INTRODUCTION

NUMBERS UP

I.1 Poetic Figures

This book explores Graeco-Roman poetry's engagement with and use of numbers. What I mean by this can best be explained by turning to Homer's self-presentation in the *Iliad*, where the matter of enumeration intersects with the question of poetic expression.

ἔσπετε νῦν μοι, Μοῦσαι Ὀλύμπια δώματ' ἔχουσαι –
ὑμεῖς γὰρ θεαί ἐστε πάρεστέ τε ἴστέ τε πάντα,
ἡμεῖς δὲ κλέος οἷον 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' ὅσοι ὑπὸ Ἴλιον ἦλθον·
ἀρχοὺς αὖ νηῶν ἐρέω νήάς τε προπάσας.

(Homer *Iliad* 2.484–93)

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, were to call to my mind all those who came beneath Ilion. Now I shall tell the leaders of the ships and all the ships.[1]

The passage addresses the presence in poetry of numerical as well as heroic figures. Faced with the prospect of describing the entirety of the gathered Achaean troops in the ninth year of the war, Homer turns to address the Muses again.[2] While it precedes the Catalogue

[1] The Greek text of Homer follows Allen (1920), with translations adapted from Murray and Wyatt (1999) for the *Iliad* and from Murray and Dimock (1995) for the *Odyssey*.

[2] Scholarship on the Invocation and Catalogue is vast. One traditional concern has been the historical period and geographical politics it encapsulates, see Allen (1921); Burr (1944); Hope Simpson and Lazenby (1970); Visser (1997). In terms of the make-up of the *Iliad*, it

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of Ships and the detailed counting up of the troops, it also follows on from Homer's series of similes variously describing the gathering. In the run of similes, the host's armour shines like a fire ravaging a forest, the troops appear like flocks of birds gathering in a meadow, like all the leaves and flowers in a meadow, and like a swarm of flies round a milk pail (*Il.* 2.445–73), and their organisation is then likened to goatherds ordering their flocks (474–7). The Invocation thus functions as a hinge, mediating between poetic modes: the similes' poetics of likeness and the Catalogue's poetics of enumeration. Yet it is not frequently observed that the passage is an extended reflection on the tension between poetic content (how many things you want to describe) and the poetic resources required to recount it (how many verses it will take). Prior to accounting for the ships at length in the Catalogue, in other words, the poet is exploring and commenting upon his *enumerative* abilities.

The role of the subsequent enumeration in the Catalogue depends on the interpretation of this passage. On the one hand, in contrast to the similes, which require no introduction or justification, the Catalogue's poetics of enumeration need the support of the Muses in order to be achieved. The ability to fully recall the host lies solely with the Muses. On the other hand, the Muses' support in recounting the entire host is in fact a condition (note the optative mood of μνησαίαθ'), and the poet turns instead to recounting only the leaders and the ships. The poet admits that the problem is one of poetic capacity. The implication of his claim that he 'could not tell or name the multitude, not even if ten tongues were his and ten mouths' (*Il.* 2.488–90) is that a great amount of content requires a concomitant extension of the poem, which, in this case, even a division of labour by a multiplication of mouths can do nothing to foreshorten. (Later Latin poets enact their own numerical expansion from ten mouths to a hundred, but

has often been considered a later insertion, more appropriate to the gathering of the troops at Aulis than to the troops on the Trojan plain in the ninth year of the war, see Allen (1921) 169–70; Wade-Gery (1952) 53–7; Jachmann (1958); Kullmann (1960) 63. For a more literary evaluation of the dislocation see Sammons (2010) 140–8. The following is a necessarily brief account of the passage which glosses over certain interpretative issues; see Chapter 3, Section 2 for more detail about the varying interpretations and for my approach.

equally to no avail.)[3] His solution to the expected increase in extension is remarkable. The Catalogue accounts for the number of men per ship, the number of ships per leader and the number of leaders. So, in lieu of counting up the number of warriors who went to Troy (ὅσοι ὑπὸ Ἴλιον ἦλθον, 2.492), he allows for the audience to reach a total instead based on the leaders and their ships (ἀρχοὺς αὖ νηῶν ἐρέω νῆάς τε προπάσας, 2.493). Rather than being an exhaustive count, the number of the host can be inferred through what would now be called multiplication.

This strategy is used earlier in *Iliad* 2 by Agamemnon to calculate the relative sizes of the Achaean and Trojan forces. He imagines groups of ten Achaeans being served wine by one Trojan and concludes that not all the Achaeans would be served (*Il*. 2.119–28): the Achaeans outnumber Trojans by more than ten to one. Equally, one of the similes preceding the Invocation displays a similar thinking. The leaders are described as organising their troops like goatherds, and among them stands Agamemnon at a higher level above those leaders (474–83). In both cases, individual soldiers are organised into groups so as to make their conceptualisation more manageable, and these groups are then organised further: by Agamemnon when he compares the Trojans with the Achaeans, and again by Agamemnon who rules over the leaders who have already arranged their troops. The organisation that enables the poet to encapsulate the host for the audience is one which was understood both by figures within the poem and by its audiences (to whom the simile is directed). Of course, the use of multiplication is a traditional means of expressing quantity in Archaic epic.[4] What is so striking in *Iliad* 2 is that the poet has harnessed these resources in order to explicitly reflect on his capacity as a poet and how certain types of calculation shape the catalogue as a poetic form.

[3] Enn. *Ann*. 469–70 Skutsch; Hostius fr. 3 Courtney; Verg. *G*. 2.42–4 and *Aen*. 6.635–7. Ovid gives up the count and settles for 'many mouths' (*pluraque . . . ora*, *Tr*. 1.5.54). Gowers (2005) 171–3.

[4] For example at *Il*. 8.562–3 (1,000 fires, 50 men by each); 9.85 (7 Greek leaders, each with 100 men); 9.383 (200 warriors coming out of each of the 100 gates of Thebes); and 16.168–71 (50 ships for Achilles, 50 men at hole pins in each and 5 leaders).

Later readings of the passage, moreover, focus on and respond to Homer's counting. In arguing that the scale of the Trojan War was not as great as often assumed, Thucydides makes his own count based on Homer's Catalogue (Thuc. 1.10.1–2). He first surmises there to be 1,200 ships, which is not far from the 1,186 ships that is reckoned in modern scholarship on the basis of the Catalogue's count. He then recognises that only the Boeotian contingent and Philoctetes' contingent are given explicit numbers of men per ship, at 120 and 50 men respectively, and conjectures that this is the upper and lower limit of the men per ship (Thuc. 1.10.4). From this he states – but does not calculate – that if one were to take the mean number of men per ship (85) the force would still be small at 102,000 men (Thuc. 1.10.5). Setting to one side whether this is in fact a small contingent by ancient standards, he brings to bear his own numerical abilities in reading Homer's Catalogue and so elevates the numerical aspect as a key point of interest.

Other readers, though, could come to different totals. The mythological handbook attributed to Apollodorus of Athens (a historian and geographer) concludes in the relevant chapter that 'the total number of ships was 1,013' (νῆες μὲν οὖν αἱ πᾶσαι ˏαιγ΄, Apollod. *Epit*. 14). Similarly, in the Latin mythological handbook attributed to Hyginus, the *Fabulae*, a count is made, although it is marred by textual corruption. The chapter gives the reckoning of the ships as 245 (*summa naues CCXLV*, *Fab*. 97.55) despite the individual numbers given in Hyginus' list adding up to 1,286 (which is a round 100 from the accepted 1,186). These counts of ships and people also guided later readers approaching Homer's Catalogue. A *scholium* to the beginning of the Catalogue directly invokes Thucydides' language and his method of taking the mean number of men per ship in explaining that Homer 'further, does have something to say about the multitude [of the host]' (καίτοι λέγει καὶ περὶ τοῦ πλήθους, bT-*scholia* on Homer *Iliad* 2.488) and that the reader is readily able to compute the total. The lack of a final sum in the poem, which in an original oral context may have contributed to a purposeful overload of information for the audience, became a prompt to engage numerically with epic for later readers encountering Homeric poetry on the page.

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These readings also fed into new poetic compositions and their reformulations of the poet and his work. To keep with the Catalogue of Ships, a more overt mathematicisation is found in the *Contest of Homer and Hesiod* and its reimagining of Homer's Invocation. When asked by Hesiod how many *men* sailed to Troy, he replies with a calculation much shorter in length than the Iliadic catalogue.

πεντήκοντ' ἦσαν πυρὸς ἐσχάραι, ἐν δὲ ἑκάστῃ
πεντήκοντ' ὀβελοί, περὶ δὲ κρέα πεντήκοντα·
τρὶς δὲ τριηκόσιοι περὶ ἓν κρέας ἦσαν Ἀχαιοί.

(*Contest of Homer and Hesiod* 143–5 Bassino)
(50 × 50 × 900 = 2,250,000)

'There were fifty hearths of fire, in each were fifty spits, and around each were fifty pieces of meat: three times three hundred Achaeans were around one piece of meat.'

The Homer of the *Contest* has progressed from the Catalogue that counts to the more complex calculation that is multiplication. For the audience(s) of the *Iliad*, it was necessary to estimate the number of men in each ship and add together the troops under each leader in order to reach a sum for the entire Achaean contingent, in the manner that Thucydides had theorised. The Homer of the *Contest* bypasses the need to display his counting, or indeed to place his counting abilities under any scrutiny. He reaches a number for the entire contingent in only a few lines where the Iliadic Homer had professed his inability to account for the multitude at all (πληθύν, *Il.* 2.488).[5]

A further reworking of the Catalogue in Latin focuses on the numerical abilities of the reader. The *Ilias Latina*, a Neronian-era poem attributed to Baebius Italicus, compresses the key events of the *Iliad* into 1,070 hexameter verses.[6] Its rewriting of the Catalogue is prefaced by its own second invocation – *Vos mihi nunc, Musae . . . referte* ('recount to me now, Muses', 161–2) – and it begins also with the Boeotian contingent: *Boeoti decies quinas egere carinas | et tumidos ualido pulsarunt remige fluctus* ('the

[5] I offer a more detailed analysis of this scene in the introduction to Part II.
[6] For his name and date see Scaffai (1997) 15–29. The Latin text also follows Scaffai, while the translations are my own.

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Boeotians drove ten times five ships and hit the swollen waves with their strong oarsmen', 169–70). In the following catalogue the sum of ships is outlined by a combination of multiplication as in the case of the Boeotians, simple addition as in the case of Agamemnon's 100 ships (171–3) and even subtraction as in the case of Eumelus, who sets off with one less ship than Telamonian Ajax's twelve (197–8). This poet, however, extends his redrafting also to give a total account of the ships: *his ducibus Graiae Troiana ad litora puppes | bis septem uenere minus quam mille ducentae* ('To the Trojan shore with these leaders there came twice-seven less than one thousand two hundred Greek ships', 220–1; 1,200 – (2 × 7) = 1,186). Both the *Contest* and the *Ilias Latina* draw in the reader, since the total number of soldiers or ships must again be achieved through calculations of different kinds. Yet, whereas Homer in both the *Iliad* and the *Contest* had allowed the sum to be inferred, in the *Ilias Latina* the reader can check their own calculating against the poet's final tally. It is a total, moreover, which matches the ships that Homer had enumerated. Homer's audiences summed up the number of ships and soldiers across the centuries and in turn tried out composing their own calculations.

A keen interest in Homeric numbering extends beyond the Catalogue. A close eye, for example, was also kept on the number of ships and people in readings of the *Odyssey*. Odysseus recounts to the Phaeacians that, following his contingent's escape from the Cicones, 'six fine-greaved companions from each ship died' (ἓξ δ' ἀφ' ἑκάστης νηὸς ἐϋκνήμιδες ἑταῖροι | ὤλονθ', *Od*. 9.60–1). This line was a subject of lively debate: already in the fourth century BCE the Homeric critic Zoilus found it unbelievable that Odysseus would have lost an equal number from each ship (*FGrH* 71 F 19); the Pergamene critic Crates responded in the second century BCE that it is, however, a believable *fiction* (fr. 48 Broggiato). Zoilus' suspicion of Odysseus' 'averaging out' of the number of perished crew was not shared by all readers. It is at least taken as an acceptable total for exegesis of subsequent passages. Later in the same book, Odysseus recalls that, on arriving at Aeaea, he numbered (ἠρίθμεον, *Od*. 10.204) his crew into two groups and sent one group of twenty-two with Eurylochus as leader to investigate the

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island (*Od.* 10.205–8), where they would meet Circe and would be transformed into pigs. The scholiast quotes that earlier passage, noting that 'since six from each ship have died, there remain 44, of which a half is 22' (ἓξ γὰρ ἀφ' ἑκάστης νεὼς ἀπολομένων περιελείποντο μδ΄, ὧν οἱ ἡμίσεις εἰσὶ κβ΄, *scholium* on Homer *Odyssey* 10.208). Just as Odysseus continues to count off the declining tally of his crew to the listening Phaeacians, so too ancient audiences of the *Odyssey* were keeping count.[7]

Homer's numerical ability is a cornerstone of his self-presentation as a poet in the *Iliad*, and the *Contest of Homer and Hesiod* shows that this remained a salient aspect of the figure of the poet; as will become clear in the introduction to Part II, the author of the *Contest* returns to the issue and builds his reimagining of Homer's enumerative capacities out of verses drawn from the Catalogue and surrounding context. Yet number in poetry is not only a matter that affects the profile of the poet: *reading* Homer's poetry meant observing the numbers and submitting them to analysis. This is a mode of poetic appreciation that is evidenced in the Homeric *scholia* and is set in high relief by the *Ilias Latina*'s translation and rewriting of the Catalogue. Its concluding total makes patent what was only implicit in *Iliad* 2, namely that the Catalogue is a form of organising information in poetry that calls for participation and specifically calculation on the part of the reader. Over the course of Graeco-Roman antiquity, in other words, numerical thinking and diverse forms of calculation played an important role within ancient poetics for both poets and audiences alike.

I.2 Poetry by Numbers

This celebrated passage of Greek poetry gives a prominent position to counting and calculation in verse, and subsequent readings of Homer likewise could be avowedly numerical. But the phenomenon is not peculiar to Homeric poetry and its reception. Poetic

[7] Two men are chosen to visit the Lotus-eaters and a third as herald (*Od.* 9.90); twelve ships' worth of men join Odysseus in hunting on the Cyclopes' island (9.159–60); after the Cyclops twice kills two companions (9.289 and 311), four men remain with Odysseus in the cave (9.335).

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engagements with numbers and with a whole range of calculations can be found throughout Graeco-Roman antiquity. Numbers of people, objects and events were calculated in poems on the basis of supplied ratios; the number of lines, poems or books of poetry were counted up; so too, the letters in a verse were treated as numbers and summed up (a practice called isopsephy; see Chapter 3); and counting was even used to evaluate a poem's worth. In this book, I will thus be casting a wider net to bring together all these cases of poetry in which numerical and arithmetical procedures play an active role.

Yet what the example demonstrates, importantly, is that examining poetic engagements with number provides a way into wider questions of aesthetics and poetic form. A shared culture of mathematical competency undergirds not only the poet's self-fashioning and the formation of his poems but also the subsequent approach to, and aesthetic judgement of, poetry. To get to grips with this mathematical competency and its particular applications within poetry and in divergent approaches to poetry is to gain a deeper understanding of how Greek and Roman poetry works. More specifically, this study provides a window on to the cognitive dimensions of poetry – that is, how it was processed in the mind of both composers and audiences – and what mathematics in addition contributed to its production and reception. In evaluating a range of intersections of poetry and number, I address ancient conceptions of poetry's fundamental workings as medium and cultural artefact and those aspects it was thought to share with mathematics. I focus on poets throughout antiquity who discussed and utilised mathematical operations with the aim of commenting upon their activities and upon the shape of their resulting poetic product. I also explicate the range of numerical analyses that were expected on the part of the reader in making sense of that poetry. Counting and calculating were more important for Greek and Roman poets than has generally been acknowledged. This book therefore contributes a chapter to Graeco-Roman literary history which argues for the critical place of number in the formation and development of poetic culture.

This endeavour is supported, in one sense, by the fact that poetry is numerical in its core structure: it is defined by its use of

metre.[8] Both the composition and reception of metre require the ability to follow rules predicated on number and complex combinations of long and short syllables. Llewelyn Morgan has demonstrated the mathematical acumen that goes into Latin poetry: poets manipulated rhythms in sophisticated ways and expected audiences to notice unusual patterns.[9] An explicit awareness of the role metrical form plays is evident already in Hellenistic Greek poems. Boiscus of Cyzicus, for example, self-reflexively points to his poem in the obscure metre of the catalectic iambic octometer: 'the writer of a novel poem, [having] discovered the eight-foot line' (καινοῦ γραφεὺς ποιήματος | τὸν ὀκτάπουν εὑρὼν στίχον, *SH* 233.1), and in a similar vein Castorion of Soli advertises his *Hymn to Pan* as a poem where the words in any verse can be rearranged but the metre maintained (*SH* 310: see Chapter 4, Section 2 for further discussion). Musical theorisation in antiquity was predominantly geometric.[10] (For this reason, harmonics and the harmony of the spheres are concepts not addressed here.) In this respect, then, poetic metre is one aspect of ancient musical culture that is defiantly numerical in its counting out of beats. Yet numerical dexterity – as the reception of Homer's Catalogue shows – was evidently not confined to constructing and deciphering poetry's rhythmical schemes alone. A stark later example is the shape of Vergil's *Eclogues* and *Georgics*, which John Schafer has cogently demonstrated to be informed by a regular line per column division (35 and 40 lines respectively) corresponding to their original pagination: meaning is derived in part from the reader's awareness

[8] Cf. e.g. Gorgias (*Helen* 9) and Aristotle (*Poetics* 1447a25–b20). Herodotus identifies poetic works by the number of 'measures' (μέτρα) in them: Archilochus sang of Gyges ἐν ἰάμβῳ τριμέτρῳ (literally 'three-measure iambic', 1.12), and the Pythia gives an oracle to Croesus ἐν ἑξαμέτρῳ τόνῳ ('six-measure strain', 1.47). Whereas μέτρον in Greek could mean any sort of measure – dry or liquid, temporal or spatial – in Latin the association between poetic metre and enumeration is clearer. The term *numerus* is used to refer to poetic metres, but it also designates any countable quantity (that is, it is closer to the Greek ἀριθμός: 'number').

[9] Morgan (2010).

[10] There is an extensive bibliography here, but for a clear orientation of the place of geometry in Greek harmonics, see Creese (2010) introduction and chapter 1, where he demonstrates that the science of harmonics relies on geometry but also arithmetic. This is a Euclidean arithmetic, however, that is dependent on the magnitude of straight lines rather than on the manipulation of numbers alone, as in modern arithmetic and algebra.

of the arithmetic shape of the text.[11] The substance of this book is dedicated to demonstrating that numerical thinking thus extended further, to reflecting on the stuff of poetry, its content and formal properties.

Despite the underlying numerical foundation of poetry and the rich seam of interpretation emanating from no less a source than Homer, numbers in poetry have been a focus of modern scholarship in only a limited way. Most approaches have been positivistic, treating numbers in these works as being used only to impart information or 'facts'. Catherine Rubincam, for example, has examined the use of numbers in Greek poetry as well as historiography, building on and responding to Detlev Fehling's critique of Herodotus' use of numbers.[12] Her study is indicative of a wider attitude towards poets' appeals to number and displays of counting. She provides statistics for the uses of numbers across Greek prose and poetry and the extent to which either might be called precise in their use of figures. The approach may in part work for historiographical prose – it is clear that Thucydides is positivistic when it comes to the Catalogue of Ships – but it is ill-suited to fully explaining a poet's engagement with number and the kind of poetic effect they wish to bring about.

In certain instances, scholars have identified the intriguing nature of poetry that foregrounds matters of counting and calculation, and they have sought to situate poets' engagement with number in a variety of ways. Reviel Netz examines works of Hellenistic poetry and their incorporation of scientific ideas in his 2009 book *Ludic Proof: Greek Mathematics and the Alexandrian Aesthetic*.[13] His study includes a brief discussion of Archimedes' intertwining of poetry and calculating in his *Cattle Problem* (see Chapter 3). For the most part, he is interested in how geometrical activities in antiquity can be fruitfully set beside wider literary practices. Archimedean treatises are interpreted as twisting narratives, the solutions of which are designed to dazzle

[11] Schafer (2017). In a similar vein, stichometric allusions have been observed in Latin poetry, where an echo of an earlier poem appears at the same line numerically; see Lowe (2013); Lowe (2014).
[12] Rubincam (2003). [13] Netz (2009).

a reader, and he observes similar dazzling displays of sophistication and erudition in contemporary poets such as Aratus, Nicander and Callimachus. He has much less to say about what it meant for poetic forms to incorporate number. From a different perspective, Christine Luz collates and discusses games with literary form in Greek poetry, such as acrostics, pattern poems, palindromes and anagrams. She devotes a whole chapter to isopsephy in poetry, the practice of making verses of poetry add up to the same total when the individual letters are read as numbers.[14] Her study similarly lacks an exploration of the ways in which poets reflected upon the numerical component of their works. The same issue arises with Liba Taub's study of poetry as a genre of science writing in Graeco-Roman antiquity, where she examines both Archimedes' *Cattle Problem* and later versification of arithmetical problems.[15] She provides a clear intellectual and educational background to these poems, but what does not come into focus is the importance of these arithmetical poems for thinking about how readers and poets alike conceptualised the relation between poetry and number. Interest in the intersection of number and poetry, then, has arisen sporadically in various quarters but within the context of rather different analytical projects. What has yet to be described is the significance of numerical operations for an understanding of these various works *as poetry* and the contribution of numerical thinking to both their form and aesthetic programme.

An important starting point is to acknowledge the very strangeness of foregrounding number in poetry. Number as a means of describing the world could be understood as *least* requiring poetry as a medium of communication: numbers and calculations possess their own signifying system that is not, or not entirely, shared with spoken or written language. Poetry is at the opposite end of the spectrum. It is a highly stylised, semantically rich and expressive verbal form. But as Homer's Invocation and its reception demonstrate, points of intersection between the world of poetry and the world of number did not go unexamined. Rather, the combination of diametrically opposed systems of signification – words and

[14] Luz (2010) chapter 6.
[15] Taub (2017) chapter 1. However, Kwapisz (2020a) does move the analysis of the arithmetical poems forward. I engage with his work more closely in Chapter 4.

numbers – sparked reflections on the capacity of the poet and the nature of poetry. Instead of poetry and numerical thinking being kept separate, later engagements with Homer's Invocation and Catalogue demonstrate an emerging poetics of number that explored the ways in which the poetic medium accommodated counting and calculating as well as the poet's intentions in doing so. My approach is thus to treat the various engagements with number that appear in Graeco-Roman poetry as constituting a productive tension and to examine how poets' representations of these mathematical operations implicitly and explicitly reflect on the implications of this intersection.

The two operations I focus on in this book are counting and calculation, although I do not mean to imply that they are different categories: any manipulation of numbers is calculation. For purposes of organisation and analysis I treat counting as the most basic operation. I call other, more complex operations, such as multiplication, 'calculation'. It is a hermeneutic distinction, but not a categorical division, between addition and arithmetic. 'Counting and calculation' is thus a *conjunctive* shorthand. Unsurprisingly, the sort of mathematical operation displayed is inextricably related to the thought the poet wishes to advance or the effect they wish to produce. Both counting and calculation can already be seen at issue in the examples with which I began. In *Iliad* 2, counting is a concern for Homer inasmuch as he identifies the insurmountable task of counting up such a large number and the poetic extension that it would require. Equally, later readers were attuned to the counting in the passage, which was for them a feasible task, whether it was the ships or individual soldiers who were to be counted. Readers may have had a keen eye for the numerical tally of what is described in poetry, then, but it was a critical interest brought to the fore already by the poet. Yet calculation is also introduced in the Invocation and Catalogue. The arithmetical operation of multiplication enables the poet to present unwieldly content in a more manageable form and to represent himself, not the external Muses, as in control of his narrative material. It is this aspect that the author of the *Contest* has taken to heart in his reworking of Homer's Catalogue as an explicitly arithmetical operation and one that does not (or need

not) require any form of counting. The ability for arithmetic to bypass simple addition is evident also in the *Ilias Latina* with its concluding calculation that gives the sum of all the ships. Here the reader can even compare and contrast their addition of the different contingents with the final arithmetical account of the ships. The distinction between counting and calculating, elaborated neatly in these examples, provides the two-part structure of the present study, which organises diverse poets' numerical manoeuvres into a progression from the basic to the more complex. But it also responds to the two different roles of counting and calculating: they help poets achieve different aims, and they have different effects on their audience.

As I sketched out in the case of Homer's Invocation, the poet is aware of what effect counting can have on his poetry and – by implication – how this may be judged; he is forestalling any criticism of his Catalogue of Ships not being a full and exhaustive 'catalogue of soldiers'. Part I of the book, 'Counting and Criticism', addresses the phenomenon of counting in later Greek and Roman poetry where it too plays a crucial role in the poet's positioning of their work – or judgement of others' – in terms of both form and content. More specifically, it will focus on a programmatic discussion penned by the Hellenistic poet Callimachus at the opening of his *Aetia* and its influence on later poets.

Chapter 1 first examines Callimachus' well-known Reply to the Telchines in detail. Its aim is to bring out more fully Callimachus' emphasis on counting as a concern of his critics and to highlight how this connects to his wider attempt to use the Telchines as a foil for introducing (as a kind of response) his own aesthetic criteria. This same interest, I then show, is picked up and developed by later poets, who observe Callimachus' stress on the critical importance of counting but who turn their rejection of it to their own ends. Much less positive than the engagements with number discussed in this introduction, these later poets distance themselves from counting as a viable critical mode. Yet also in Callimachus' wake, counting is an aspect of their poetic world that they are unable to ignore. Paradoxically, they end up relying on counting as a possible means of appreciating poetry while simultaneously arguing for quite different criteria of aesthetic value.

Chapter 2 follows up this conclusion with an analysis of the surviving poems of the Neronian-era epigrammatist, Leonides of Alexandria. Because Greek letters also stand for numerical values, words and whole verses can be counted up; his epigrams are composed so that the two couplets of his four-verse poems add up to the same total. What is so fascinating about these under-appreciated poems, I demonstrate, is that they reverse the trend of rejecting counting as a form of poetic appreciation seen in the previous chapter and instead combine this further type of counting in poetry with a repeated and concerted engagement with Callimachus. Rather than seeing counting as anathema to poetic evaluation as Callimachus had, Leonides engages in a project of presenting his epigrams as nevertheless adhering to Callimachean aesthetics. In Leonides' poems, Callimachus' pronouncements on aesthetics in the *Aetia* and elsewhere are turned to argue for the aesthetic value of his counting compositions.

Part II, 'Arithmetic and Aesthetics', moves from counting to arithmetical operations. Homer and the *Contest* show that multiplication was a form of calculation present in poetry from the earliest times and that it was perceived as such by later readers. However, later poetry sets more complex calculations within poetry (from the perspective of both the composer and the reader), where the ratios of a series of objects are given. In the modern West, such problems would typically be solved algebraically by rephrasing the ratios as a set of simultaneous equations. The form of calculation that the Greeks would have interpreted this to be, and the method they would have employed to solve it, is called logistic, an arithmetical category that will be explained in detail in the introduction to Part II. This second half of the book investigates the subjects of these poetic calculations, the poets' aestheticisations of the calculations and their reflections (both explicit and implicit) about how mathematical operations mould the form in which the 'stuff' of poetry is presented. This analysis will also address larger questions about what happens to the more typical aspects of poetry – especially the role of the reader – when a work is fashioned so as to express an arithmetical calculation.

Chapter 3 offers an in-depth study of the *Cattle Problem* attributed to Archimedes, which outlines the various ratios of the

different-coloured herds comprising the Cattle of the Sun, figures familiar from Homer's description of them in *Odyssey* 12. The poem was supposedly sent to Eratosthenes, the head of the Alexandrian Library, a fellow mathematician and poet. The chapter begins by reappraising Archimedes' poetic abilities and demonstrates his keen awareness of generic conventions and literary debates as well as his sophisticated allusions to earlier poetic works. I then show that Archimedes, through extensive allusion to Homer's Catalogue of Ships in *Iliad* 2, puts forth a critical attitude both to the calculating capacities of the reader and the traditional capacities of the poetic medium. I subsequently propose that in setting an arithmetical problem for Eratosthenes, Archimedes has drawn inspiration from earlier poetry that incorporates arithmetic and addition in a range of intellectually and culturally competitive scenarios. In so doing, Archimedes signals the stakes of his challenge to Eratosthenes. Archimedes' message to Eratosthenes in the *Cattle Problem* is at once about the mathematical resources of poetry and about the inability of counting and calculation ever to completely encompass and sufficiently express the stuff, the content and the cultural value of poetry.

Chapter 4 examines a collection of arithmetical poems preserved in the fourteenth book of the *Palatine Anthology*, which are largely the product of the Greek Imperial period and of Late Antiquity. These generally overlooked works show later poets again seeking to cloak arithmetical problems in traditional poetic dress. As in the case of Archimedes' *Cattle Problem*, I highlight how the poetic form of these problems indicates the various ways that earlier poetry could be reinterpreted by later readers as containing the seeds of arithmetic. I also contend, however, that these works combine arithmetic and poetry as part of an aesthetic that is notably late antique in nature. The use of arithmetic within poetry becomes an additional strategy of gaining social distinction, on the part of the poet who is able to integrate the two and on the part of the reader who is able to solve the arithmetic. This in turn realigns responsibility for the creation of meaning: the readers themselves must engage with the poem, configure the pieces of the puzzle supplied by the poet and generate a solution. These are poems that predicate poetic appreciation on mathematical competence to

a degree not seen in earlier works. I conclude the chapter by tracing the poems' afterlife, first in a collection attributed to one Metrodorus and then within the structure of *Palatine Anthology* 14. Here, I argue, it is possible to observe the cultural value placed on arithmetical poetry in the *longue durée*.

My analysis constitutes a series of readings of Graeco-Roman poetry in which counting and calculation are essential components of the works' medium and message. A continuous narrative could well have been taken further, from Homer all the way to modernity. Robert Curtius, for example, has expounded the close links between the poetry of Late Antiquity and the 'numbered compositions' of the Latin Middle Ages.[16] Similarly, the twelfth-century *Carmen de algorismo* (*Poem about Arithmetic*) is a significant point in this history, since the Latin poem popularised for the West the Arabic number system and its methods of computation (and it is not so distant in time from the Byzantine editors of the *Palatine Anthology* with whom the final chapter concludes).[17] Closer to the present day, scholarship is beginning to appreciate number in early modern literature such as Shakespeare, as well as in contemporary literature and poetry.[18] A prime case study of modernist literature would be Raymond Queneau's *Cent mille milliards de poèmes* (*One Hundred Thousand Billion Poems*) that comprises ten sonnets of fourteen lines. The corresponding lines in each sonnet share the same rhyme scheme and rhyme sound, so that any of the sonnets' lines can be substituted with any of the other nine equivalent lines, producing potential combinations of the order 10^{14}. Indeed, while it might be thought of as *avant-garde* from a contemporary perspective, it shares a fundamental principle with the combinatory poetics of late antique Latin poetry, as will become clear in Chapter 4 (Section 2). The story told in this book is evidently part of a much greater poetic phenomenon.

[16] Curtius (1953) 501–9.
[17] Reportedly composed by the polymath Alexander of Villedieu: see Halliwell (1839) 73–83; Steele (1916) Appendix II.
[18] See for example the contributions in the special volume of the *Journal of the Northern Renaissance* (2014) for early modern works, and for contemporary English literature see Connor (2016).

Number is a topic to which Greek and Roman poets were repeatedly drawn. The Hellenistic period in particular seems to me – on current evidence – to be a formative time for poets being explicit and programmatic in their reflection of the place of number in poetry; this topic is then self-consciously picked up by subsequent poets in the Imperial period and Late Antiquity. Since over half of the Greek poems studied here were written under Roman rule, however, I have defined the time frame as ‘Graeco-Roman’ in order to encompass the fact that I address Greek and Latin poems, but also many Greek poems from the Roman Empire. Certainly, the corpus of texts examined here is also limited: not all Greek and Latin poets have something explicit to say about number, counting or calculation, nor have they marked the introduction of numbers into their verses. Thus, my individual chapters could be read in isolation, since each poet’s focus is relatively discrete and *sui generis*: Leonides and Archimedes, for example, have very different attitudes to the presence of number in poetry. Yet there is a distinct advantage to zeroing in on the narrower scope of Hellenistic and later poetry: by taking them together, a clear picture of a *concerted* poetics of number across antiquity can be discerned. As I set out in the Conclusion, there are recurrent patterns of thought which unite all these attempts to experiment with, to interrogate and to champion the presence of number in poetry, both within the two parts of the book and across them. Not only do poets employ counting and calculation as a means of exploring how poetry handles and presents material and the concomitant effect on poetic form, but they do so by returning to early passages that raise similar issues. What I hope this study as a whole reveals is that engagements with number emerge through the course of antiquity as a constituent aspect of the poetic tradition.

I.3 ‘Poetic Numeracy’ and Greek Mathematics

Poetry’s engagement with number is my primary focus in this book. Yet my analysis also has ramifications for the history of Greek mathematics. The late Classical and early Hellenistic period is crucial for the development of mathematics, if not as

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a discipline, then as a series of connected practices.[19] For François Lasserre, the age of Plato saw the flourishing of geometrical thinking, and David Fowler goes even further in arguing that Plato's Academy played a central role in the perpetuating of mathematics as an intellectual discourse.[20] By the end of the fourth century, Aristotle's pupils had produced various mathematical treatises and Euclid had produced the thirteen books of his *Elements*, which gathered and systematised earlier knowledge. Significant developments were made in the following century by Archimedes and Apollonius of Perga. Undoubtedly, these mathematicians built on much longer traditions now lost to the historical record (both those writing in Greek and the more distant contributions of, *inter alios*, the Babylonians). Nevertheless, this period saw the formation of mathematical literature, inasmuch as a habit developed of producing self-contained works written by identifiable authors. In each case, however, their core interest was geometry, the branch of mathematics that deals with the properties of points, lines, surfaces and solids and their relation to one another. When Fowler talks of the Academy's influence on the development of mathematics as a discourse, he is essentially referring to geometrical developments. As Reviel Netz has described, furthermore, ancient mathematical thinkers and mathematicians were a close-knit group, whose knowledge and practices were not necessarily known to those beyond the profession.[21] He builds on the sociological work of Pierre Bourdieu in arguing for a phenomenon of distinction and exclusion through cultural capital in ancient mathematical texts. Their dense form was attributable to the fact that the mathematician 'had to prove that his writings were a form of literature in their own right' and so produced a text that 'aimed at a few elite members and no one else'.[22] On these terms, the history

[19] Netz (1999) 292–8. For the rise in mathematical thinking, cf. Netz (1999) 274–5: '[u]p to and including the middle of the fifth century BC, not a single alleged reference to mathematics would bear scrutiny'; 'I therefore think mathematics, as a recognisable scientific activity, started somewhere after the middle of the fifth century BC.'

[20] Lasserre (1964); Fowler (1999).

[21] Netz (1999) 292–311: 'Greek mathematics is the product of Greek elite members addressing other elite members' (305); Netz (2002a) 215: 'Greek mathematicians formed an inward-looking group.'

[22] Netz (1999) 306.

of Greek mathematics has often been written with the elite practices of geometry at its centre.

With regards to arithmetic, David Fowler puts forward the contemporary scholarly consensus at the opening of his study of early mathematics by declaring that 'my first characteristic of early Greek mathematics is negative: it seems to be completely non-arithmetised'.[23] Even Books 7–10 of Euclid's *Elements*, which deal specifically with arithmetic, are remarkable for their lack of numbers and the use instead of lines of varying magnitude.[24] Yet this is the picture that arises by focusing solely on the geometrical treatises that survive, which are, as Netz has noted, the product of an inward-looking elite. But it is possible to produce a broader history of Greek mathematics which extends beyond the traditional remit of Euclid, Archimedes and their kind. For Markus Asper, this has involved identifying two cultures of mathematics in Ancient Greece: practical, everyday mathematics directed towards applicability and the mathematics theorised in highly sophisticated, and undoubtedly elite, treatises.[25] Serafina Cuomo, on the other hand, has written extensively on mathematics as it was practised beyond the elite and challenges any simple delineation between the practical and theoretical.[26] So too, Reviel Netz has produced a provocation for further study into Greek numeracy that seeks to analyse the use of pebbles and counters in Greek culture and their implications for cognitive numerical habits spanning economic, political and symbolic domains: a so-called 'counter culture'.[27] Historians of mathematics in Graeco-Roman antiquity are thus turning their sights to numeracy as a practice separate from, as well as parallel to, geometrical proof. And in contrast to the circumscribed tradition of geometrical treatise, the study of numeracy covers a wide proportion of ancient society.

[23] Fowler (1999) 10. See the similar summary in Heath (1921) 1, 16.
[24] Fowler (1999) 222. [25] Asper (2009), esp. 128–9.
[26] Cuomo (2012) 1–2. See in general Cuomo (2007a); Cuomo (2007b), esp. chapters 2 and 4; Cuomo (2011); Cuomo (2013); Cuomo (2019). Her forthcoming monograph on ancient numeracy will advance this argument across a wide range of material, and it is eagerly awaited.
[27] Netz (2002b).

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Since my aim with regard to the history of Graeco-Roman poetry is to uncover a sustained and embedded critical engagement with counting and calculation, this book will also offer an intervention in this developing scholarly trajectory. In calling for a closer analysis of numeracy in his 'counter culture', Netz commented that 'a crucial feature of élite, literate Greek mathematics (by which I mean the kind of mathematics for which we have evidence in the literary tradition) is its marginalisation of the numerical'.[28] This book seeks to answer that call by proposing that poetry is an underexplored aspect of the literary tradition that does evidence a range of numerical practices and often underscores or comments on the place of counting and calculation in the wider cultural and mathematical *milieu*. And, by beginning in the late Classical and early Hellenistic period, the study expands the arithmetical aspect of ancient Greek mathematics in literate culture precisely at the point at which Greek mathematics is traditionally considered to be at its most geometrical. Of course, this will not be a comprehensive history of non-elite numeracy. I take literature to be an intrinsically elite pursuit in antiquity; in each chapter, it will be open for debate just how well known and accessible the poetic texts were. Since counting and calculating are the earliest rung on the educational ladder, though, all those who could appreciate the poetry would have probably had the skills to handle or at least attempt to handle the operations found therein. While the poems discussed in this book do not exhibit innovation in numerical or arithmetical thinking in the same way that Hellenistic geometrical works do, what this study will demonstrate is that the wider literate culture of antiquity did not marginalise the numerical.

[28] Netz (2002b) 346.