As the passages from the *Alexandra* and the *Alexander Romance* show, an oracle – a directive from a god – is a particularly irrefutable way to justify the Greek claims to land across the Mediterranean. A fragment from Hesiod's *Melampodia*, a hexameter poem tracing the lives of mythical seers, further demonstrates that archaic poets were aware that calculated claims to land in oracular contexts could involve contestation. Here is the fragment and Strabo's introduction to it:

εἶτα τὸ Γαλλήσιον ὄρος καὶ ἡ Κολοφών, πόλις Ἰωνική, καὶ τὸ πρὸ αὐτῆς ἄλσος τοῦ Κλαρίου Ἀπόλλωνος, ἐν ᾧ καὶ μαντεῖον ἦν ποτὲ παλαιόν. λέγεται δὲ Κάλχας ὁ μάντις μετ' Ἀμφιλόχου τοῦ Ἀμφιαράου κατὰ τὴν ἐκ Τροίας ἐπάνοδον πεζῇ δεῦρο ἀφικέσθαι, περιτυχὼν δ' ἑαυτοῦ κρείττονι μάντει κατὰ τὴν Κλάρον, Μόψῳ τῷ Μαντοῦς τῆς Τειρεσίου θυγατρός, διὰ λύπην ἀποθανεῖν. Ἡσίοδος μὲν οὖν οὕτω πως διασκευάζει τὸν μῦθον· προτεῖναι γάρ τι τοιοῦτο τῷ Μόψῳ τὸν Κάλχαντα·

θαῦμά μ' ἔχει κατὰ θυμόν, ἐρινεὸς ὅσσον ὀλύνθων
οὗτος ἔχει, μικρός περ ἐών· εἴποις ἂν ἀριθμόν;

τὸν δ' ἀποκρίνασθαι·

μύριοί εἰσιν ἀριθμόν, ἀτὰρ μέτρον γε μέδιμνος·
εἷς δὲ περισσεύει, τὸν ἐπενθέμεν οὔ κε δύναιο.
ὣς φάτο· καί σφιν ἀριθμὸς ἐτήτυμος εἴδετο μέτρου.
καὶ τότε δὴ Κάλχανθ' ὕπνος θανάτοιο κάλυψεν.

<div align="right">(Hesiod fr. 278 M–W = Strabo Geography 14.1.27)</div>

Then one comes to the mountain Gallesius, and to Colophon, an Ionian city, and to the sacred precinct of Apollo Clarius, where there was once an ancient oracle. The story is told that Calchas the prophet, with Amphilochus the son of Amphiaraus, went there on foot on his return from Troy, and that having met near Clarus a prophet superior to himself, Mopsus, the son of Manto, the daughter of Teiresias, he died of grief. Now Hesiod revises the myth as follows, making Calchas propound to Mopsus this question:

'I am amazed in my heart at all these figs on this wild fig tree, small though it is; can you tell me the number?'

And he makes Mopsus reply:

'They are ten thousand in number, and their measure is a medimnus; but there is one over, which you cannot put in the measure.' Thus he spoke; and the number that the measure could hold proved true. And then the eyes of Calchas were closed by the sleep of death.[78]

Colophon was founded when the seer Manto arrived there, having left Thebes in the aftermath of the war of the Seven against Thebes (cf. e.g. *Epigonoi* fr. 3 *EGF*). The famous seer Calchas, in the aftermath of the Trojan War, arrived at Colophon and challenged Manto's son, Mopsus, to a contest of their oracular abilities. Numerous versions of the meeting between Mopsus and Calchas have survived (Strabo 14.1.27; Apollod. *Epit.* 6.2–4).[79] Across the range of retellings, as Naoíse Mac Sweeney has shown, there is variability in the agency ascribed to Manto and to her son, Mopsus, regarding which of the two founded Colophon and the Oracle at Clarus.[80] Whichever narrative one follows, though, a notable constant in the accounts is that Mopsus prevails in the contest with Calchas. In its broadest outline, the contest constitutes an *aition* for the continued Theban and Mantid control of that oracular site following the Trojan War and the challenge of Calchas. The second constant is that the oracular challenge always has a numerical element.

Archimedes may have had this story, or a version of it, in mind. As befits a contest, 'calculating' the figs on the tree has a question-

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157

and-answer format. This 'tell me' formula is recognisable from the *Contest of Homer and Hesiod* passage (above, introduction to Part II) and is similar to the opening of the *CP* (ὦ ξεῖνε, μέτρησον, 1). More notably, Mopsus' answer has two stages: he gives Calchas the exact number of figs, but then goes on to explain how that number might be expressed as a volume measurement by introducing the medimnus. The *Alexandra* preserves a variant account which places Calchas in southern Italy by the banks of the river Siris: 'there lies unhappy Calchas, a Sisyphus of uncountable figs' (ἔνθα δύσμορος | Κάλχας ὀλύνθων Σισυφεὺς ἀνηρίθμων | κεῖται, 979–81). The *scholium* to Lycophron's elliptical reference describes how Calchas met not Mopsus, but Heracles after he had carried off the oxen of Geryon, and how he successfully responded to Heracles' challenge to enumerate the figs on a tree. Calchas numbered them as ten medimni and one fig and mocked Heracles when 'having measured them and greatly forcing the one left-over fig into the measure [i.e. medimnus], he was unable to' (τοῦ δὲ Ἡρακλέος ἀναμετρήσαντος καὶ πολλὰ βιαζομένου τὸν ἕνα ὄλυνθον περισσὸν ἐπιτιθέναι τῷ μέτρῳ καὶ μὴ δυναμένου, *Schol.* on *Alexandra* 980a). In response Heracles kills Calchas for mocking him. Both narratives of Calchas' death focus on the fact that certain numerical totals cannot be expressed in a geometric form, such as the volume of a medimnus. Archimedes similarly structures the *CP*.[81] The *CP* first asks for the number of the Cattle of the Sun from the given ratios and then second provides the parameters that the white bulls together with the black bulls are a square number and that the brown bulls and dappled bulls are a triangular number. Given the different objects of calculation, Archimedes substitutes volume for area. As I outlined above, the first half of the problem (5–26) yields infinitely many solutions, with the smallest positive integer solutions yielding

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[81] Knorr (1986) 295 proposed that Eratosthenes composed the first half of the problem and Archimedes the second. The prose preface does not suggest this, and there is nothing in the text to corroborate it. As the discussion in Section 1 makes clear, moreover, I believe the political geography of the *CP* suggests rather that the entire poem is Archimedes' creation.

cattle in their millions.[82] It is the second half (33–40) and the requirement to fit the cattle into a rectangular and triangular arrangement which makes the sum astronomically large and ultimately incalculable for a Hellenistic mathematician. Arguably, the *CP*'s structural echo of the contest in the *Melampodia* and the similar retellings constitutes a hint that the further parameters lead inevitably to failure. Elsewhere Archimedes employs literary allusions to suggest to the astute reader the (im)possibility of their success, and here too they will know from earlier poetry such as the *Melampodia* that you cannot force and fudge a calculation when sensible and indivisible bodies are involved – that is, when doing λογιστική. Just like the lone fig, for the ancient reader, these cattle could not be forced simply into any old measure.

Archimedes' use of this structure also geographically frames the stakes of solving the mathematics of the *CP*: failure in a numerical challenge leads to a failure to gain possession of land. In the *Melampodia*, Mopsus succeeds in the competition and so retains control over Clarus. The *CP* similarly offers up a numerical challenge but also sets the challenger up to fail in that task. Since these are Sicilian cattle and since such counts as those discussed above connect censuses of the land with possession over the *same* land, it would be logical to suppose that Archimedes presents the calculation in the *CP* as offering the potential for possessing Sicily. Archimedes, just like Mopsus at Clarus, retains dominion over Sicily, whereas Eratosthenes would have failed in his attempt to calculate the number of the cattle, as did Calchas. Unlike the passages from Theocritus' *Idyll*, the *Alexandra* or the *Odyssey*, where those counting seem only to have to assert their possession over the land, I would suggest that the *Melampodia* (or something like it) provided Archimedes with a model of an arithmetical challenge between two famed intellectuals who have competing claims to a location. Given that, as I discussed above, this is a poem about Sicily sent to an intellectual who denied its Homeric pedigree, the importance of this model helps clarify the

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[82] White Bulls = 10,366,482; Black Bulls = 7,460,514; Brown Bulls = 4,149,387; Dappled Bulls = 7,358,060; White Cows = 7,206,360; Black Cows = 4,893,246; Brown Cows = 5,439,213; Dappled Cows = 3,515,820.

159

purpose of the *CP* and the nature of the challenge Archimedes sent
Eratosthenes: if you can calculate the number of the Cattle of the
Sun, you can then claim possession of (knowledge about) Sicily.

The focus on the number of Sicilian livestock finds
a contemporary parallel in Theocritus' *Idyll* 16, as Marco
Fantuzzi notes and Reviel Netz develops. That 'patriotic' *Idyll*,
addressed to Hieron II of Sicily, looks towards the island's reinvig-
oration with ἀνάριθμοι | μήλων χιλιάδες ('countless thousands of
sheep', Theocritus *Idyll* 16.90–1). Netz pushes this numerical
aspect, suggesting that Theocritus' emphasis on 'those who
wished to slaughter its [Sicily's] cattle' refers to contemporary
events, perhaps Marcellus' attacks and siege of the city.[83] Thus, in
two political poems, Theocritus' poetry preserves two contrasting
political connotations of enumeration. For the Ptolemies in *Idyll*
17 (above), fertility is something which can be emphatically
brought under control and measured; for Sicily, conversely, its
fecundity is immeasurable as the island teems with cattle. In the
CP, admittedly, it is the number of the legendary Cattle of the Sun
and the Thrinakia of Homeric poetry that is to be calculated and so
controlled rather than the contemporary livestock of Sicily.
Nevertheless, many such political interactions between
Hellenistic states and *poleis* were effected through appeals to
their (fictive and recently fashioned) epic past.[84] Whereas
Theocritus states the immeasurability of Sicily's cattle,
Archimedes offers the expectation of grasping the quantity of
cattle, which the arithmetical complexity duly thwarts; Sicily's
cows are innumerable and Sicily unlimited in its resources. His
language and mathematics equally contrive an uncontrollable,
incalculable situation in the same vein as the teeming livestock
of *Idyll* 16, and it is directed against a Ptolemaic intellectual who
might well have been in a position to calculate the number of cities
in the vein of *Idyll* 17. Unlike the earlier counting contests over
land, Archimedes' *CP* resists simple scientific judgements being

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[83] Netz (2009) 168, where Fantuzzi's thought *per litteras* is noted. See also Gow
(1952) 128.
[84] On kinship ties in antiquity and the role of myth see Jones (1999) 8–16 and chapter 2; for
a case study see e.g. Erskine (2002).

160

made about Sicily. It cannot be counted by – and so potentially ruled by – the Ptolemaic Empire.

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This chapter set out to demonstrate that the *CP* engages with its readers on literary, intellectual and cultural levels as well as on the arithmetical level: evident by now, I hope, is the sophistication of Archimedes' agonistic arithmetic aesthetics aimed at Eratosthenes. The *CP* works because it problematises scientific and mathematical descriptions of cultural and literary artefacts, especially for Eratosthenes, whose rationalising geography sees him strip Sicily of its Homeric past. Archimedes beats Eratosthenes at his own game, pairing poetry and mathematics, and offers a scientific expression of the Greek cultural idea of the Cattle of the Sun (not to mention the dimensions of Sicily itself). The irresolvable ratios of cattle underscore the sheer fecundity of the Sicilian land and its inability to be fully encompassed, an immeasurability that might even be seen to stand for the boundlessness of the Homeric tradition. This is an aesthetics of arithmetic, in other words, that points up the very tension of setting arithmetic in verse as well as the contested capabilities of mathematics as a means of describing the world.