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ERATOSTHENES' LETTER TO PTOLEMY: THE LITERARY MECHANICS OF EMPIRE

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Abstract. Eratosthenes of Cyrene (276–194 B.C.E.), the third head of the Alexandrian Library, sent a letter to King Ptolemy outlining his solution for the geometric problem, the doubling of the cube. Although traditionally the preserve of historians of mathematics, the text quotes from tragedy, recounts mathematical research at Plato's Academy, and concludes with an epigram. Here, I address each generic gesture and its particular audience and aim. This article reads the letter not only as a dynamic unified whole which innovatively integrates mathematics and literature, but as a text which lays out the mechanics of the Ptolemaic empire for its readership.

INTRODUCTION

EUTOCIUS OF ASCALON (born ca. 480 C.E.) in his commentary to Archimedes' *The Sphere and the Cylinder* preserves a letter purportedly written to King Ptolemy by Eratosthenes of Cyrene (born ca. 276–272, died 194), the third head of the Alexandrian Library.[1] It presents Eratosthenes' unique method for solving a mathematical problem which had been multiplying and dividing ancient philosophical and mathematical opinion since the earliest times: to double the volume of a given cube, while keeping its dimensions in proportion. The form of the text is striking:

i. An address to King Ptolemy by Eratosthenes (page 102, line 21 Heiberg).
ii. The history of the problem (102.22–106.8 H).

[1]The standard editions of Eutocius are Heiberg 1881, vol. 3, and Mugler 1972. The Greek text of the letter here follows Heiberg 1881, vol.3, 102–114, with all references in the form "page.line H," while the English is taken from Netz 2004, 294–8, with modifications. The first edition of Eratosthenes' poetic works contains in an appendix the text of the entire letter; Hiller 1872, 122–30. I do not tackle the question of authenticity head-on. At any rate, I am persuaded by the conclusions of Knorr 1986, 17–20, and 1989, 131–53, suggesting minor changes to the mathematical exposition, and Geus 2002, 195–205, that the work is authentic. Rather, I hope that my discussion will act as further proof of Eratosthenes' authorship—and genius.

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a. (102.22–24 H) a summary of the myth of Minos who builds a tomb for his son, Glaucus, which raises the issue of the geometric problem.
b. (104.1–3 H = *TrGF adesp.* F166) a quote from tragedy elaborating on the myth.
c. (104.4–9 H) Eratosthenes' exegesis of the quote and the naming of the problem.
d. (104.10–16 H) the problem's contemplation by Hippocrates of Chios.
e. (104.17–106.8 H) the story of an oracle on Delos requiring a solution to the problem and the problem's arrival at Plato's Academy.

iii. The practical advantages of Eratosthenes' solution (106.8–27 H).
iv. The solution (106.28–112.12 H).
a. (106.28–108.24 H) the geometrical proof of his mechanical solution.
b. (110.1–19 H) a description of the mechanical device fitted onto a *stele*.
c. (110.20–112.12 H) the geometrical proof as inscribed on the *stele*.

v. A concluding epigram on his solution inscribed on the *stele* (112.13–114.8 H = Eratosthenes fr.35 Powell).

Eratosthenes, then, does not follow closely the format of many mathematical texts, such as the treatises of Euclid and Archimedes which exhibit a dense, formulaic style.[2] How should one make sense of this combination of different parts? Why provide an extensive history of the problem? What is so important about his method? Why include a citation of tragedy and an epigram? What is so exceptional about this particular academic problem that it warrants a letter to the king?

This unique text generates numerous questions, but has received little attention. Certainly, it has been mined by historians of mathematics and so holds a notable place in the Greek tradition of geometric problems—here Knorr (1986, 210–18; 1989, 131–53) is exemplary and most accessible—but scholarship on the letter in relation to Hellenistic literary culture is still lacking. The most recent edition of the text is to be found in Mugler 1972, 64–9, while for a specific edition of the letter one has to look over a century ago to Hiller 1872, 122–30, and to Heiberg 1881.3, 102–14, for the foundational modern text of Eutocius. In terms of literary discussion during this period there is very little, though as often an early exception is Wilamowitz 1971, who argues that the final epigram is genuine, but that the majority of the letter is a later fabrication. In the twenty-first century, interest in Eratosthenes and his writings

[2] E.g., Euclid's *Elements*, or Archimedes' *Measurement of the Circle*, *On the Equilibrium of Planes*, or *On Floating Bodies*.

has increased. Geus 2002 deals with the entirety of Eratosthenes' output, in a study which offers immense help for navigating his works, including the mathematics and poetry of the letter,[3] while the range of discussion is equally broad in the edited volume of Cusset and Frangoulis 2008. The contributions contextualise the Hellenistic thinker's writings within their various intellectual traditions: geography, mathematics, astronomy, and philosophy. The letter has garnered less discussion; Netz 2009, 160–4 and 228–9, considers the intersection of science and literature with regards to the tragic quotation and the epigram, and Asper 2013a reads the letter against recurring narrative patterns in ancient science. To my knowledge, Taub 2008 offers the only study dedicated to the letter, its textual form, and its generic awareness. The short commentary on the epigram by Sider (2017) was made known to me after this article went to press. Its explanation of the geometry is extremely helpful, and its inclusion in an anthology of Hellenistic poetry is a sure sign that scholars are taking note of Eratosthenes' works as literature. With advances in the understanding of Eratosthenes' place in various intellectual histories, and of his use of literature, it is time to ask how Eratosthenes' letter to Ptolemy functions as a unit combining such intellectual and generic diversity.

Thus, here, I want to take apart Eratosthenes' manufactured text in order to understand how the literary dynamics of the Hellenistic period generated this hybrid work. I ask: what peculiar mechanics of empire at Alexandria induced the Cyrenaean polymath to assemble his workings into a letter? Taking each cog of this textual machine in turn, I trace how the individual parts of the letter are engineered to create a working whole. Section 1 considers the importance of the epistolary opening (i), while Section 2 analyses in detail the various aspects of the problem's history and their significance for an Alexandrian audience (ii–iii).[4] Section 3 will then offer a reading of the epigram (v) and how it relates to the immediate context of the second half of the letter (iii–iv). Section 4 reflects on the constraints and developments the epigrammatic genre encountered in the Hellenistic period and proposes a way of reading Eratosthenes' epigram in light of these parameters. Section 5, finally, argues the significance of the epigram, and even its specific wording, as a means of concluding the letter and encapsulating Eratosthenes' mathematical message.

[3] Geus 2002, 195–205. Very little is said about how the letter functions as a unit. This is in part because he takes the text as a window onto a historical reality, rather than as a text operating within that reality.

[4] This will include some discussion of the ancient mathematics, though since I am not adept at deciphering ancient Greek geometry, nor is this my interest here, I restrict myself to dealing with the specific workings of Eratosthenes' geometric arguments only as they relate to my broader points.

There are a number of reasons why dealing with each component of this letter with an eye to the text as a unit is an important enterprise. The combination of prose and poetry, of tragedy and epigram, of narrative and mathematics, is a prime example of the generic hybridity often seen as a hallmark of the age, although for Eratosthenes, I will suggest, this is more than mere literary experiment. At stake here, too, is the reputation of an underrated Alexandrian personality, maligned in antiquity as Πένταθλος ("Jack of all trades, Master of none") or Βῆτα ("Second Best," "Runner-up") (Suda *s.v.* Ἐρατοσθένης 2898),[5] and his multidimensional text dismissed by Wilamowitz as a forgery. That this text, moreover, draws into its orbit Greek myth, Classical tragedy and Plato's Academy attests not only to an already strong fascination with the Classical Greek past in the third century and the depths to which it has penetrated this mathematical work, but also its deployment, and possible distortion, for political ends.[6] Yet the greater import of this study is that it will shed light on the complex relationship between the specialized knowledge of intellectual communities and the access and understanding which the form of these texts suggests. The standard, and in some sense traditional, view of mathematics' relation to Greek society is the analysis of Netz 1999, 292–311, that mathematical practices were largely separated from political and economic life in antiquity. While this may appear so when considering a solely Euclidean view of Greek mathematics, recent work has emphasised the extent to which mathematics was integral to Greek life.[7] One route to gauging the wider access to mathematical knowledge, and its historical significance, is to take seriously the written forms in which mathematical developments were recorded, and on which their existence hinges. This is a path explored by an increasing number of commentators.[8] Building on the earlier works on Eratosthenes' letter to Ptolemy, and the growing trend of taking literary form as an indication of social and intellectual context, I lay out how Eratosthenes' generic dexterity aims to embed complex mathematical knowledge within a broader, and so more accessible, cultural and political *milieu*.

I hope to show here that in arguing the significance of his extremely

[5] For further discussion on his nicknames see Geus 2002, 31–41.

[6] The arguments of Pàmias 2004 for Eratosthenes' criticism of the Ptolemies through literature do not seem particularly convincing.

[7] The interrelation of mathematics and daily life are captured well in Cuomo 2002; 2007; 2011.

[8] Particularly useful are Kullmann and Althoff 1993; Kullmann, Althoff and Asper 1998; Asper 2013b.

specific research through a variety of strategic textual gestures, Eratosthenes is unique in responding to the external—real life—exigencies of funding bodies and public understanding; perhaps the earliest example of academic "outreach." I want to make clear that this letter is more than a letter, sent by a librarian who is more than a librarian, concerning a mathematical problem which is more than a mathematical problem. Eratosthenes' letter is a memorandum of its context, a signature of its location; certainly not a postscript to Hellenistic Literature.

1. OPENING THE LETTER

The opening line makes clear that the mathematical text is framed as a letter. (Eratosthenes, "Letter to Ptolemy" 102.21 H):

> Βασιλεῖ Πτολεμαίῳ Ἐρατοσθένης χαίρειν.
>
> Eratosthenes to King Ptolemy, greetings.

Wilamowitz 1971, 52, had reasoned that if the monument which Eratosthenes describes in the letter was accessible to Ptolemy, he would have no need for the letter.[9] Working within the Alexandrian royal quarters, and tutoring the king's son, formal communication may not in practice have been necessary. Yet Knorr and Taub have prompted scholars to see the work as a text operating within the bounds of the developing idea of the published letter.[10] The epistolary genre is the Hellenistic genre that is "going places," and its growth is phenomenal.[11] It is worth addressing a number of dynamics at play in Eratosthenes' epistolary opening, since each provides a different frame for the mathematical content.[12]

First, a range of mathematical works from the Hellenistic period

[9] See also Fraser 1972.1, 412, Taub 2008, 291.

[10] Knorr 1989, Chapter 6. The terms "open letter" and "letter to the editor" of Taub 2008, 298, I find useful to think with, though I hesitate to employ them as terms for ancient works here.

[11] Taub 2008, 286, gives the example of Epicurus. The Zenon Papyri preserve the fascinating administrative functions of letters on which see Clarysse and Vandorpe 1995. Letters from Hellenistic rulers had a presence in the landscape, often being inscribed, Welles 1934. For further evidence and bibliography see Rosenmeyer 2001, 98–130; Trapp 2003; Muir 2009; Ceccarelli 2013, chapter 7 and *passim*. None of them discussed Eratosthenes' letter.

[12] The ways of reading a letter are taken from Langslow 2007, who applies them with great success to Latin medical letters, as well as raising a whole host of further questions.

employ an epistolary opening to various degrees,[13] unlike Euclid's treatises where the rigour of the mathematics produces (perhaps, requires) a dense formulaic style.[14] Two works sent by Archimedes to Eratosthenes highlight the possible registers of communication (Archimedes, *The Method to Eratosthenes* 82.3 and 83.18–21 Mugler):[15]

> Ἀρχιμήδης Ἐρατοσθένει εὖ πράττειν
> . . .
> ὁρῶν δέ σε, καθάπερ λέγω, σπουδαῖον καὶ φιλοσοφίας προεστῶτα ἀξιολόγως καὶ τὴν ἐν τοῖς μαθήμασιν κατὰ τὸ ὑποπίπτον θεωρίαν τετιμηκότα ἐδοκίμασα γράψαι σοι . . .
>
> Archimedes to Eratosthenes, greeting.
> . . .
> Moreover, seeing in you, as I say, a zealous student and a man of considerable eminence in philosophy and who values inquiry into mathematics as the occasion arises, I decided to write to you . . .[16]

In between addressing Eratosthenes and explaining the reason for his communication here, flattery and all, Archimedes has already given his reader a tantalising glimpse of the tricky mathematical questions which await (82.4–83.18 Mugler).[17] The generic form of the letter and the mathematics

[13] For this "balance" between a letter and treatise, cf. Demetrius *On Style*. 233–5 with Taub 2008, 292; for the extent to which these are letters at all, see the incisive discussion of Langslow 2007, 214–5 and 221–3.

[14] The key work for understanding the style of mathematical texts remains Netz 1999.

[15] Archimedes also had a long running exchange with Dositheus, to whom he addressed his *On the Sphere and the Cylinder*, *On Conoids and Spheroids*, and *The Quadrature of the Parabola*. In his *On Spiral Lines*, Archimedes jettisons the epistolary function having initially greeted Dositheus and justified his topic (2.1–14.11 H). Yet he does recall that Dositheus' mentor and earlier Alexandrian correspondent, Conon, died before he could solve, and respond to, Archimedes' questions. Conon's intelligence, he laments, was no common ability and his industry excellent, and few problems had been solved since his death (*On Spiral Lines* 2.16–21 H). Similarly, Apollonius of Perga (ca. 260–190 B.C.E.) working at Alexandria under Ptolemy Euergetes addressed the books of his *Conics* to a Eudemus of Pergamum and an Attalus—who *may* be synonymous with Attalus I who ruled Pergamum from 241–197 B.C.E. And, likewise, from book four onward Apollonius addresses his *Conics* to Attalus explaining in the preface that Eudemus had died, but that he knew Attalus was still eager to possess his study, cf. Heiberg 1974, 2–5, and Heath 1961, lxviii-lxxv. It is not just these men's research present in these works, but their lives and allegiances.

[16] The Greek is taken from Mugler 1972, 82–3, the English is adapted from Heath 2002, 12–3.

[17] The choice of εὖ πράττειν over χαίρειν in a letter was explicitly advocated by Plato (or "Plato") in his third letter (315a–c) as being the more appropriate form of address, and this may be significant here given Archimedes' "Platonic" addressee (on which, see below).

combine to generate a particular reading experience; the second address delays the exposition of the mathematics rather briefly hinted towards, as well as clarifying why Eratosthenes would want to read on at all. In a more ludic vein, Archimedes reportedly sent in a letter to Eratosthenes an epigram which was a versified account of the ratio of the Cattle of the Sun (*Od.* 12.127–30); the so-called *Cattle Problem* (450–54 H). As has recently been argued, the efficacy of the work derives from the knowledge that it was sent between the two intellectuals.[18] I have even suggested (2015, 205–7) that it playfully questioned Eratosthenes' scientific claims, aligning his mathematical expertise to his anti-Homeric conception of Greek geography. That is, the inability of Eratosthenes to calculate the exact number of the Cattle of the Sun stands as a pointed rejection of his mathematical measurement of Greek space, and of Sicily in particular.[19] Just like the more serious work, the form suggests methodological and disciplinary allegiances, but also advertises mathematical progress.[20] So too, Archimedes' playfulness in the *Cattle Problem* is a reminder that all the mathematical works with particular addressees engage, to an extent, in intellectual competition and the self-presentation of a mathematician who succeeds where others have failed.

Second, Eratosthenes' address to Ptolemy recalls another mathematical text to a ruler. In his *Sand Reckoner*, Archimedes explains to King Gelon his consideration of how to express extremely large numbers verbally by means of the common image of the number of the sands (*Sand Reckoner* 242.6 H):

> οἰόνται τινές, βασιλεῦ Γέλων, τοῦ ψάμμου τὸν ἀριθμὸν ἄπειρον εἶμεν τῷ πλήθει· λέγω δὲ οὐ μόνον τοῦ περὶ Συρακούσας τε καὶ τὰν ἄλλαν Σικελίαν ὑπάρχοντος, ἀλλὰ καὶ τοῦ κατὰ πᾶσαν χώραν τάν τε οἰκημέναν καὶ τὰν ἀοίκητον.
>
> Some think, King Gelon, that the number of the sands is infinite in multitude; and I mean the sand not only around Syracuse and the rest of Sicily, but in every region, both inhabited and uninhabited.

There is no external evidence to suggest Gelon was interested in mathematics, but the manoeuvring here is about more than the king. Archimedes is developing a system which gives verbal, controllable form to the

[18] Cf. Benson 2014 and Leventhal 2015.

[19] On Eratosthenes' *Geographica*, see Roller 2010, for his arguments against Homeric geography, see now Kim 2010, 47–67, and for his mathematical geography, see most recently Bianchetti 2015, with further bibliography.

[20] Langslow 2007, 225–8, for more on the intellectual dynamics of sender and recipient.

amorphous world of numbers (cf. Netz 2003). Alerting Gelon to this is about selling the idea of knowledge as power and control, and the rather informal tone of the opening address seems aimed at getting him on side, making the king someone "in the know."[21] Equally, while Archimedes sets up the contemporary context—all the sands of Sicily—he immediately outgrows it; his mathematics concerns the whole world, and this, too, is an important aspiration for a Hellenistic ruler (cf. 242.16–244.3 H). For the text's readership beyond the king, the communication may portray Gelon as a ruler with his finger on the pulse of scientific developments in his kingdom; mathematics bound in an epistolary form here broadcasts an intellectual tête-à-tête. Whether written with Gelon or a wider readership in mind, it is at least clear that Archimedes is keen to argue for the applicability of his work, how important his number system was and could be, and in that sense this text looks beyond the concerns of the mathematical community and its specialized knowledge.

It can briefly be observed, in addition, that addresses to rulers could take a philosophical turn. The pseudo-Platonic letters document and display the significant intellectual and political interactions of the late-Classical period. Following Plato, Speusippus would address his thoughts on, and disagreements with, Isocrates' treatise, *Philip*, to Philip II of Macedon (Speusippus *Letter to Philip* 1). Certainly there are questions over the authenticity of both these works, but even if they did not write such letters, the forgers' ability to convince hangs on this type of communication appearing plausible.[22] In reality, though, these epistolary configurations will be seen simultaneously at work within the letter. Ptolemy is figured as a fellow scholar "in the loop,"[23] Eratosthenes as a philosopher "speaking truth to power." The average reader, too, partially gains access to this royal exchange, and partially takes on the role of an addressee as a fellow scholar being enlightened. Nonetheless, each dynamic to which the reader gains access has individual significance, as will become clear in the subsequent section.

[21] Of course, Archimedes states later that he will explain everything so that Gelon can follow (242.17 H), yet the conclusion makes it clear that Archimedes sees his arithmetic development as fit for a king (290.17–24 H).

[22] On the authenticity of Speusippus' letter, see Natoli 2004, 23–31, and on Plato's letters, and their relation to Speusippus', Burnyeat and Frede 2015.

[23] Cf. Plutarch *Phoc*. 17, where Ptolemy I, in Hecataeus of Abdera's somewhat idealised account, made early morning letter writing a daily affair.

2. TAKING HOLD OF THE TRADITION

Eratosthenes was the first person to write a history of the problem, so the current state of the evidence suggests. What was the significance of providing a history of the mathematics? This section looks at the story which Eratosthenes tells, the way he tells it, and the contemporary concerns his version addresses. I contend that the traditions to which the narrative appeals are carefully calculated to argue the importance of his mathematically specific breakthrough not just to a mathematician, or a king, but to any educated Greek reader.

a. The Problem and the Royal Household

Unsurprisingly, Eratosthenes begins at the historical beginning (Eratosthenes, "Letter to Ptolemy" 102.20–104.4 H = *TrGF adesp.* F166):

> τῶν ἀρχαίων τινὰ τραγῳδοποιῶν φασιν εἰσαγαγεῖν τὸν Μίνω τῷ Γλαύκῳ κατασκευάζοντα τάφον, πυθόμενον δέ, ὅτι πανταχοῦ ἑκατόμπεδος εἴη, εἰπεῖν·
> μικρόν γ' ἔλεξας βασιλικοῦ σηκὸν τάφου·
> διπλάσιος ἔστω· τοῦ καλοῦ δὲ μὴ σφαλεὶς
> δίπλαζ' ἕκαστον κῶλον ἐν τάχει τάφου.
> ἐδόκει δὲ διημαρτηκέναι. τῶν γὰρ πλευρῶν διπλασιασθεισῶν τὸ μὲν ἐπίπεδον γίνεται τετραπλάσιον, τὸ δὲ στερεὸν ὀκταπλάσιον.
>
> They say that one of the ancient tragedians portrayed Minos constructing a tomb for Glaucus and that, when he learned that it was a hundred feet on each side, he said,
> Quite small, you called the precinct of the royal tomb;
> let it be double, and, without marring its beauty,
> quickly double each side of the tomb.
> But he seemed to be mistaken. For when the edges are doubled, the surface area is increased four-fold and the volume is increased eight-fold.

Minos, the king of Crete, wanted the tomb in honour of his dead son, Glaucus, to be doubled and erroneously equated a doubling of volume or area with the sides being doubled. This is where, Eratosthenes claims, the problem(s) originated. Netz 2009, 161–2, reserves judgement on whether the quotation is real or fabricated, seeing the extract as mythicised mathematics/mathematized myth. He concludes that Eratosthenes' conclusion (ἐδόκει δὲ διημαρτηκέναι) is a typical Hellenistic example of

"rapid transition" from one topic to another. It is worth not turning from this tragic quotation so quickly.

Netz, it seems to me, is mistaken. This opening gambit looks towards a particular figure of Greek myth, and a particular tragic narrative. Out playing, Minos' son Glaucus falls into a jar of honey and dies. With requests made to the Delphic oracle, and with the help of the Corinthian seer Polyidus, the child is sought. Polyidus finds the boy, and he is brought back to life. The narrative was reworked in a number of lost and fragmentary tragedies, including Aeschylus' *Kressai* (*TrGF* III frr.116–20), Sophocles' *Manteis* (*TrGF* IV frr.389–400) and Euripides' *Polyidus* (*TrGF* V.2 frr.634–46).[24] Regardless of whether the quotation is authentic, the subject of Glaucus was not only part of myth, but had been well worked as a tragic motif.[25]

Still, it is not obvious how to interpret these words; the citation offers no weighty dialogue or a contemplation of character for the reader. The repetitious language (τάφου../../..τάφου; διπλάσιος../.. δίπλαζ'), the snapped command (διπλάσιος ἔστω), and the initial lament μικρόν γ' ἔλεξας ("quite small, you call the precinct of the royal tomb!") sketch out a character incensed at the size of his son's memorial. Is it a reaction to another's opinion (cf. ἔλεξας), a lament, a key moment, or a momentary outburst from an emotionally drained king? It can at least be said that, in these few lines, the problem has been imbued with all the tragic emotion and turmoil of a royal household. Even after the quotation, significantly, Eratosthenes is still thinking in tragic terms. Ideas of success or failure in ancient tragedy can be understood through the language of erring—ἁμαρτάνειν—or hitting the mark—τυγχάνειν. According to the study of Bremer (1969, 44 and 30), this compound—διαμαρτάνειν—can mean "miss" in the sense of "fail a purpose," as well as "be under a false impression" or "make a mistake." Taking seriously the tragic context in which Eratosthenes has placed the reader improves upon Netz's suggestion of a rapid transition. He is claiming more than that Minos was merely mistaken, he argues why this fragment is important at all. The entire clause could be translated with more nuance as "he seems to have made a mistake—and tragically so" (LSJ *s.v.* δοκέω II.5). The particular moment, Eratosthenes suggests,

[24]The various forms of this narrative, in addition to the tragedians, are found in Apollod. *Bibl*. 3.3 and Hygin. *Fab*. 136.

[25]The recent work of Carrara 2014, 400–8, discusses in depth all fragments related to this myth, and in fact argues for Euripidean authorship for this *adespotum*. This may well be true, though my argument is not dependent on it.

represents Minos' tragic failure.[26] Here, though, the tragic motif of lack of foreknowledge is replaced by a tragic lack of mathematical knowledge.

Two further observations set Eratosthenes' intentions in sharp relief and suggest an underlying political motive. First, he constructs a comparison in status associating King Ptolemy—Βασιλεῖ Πτολεμαίῳ ("to King Ptolemy") with King Minos—βασιλικοῦ . . . τάφου ("the royal tomb"). This implies that the mathematical problem is not only a tragic problem, but one that has, historically, affected kings. Moreover, it affects their public display of grief: it is a mathematical problem that hinders their attempts at monumentality. Eratosthenes' tragic model is a warning, a historical *exemplum* of a king's failure because of his lack of mathematical understanding. More importantly, it gestures towards the son of a king. Whether or not Knorr 1989, 144–5, is correct in asserting that the letter was sent to Ptolemy IV Philopator, rather than III Euergetes early in Eratosthenes' career (the previous scholarly assumption), as royal tutor Eratosthenes would have been in prime position to exploit a familial relationship. This quotation evokes a narrative which has a king lose his son, only for him to be rescued by the famous seer Polyidus. The quotation drives at the heart of royal and familial responsibility, and the role of the intellectual. If Ptolemy is shocked by the opening scene of royal agony and despair, he may recall his very own mathematically minded, loyal "Polyidus." (Indeed, Polyidus—which might recall πολυειδία, "diversity of form, πολυειδήμων, "knowing much"—is particularly apt for alluding to the head of the Alexandrian Library working in a variety of genres.) In fact, Eratosthenes' narrative has two concerns, the livelihood of Minos' son Glaucus and the inability to offer an exacting memorial. Unlike Minos, Ptolemy patronised someone knowledgeable about the complexities of mathematics who is the very same man now charged with the education of his son. Through the tragic *exemplum*, Eratosthenes intimates his importance in relation to the royal family, the continued happiness of the father, and the continued safety of the son. The Ptolemies, as a family and as a ruling power, need Eratosthenes.

[26] Richard Hunter has expressed his doubts to me whether the meaning of ἁμαρτία as it appears in Aristotle's *Poetics* 13.6 was a term in tragic theory, or even in common parlance, in use during Eratosthenes' lifetime. In theoretical terms the evidence is slim. I would, however, point towards the works of Menander (*Aspis* 110, 205; *Epitrepontes* 908) in which the use of the word and its cognates is bound up with an error intrinsic to the drama, as well as being a moral descriptor, Gutzwiller 2000, 123–4. By the time of Eratosthenes' younger contemporary Aristarchus (ca. 216–144 B.C.E.), Aristotle is a very likely influence, cf. Schironi 2009, with further bibliography.

b. The Problem and the Platonic Tradition

With a generic shift from tragic verse to prose, Eratosthenes moves the focus from rulers and royalty, to intellectuals and citizens. While the narrative traces the historical context of the problem into the recent past, it also sets up expectations of the tradition in which Eratosthenes is working. The first named mathematician to consider, and make progress with the problem, is identified as Hippocrates of Chios (Eratosthenes, "Letter to Ptolemy" 104.11–16 H):

> πάντων δὲ διαπορούντων ἐπὶ πολὺν χρόνον πρῶτος Ἱπποκράτης ὁ Χῖος ἐπενόησεν, ὅτι, ἐὰν εὑρεθῇ δύο εὐθειῶν γραμμῶν, ὧν ἡ μείζων τῆς ἐλάσσονός ἐστι διπλασία, δύο μέσας ἀνάλογον λαβεῖν ἐν συνεχεῖ ἀναλογίᾳ, διπλασιασθήσεται ὁ κύβος, ὥστε τὸ ἀπόρημα αὐτοῦ εἰς ἕτερον οὐκ ἔλλασον ἀπόρημα κατέστρεφεν.
>
> While many people found this difficult, after a long time Hippocrates of Chios first conceived that, if a way can be found to take two means between two straight lines in continued proportions, of which the greater is double the lesser, the cube would be doubled. As a result, he transformed his problem into another no less difficult problem.

The account is succinct. Hippocrates is the first step along the path to rationalising and answering the problem. Moving from Chios to Athens in later life, he notably focused on the "classical" geometric problems, of which one is the doubling of the cube. Significantly, Hippocrates' achievement produces a false start. The letter constructs a narrative in which a mathematician solves the problem, only to be met with an equally difficult problem. Geometry, goes the message, is not as easy as it looks. The list of those who attempted to solve the problem grows with the subsequent narrative vignette. Eratosthenes turns to Plato and the Academy's role in solving the problem (Eratosthenes, "Letter to Ptolemy" 104.17–106.1 H):

> μετὰ χρόνον δὲ τινάς φασιν Δηλίους ἐπιβαλλομένους κατὰ χρησμὸν διπλασιάσαι τινὰ τῶν βωμῶν ἐμπεσεῖν εἰς τὸ αὐτὸ ἀπόρημα, διαπεμψαμένους δὲ τοὺς παρὰ τῷ Πλάτωνι ἐν Ἀκαδημίᾳ γεωμέτρας ἀξιοῦν αὐτοῖς εὑρεῖν τὸ ζητούμενον.
>
> Some time later they say that some Delians, devoting themselves to doubling one of their altars in accordance with an oracle, fell into the same difficulty. They sent messages to the geometers associated with Plato in the Academy thinking them worthy to find what they themselves sought.

Whereas in the narrative of Minos and Glaucus, the idea of an oracle is part of the wider narrative context but not present in the quotation,

central to the Delians' problem is its oracular origin.[27] Here too, the geographical aspect of the narrative is significant. Following Hippocrates—an immigrant to Athens—the Delians' embassy to the Academy underscores that the centre of research in the Classical period is Athens. Eratosthenes thus places his mathematical achievements in a genealogical relationship to the Athenian intellectual revolution, and in a way which emphasises intellectuals' contribution to broader public concerns; could Eratosthenes' solution also have an impact on the religious life of an island?[28]

Eratosthenes' mention of Plato, though, is about more than the completeness of his historical account. The cultural and intellectual program of the Ptolemies, as well as drawing scholars and poets to the Museum, sought to draw in philosophers from a variety of traditions. The rise of philosophical schools, their successions, and the rivalries between them, become a notable phenomenon in the Hellenistic age.[29] An epigram by Posidippus (active at least from 280–240 B.C.E.) attests to a popular concern about the survival of Plato's Academy during this period (Posidippus 89 AB):

> Λυσικλέους κεφαλὴν ὁ κενὸς τάφος οὗτος ἀπαιτεῖ
> δάκρυ χέων, καὶ θεοῖς μέμφεται οἷ' ἔπαθεν
> τοῦξ Ἀκαδημείας πρῶτ[ον σ]τόμα, τὸν δέ που ἤδη
> ἀκταὶ καὶ πολιὸν κῦμα [θανόντ' ἔλαχον].
>
> "Dearest Lysicles" is requested by this cenotaph, as it sheds tears and blames the gods for what the Academy's first voice has suffered. But him, no doubt, already the shores and grey waves [have gained in death as their own].[30]

Supposedly, Demetrius of Phalerum relocated to Alexandria, and Ptolemy tried to add Theophrastus (a Peripatetic), Stilpo (a Stoic), and Diodorus Cronus (a Dialectician) to his collection of philosophers (Diog.Laert. 5.37, 2.111–5). Posidippus' mention of Lysicles is the first indication of an Alexandrian concern with the Academy. McKechnie 2013 arguing that this epigram specifically marks a loss for the Alexandrian court, suggests that

[27] For the tradition in later texts, cf. Plut. *Quaest.Conv*. 8.2.1, *Marc.* 15.14.5–6, *E. apud Delphi*. 6386d–f, *De genio Soc*. 7.579b–d; Vitr. *De Arch.* 9. See also Breidenbach 1952 and Huffman 2005, 342–401.

[28] For more on these narrative aspects see Asper 2013a, 437–8.

[29] A useful overview can be found in Sheffield and Warren 2013, 391–538, especially the pieces Warren 2013 and Vogt 2013.

[30] Following Austin and Bastianini 2002, 115. There are problems with the Greek, though they do not affect the sense for the present discussion.

Lysicles' trajectory is Egypt. Certainly the epigram *qua* cenotaph marks a death and an absence, and a shipwreck would suggest Lysicles was in transit, although to where the epigram does not reveal. Nor does Posidippus' writing a lament for circulation among the Alexandrian elite in the first instance necessarily imply that Lysicles had accepted an invitation from the Ptolemies.[31] What the epigram signals, however, is an interest in the Academy among certain circles in Alexandria, and their apparently sincere sadness at the Academician's death. Eratosthenes continues this Alexandrian interest in the Academy, as well as the habit of advertising that interest through literary works.

The tradition to which Eratosthenes specifically alludes in the letter is that of Plato as proto-mathematician and the Academy as a place of considerable mathematical collaboration.[32] Scientists and mathematicians, too, were in the Ptolemies' sights and one of the first jewels in the intellectual crown—reportedly—was Euclid, who worked and taught in Alexandria. Late Antique sources preserve an intriguing, probably fabricated, interaction between Ptolemy and the mathematician (Proclus *In Euc.* p. 68.13–17 Freidlein):[33]

> φασιν ὅτι Πτολεμαῖος ἤρετό ποτε αὐτόν, εἴ τίς ἐστιν περὶ γεωμετρίαν ὁδὸς συντομωτέρα τῆς στοιχειώσεως· ὁ δὲ ἀπεκρίνατο, μὴ εἶναι βασιλικὴν ἀτραπὸν ἐπὶ γεωμετρίαν.
>
> They say that Ptolemy once asked him [sc. Euclid], if there was a way to geometry more abridged than the *Elements*. He replied that there was no royal short-cut to geometry.

The tale's aim is clear; as Asper 2011, 95, puts it, "Theoretical mathematics is egalitarian and does not yield to social hierarchies." The particular synecdoche of Euclid's *Elements* (Στοιχεῖα) with the entire discipline of mathematics, moreover, brings the tale into dialogue with the Platonic

[31] McKechnie 2013, 136, "Lysicles died (the reader is invited to think) on a voyage to visit Alexandria." This is not clear, even given its place at the opening of the *Nauagika* section of Posidippus' epigram collection.

[32] The precise relationship between Plato and the mathematicians with whom he conversed is neatly and critically approached by Zhmud 1998. That being said, I am still not persuaded that the *Platonicus* which is recorded in Theon is the source from which Plutarch got his story; there are linguistic similarities also with the letter.

[33] A similar anecdote is preserved in Stobaeus (2.31.115) involving instead Menaechmus and Alexander the Great. It is a slightly elaborated version, which leads me to think it is the later of the two anecdotes. In any case, important for my purposes is that the key term συντόμως is also employed there, and so part of the anecdotal "core."

stoicheia or "elements," being both the ultimate components of matter, fundamental principles, numbers, and even letters of the alphabet.[34] Ptolemy's purported desire to know Euclid's geometry is subsumed in the wider aim of total knowledge, a project which the Alexandrian Library might be said to represent. Were Euclid directly associated with Plato, too, Ptolemy's patronage would have ensured not only a mathematician present at Alexandria, but a representative of those working around the late Classical–early Hellenistic Academy.

Roughly a generation later, Eratosthenes' letter picks up this Academic and mathematical interest. According to Strabo (1.2.2), Eratosthenes in fact arrived at Alexandria *via* Athens, where he frequented the Academy. Whether genuine or not, his nicknames δεύτερος Πλάτων ("Second Plato") and νέος Πλάτων ("New Plato") have an unmistakeable significance (Suda *s.v.* Ἐρατοσθένης). There can be noticed in the largest fragment of his poetic work, the *Hermes*, which detailed the cosmos, a strong influence from Plato's cosmology and the Myth of Er.[35] Two references in Theon of Smyrna record a work entitled the *Platonicus*, although its genre and content remain open for discussion.[36] What the *Platonicus* suggests is that Eratosthenes is modelled by himself and others as engaging with, and inheriting, Platonic thought. Eratosthenes' silence concerning Plato's solution and his strategically emphasising the failure of other Academic "contestants," Archytas, Eudoxus, and Menaechmus (106.5–8 H. see below), calls for a successor. The narrative of the letter highlights Eratosthenes as the "New Plato" at Alexandria taking hold of the Academy's intellectual genealogy.

c. The Problem and Platonic Mathematics

Eratosthenes, however, does not introduce Plato and the Academic angle into his letter only for reasons of self-representation or political pandering. The mathematics for dealing with the problem—as Eratosthenes' jostling with Archytas, Eudoxus, and Menaechmus suggests—in part grew out of Academic inquiry. While unlikely to be authentic, it is perhaps no coincidence that Eutocius preserves Plato's solution to the doubling of the cube first (66.21–70.2 H). Although I do not want to

[34] Cf. Plato *Cra*. 424d; *Tht*. 202e. See also LSJ *s.v.* στοιχεῖον and Fowler 1999, 381–94.

[35] Fr. 16 *CA*. Geus 2002, 128, and Di Gregorio 2010.

[36] Cf. Solmsen 1942; Zhmud 1998; Netz 2009, 163–4. An unresolved question, it seems to me, is the interrelation of the letter and the *Platonicus*.

go too far into the intricacies of the solution,[37] the geometry which lies behind the problem is worth discussion in the context of the Academy and mathematics since it contains some notable departures from the Platonic tradition of mathematics.

The problem was first generalised from the specific task of finding a cube, *B*, which is twice the volume of an original cube, *A*, to finding a cube, *B*, whose ratio to another cube, *A*, equals the ratio of two given lines. This then led to Hippocrates' equally difficult problem which allows for a geometric solution involving mean proportionals (see above). The aim is to find two mean proportionals between the two given lines, so that for lines a and b, one must find x and y, such that $a : x = x : y = y : b$. This produces the equation $a^3 : x^3 = a : b$, where x is the side of a cube in the ratio $b : a$ to the original cube, a^3.[38] In the case where the subsequent cube is double the volume of the original cube this means that $x^3 = 2a^3$, and so the ratio between the side of the original cube a^3 and the new cube, x^3, is $\sqrt[3]{x^3} = \sqrt[3]{2a^3}$, which becomes $x = a\sqrt[3]{2}$, meaning that a side, a, must be multiplied by the cube root of two ($\sqrt[3]{2}$) to produce a cube of double the volume. While it is impossible to construct the line x using a straight-edge and compass because its ratio with respect to a involves the cube root of two ($\sqrt[3]{2}$), the solution Eratosthenes provides in his letter involves sliding triangular plates which form parallelograms which can be manipulated—in a way more complex than it is worth explaining at this juncture—so that x and y may be approximated, and a cube—or its side at least—twice the volume may be constructed (106.28–108.24 H). There are a number of resonances which should be drawn from this outline of the problem and Eratosthenes' solution.

The two-dimensional version of this problem, doubling the area of a square, is possible using a straight-edge and compass, and the association between the two problems is noted by Eratosthenes when he explained King Minos' mistake (see above). The *locus classicus* of the doubling of the square is Plato's *Meno*, where Plato has Socrates teach Meno's slave boy how to produce a square double the area of a given square (82b–85d). Eratosthenes' attempt at solving the doubling of the cube sets him in a tradition of solving a sort of problem which had intrigued Plato enough to put in the mouth of Socrates. An explanation of the mathematics in the letter can be fruitfully read against the narrative of King Minos and the passage from the *Meno*. In contrast to Meno's slave who, in a matter

[37] Further explanations of varying detail can be found in Heath 2002, 244–70, Knorr 1989, Chapter 6, and, for those who want a challenge, Saito 1995 and White 2006.

[38] Cf. Saito 1995, 120–1.

of minutes has managed to double a square with Socrates' guidance, the king in the tragic quotation, so Eratosthenes represents it, is unable even to understand the two-dimensional version in his outrage. So that his royal reader is not reduced to the level of a king with less mathematical understanding than a slave, Eratosthenes leads him through the mathematics in all its intricacy and Ptolemy becomes part of the Platonic tradition of mathematical education. Even Hippocrates' reducing of the problem to an equally difficult problem could be said to be part of a geometrical education as drawn from the *Meno*, where, through another geometrical example, Socrates discusses how one ought to reduce a question to a known problem (86d–87c). Perhaps too, since the *Meno* has as its subject whether virtue is teachable, this mathematical education might have been understood to form part of a broader curriculum for a royal reader concerned with pursuing virtue.[39]

In light of Eratosthenes' engagement with geometry seen also in the *Meno*, it is all the more significant that Eratosthenes' solution is a departure from Plato's opinion on the study of geometry in the *Republic*. There he represents it as something which tends towards abstraction and "that would draw the soul away from the world of becoming to the world of being" (521d), in contrast to the other arts which are base and mechanical (βάναυσοι, 522b).[40] In the particular case of the doubling of the cube, Plutarch reports, Plato reproached Eudoxus, Archytas and Menaechmus for using instruments and mechanical devices (ὀργανικὰς καὶ μηχανικὰς κατασκευάς, *Quaest. Conv.* 8.2.718e). Eratosthenes' solution is thus quite un-Platonic. He directs the following (Eratosthenes, "Letter to Ptolemy" 108.5–7 H):

> μένοντος δὴ τοῦ μέσου παραλληλογράμμου τοῦ ΖΙ συνωσθήτω τὸ μὲν ΑΖ ἐπάνω τοῦ μέσου, τὸ δὲ ΙΘ ὑποκάτω, καθάπερ ἐπὶ τοῦ δευτέρου σχήματος, ἕως οὗ γένηται τὰ Α, Β, Γ, Δ κατ' εὐθεῖαν.
>
> So with the middle parallelogram [formed by the triangular plates], ZI, remaining in place, let AZ be pushed above the middle <parallelogram>, <and let> IΘ <be pushed> beneath it, as in the second diagram, until A, B, Γ, Δ come to be on a <single> line.

[39] Geometry and stereometry are certainly part of a Platonic education as laid out in *Republic* 7.

[40] This being said, a later section of that discussion, 528a9–b1, appears to consider the different volumes of a cube, although it is generally thought that no link with the specific historical tradition of the problem can be discerned, see now Huffman 2005, 385–92.

The form of his proof does not look so different from other geometrical proofs preserved in Eutocius. He even concludes that ταῦτα οὖν ἐπὶ τῶν γεωμετρουμένων ἐπιφανειῶν ἀποδέδεικται ("so these things are proved for geometrical surfaces," 110.1–2 H), before moving onto the description of the mechanism: ἵνα δὲ καὶ ὀργανικῶς δυνώμεθα τὰς δύο μέσας λαμβάνειν ("But so as we may also take the two means by a machine," 110.2–3). Yet the explanation that one must "push" the shapes in order create a desired single line is language which assumes the material existence of a mechanism. So too, the two diagrams which Eratosthenes provides in the letter work as a "before and after" of the mechanical operation.[41] Rather than Eratosthenes moving from the abstract to the sensible, his solution to the problem and description of the geometry seems to have applicability and a mechanism already in mind.

This mechanical applicability is made emphatic when, following a round-up of the attempts of Archytas, Eudoxus, and Menaechmus (106.1–8 H), Eratosthenes explains at some length the practical advantages of his solution (Eratosthenes, "Letter to Ptolemy" 106.8–26 H):

> ἐπινενόηται δέ τις ὑφ' ἡμῶν ὀργανικὴ λῆψις ῥᾳδία, δι' ἧς εὑρήσομεν δύο τῶν δοθεισῶν οὐ μόνον δύο μέσας, ἀλλ' ὅσας ἄν τις ἐπιτάξῃ. τούτου δὲ εὑρισκομένου δυνησόμεθα καθόλου τὸ δοθὲν στερεὸν παραλληλογράμμοις περιεχόμενον εἰς κύβον καθιστάναι ἢ ἐξ ἑτέρου εἰς ἕτερον μετασχηματίζειν, καὶ ὅμοιον ποιεῖν καὶ ἐπαύξειν διατηροῦντας τὴν ὁμοιότητα, ὥστε καὶ βωμοὺς καὶ ναούς. δυνησόμεθα δὲ καὶ τὰ τῶν ὑγρῶν μέτρα καὶ ξηρῶν (λέγω δέ, οἷον μετρητὴν ἢ μέδιμνον), εἰς κύβον καθίστασθαι καὶ διὰ τῆς τούτου πλευρᾶς ἀναμετρεῖν τὰ τούτων δεκτικὰ ἀγγεῖα, πόσον χωρεῖ. χρήσιμον δὲ ἔσται τὸ ἐπινόημα καὶ τοῖς βουλομένοις ἐπαύξειν καταπαλτικὰ καὶ λιθοβόλα ὄργανα. δεῖ γὰρ ἀνάλογον ἅπαντα αὐξηθῆναι καὶ τὰ πάχη καὶ τὰ μεγέθη καὶ τὰς κατατρήσεις καὶ τὰς χοινικίδας καὶ τὰ ἐμβαλλόμενα νεῦρα, εἰ μέλλει καὶ ἡ βολὴ ἀνάλογον ἐπαυξηθῆναι. ταῦτα δὲ οὐ δυνατὰ γενέσθαι ἄνευ τῆς τῶν μέσων εὑρέσεως.
>
> But we have conceived of a certain easy mechanical way of taking proportions through which, given two lines, means—not only two, but as many as one may set forth—shall be found. This thing found, we may, generally: reduce a given solid (contained by parallelograms) into a cube, or transform one solid into another, both making it [the created solid] similar [to the original solid] and, while enlarging it, maintaining the similitude, and this with both altars and temples; and we can also reduce into a cube, both liquid and dry measures (I mean, such as a *metretes* or a *medimnos*), and

[41] Only the second diagram was inscribed on the *stele*, cf. 110.18–9 H. This might well have been a pragmatic move, providing an image for an operator of how the plates should look when used correctly.

> we can then measure how much the vessels of these liquid or dry materials hold, using the edge of the cube. And the conception will be useful also for those who wish to enlarge catapults and stone-throwing machines; for it is required to augment all proportionally—the thicknesses and the magnitudes and the apertures and the *choinikids* and the inserted strings—if the throwing power is to be proportionally augmented. And these things cannot be done without finding the means.

In contrast to other solutions his is both easy and can be extended beyond the two means of the original problem. His example of altars and temples is strategic. It appends to the subsequent mechanical proof a justification of its import for monumental architecture; this is a tool which Ptolemy can employ—via his architects and builders—to augment his dedication to the gods, and possibly even the Ptolemaic ruler cult. Likewise, its application extends to food measurement and the military, suggesting the solution as indispensable in both peacetime and war, for prosperity and defence.

The mechanical aspects embedded in the mathematical instructions, as well as the variety of applications Eratosthenes proposes, conflict with Platonic mathematical doctrine. While Eratosthenes departs from Plato in his concern for practicality in the letter, a purely theoretical approach may have been taken in the *Platonicus*, which dealt with proportions and means.[42] In this case, the development which is announced in the letter to Ptolemy could be understood as a secondary output of his research. In any case, however, here Eratosthenes clearly sets himself apart from Platonic mathematics and the Academy. Eratosthenes' silence about Plato's solution could be read as implicitly allowing for Eratosthenes to take up the Platonic role, yet it might also suggest that Plato's pure geometry was not able to solve the problem. Indeed, modern scholarship has shown a pure geometrical solution with straight edge and compass to be impossible.[43] This is certainly an issue with the other Academicians' solutions, who Eratosthenes says wrote ἀποδεικτικῶς ("demonstratively") and whose solutions were difficult to put into practice (106.1–8 H). The mention of altars and temples, as well as rounding off the tragic myth and the Platonic narrative with their preoccupation on monumental structures,[44] also responds to their failures by suggesting that a practical approach,

[42] See the extensive discussions of Geus 2002, 139–94, and Vitrac 2008.

[43] Cf. Suzuki 2008 for a history of such geometric problems from Euclid through to Pierre Wantzel (1814–1848), who first provided proofs of their impossibility.

[44] Cf. Netz 2004, 295 n.160.

i.e., Eratosthenes' approach, was required after all. Importantly, while it is clear that Eratosthenes represents this problem as something with which the Academy dealt and an intellectual genealogy is constructed, the mathematics, like the narrative content, has been tailored to royal interests.

To briefly conclude this section: the plurality of concerns to which Eratosthenes responds is striking. He contextualises the problem first through the framework of a royal narrative, then through the lens of the Academic schools, then with an eye to its every-day application. Berrey (forthcoming, Chapter 3) reads Eratosthenes' self-representation here as a case of the egotism of science and the rhetoric of personal innovation against a tradition. At the same time, though, through these short narratives the Egyptian present is figured in terms of traditional myth and as a second Athens. He uses the problem's own history as a lesson for its continued importance in the present—for a royal house, for the religious life of an island, perhaps even as a means for progressing on the road to inquiry more broadly, if the *Meno* is recalled. The letter may be addressed in the first instance to Ptolemy, but the multiple generic and thematic "nods" compacted into this opening history and explanation create a texture indicative of a broader literary culture. A study of the concluding epigram (the Hellenistic genre *par excellence*) will allow for a productive reflection on this proposition.

3. GRASPING THE EPIGRAM

Following the exposition of his research's utility, Eratosthenes addresses the reader, which divides the narrative and mathematical sections of the text (Eratosthenes, "Letter to Ptolemy" 106.26–7 H):

> τὴν δὲ ἀπόδειξιν καὶ τὴν κατασκευὴν τοῦ λεχθέντος ὀργάνου ὑπογέγραφά σοι
>
> I have written out below for you the proof and the construction of the said mechanism

I would not go so far as to claim that this generic shift from a letter to a subsequent "transcription" indicates a change in intended audience—the σοι ("you," 106.26 H) re-affirms the connection with the (royal) reader—although it clearly marks a thematic transition in the letter, as the reader's attention is now directed towards technical specifics. Berrey (forthcoming, Chapter 3) suggests that this address functions to separate the letter into two halves. Instead, I take the epigram at the end to respond in a number of ways to the opening tragic quotation, and that together they

wrap the mathematics within literary texts, rather than being separable from them (see Section 5, below). This second half contains the proof (iv.a), as well as the description of the *stele* bearing the mechanism (iv.b), a version of the proof with a diagram (iv.c), and the epigram (v). That the epigram concludes the letter and is part of the technical explanation has consequences for an understanding of the epigram's form and function. This section analyses the epigram in detail and traces the motif of grasping the mechanism. The motif both underscores the practicality of his solution in comparison to the Academy's unworkable solutions (cf. Section 2c, above), and is central to articulating the political significance of the solution, and the value of Eratosthenes, for the Ptolemies.

The epigram divides into three equal sections, and addresses the public benefit, the intellectual heritage, and the relation of the solution to the Ptolemies and Eratosthenes, which reverses the sequence of the letter and thematically folds the text into a unified whole. The first section addresses the reader and introduces the function of the mechanism (Eratosthenes, "Letter to Ptolemy" 112.13–18 H = fr.35.1–6 *CA*).

> εἰ κύβον ἐξ ὀλίγου διπλήσιον, ὦγαθέ, τεύχειν
> φράζεαι ἢ στερεὴν πᾶσαν ἐς ἄλλο φύσιν
> εὖ μεταμορφῶσαι, τόδε τοι πάρα, κἂν σύ γε μάνδρην
> ἢ σιρὸν ἢ κοίλου φρείατος εὐρὺ κύτος
> τῇδ' ἀναμετρήσαιο, μέσας ὅτε τέρμασιν ἄκροις
> συνδρομάδας δισσῶν ἐντὸς ἕλῃς κανόνων.
>
> If you plan, of a small cube, its double to fashion, or—dear friend—any solid to change to another in nature: it's yours. You can measure as well: be it byre, or corn-pit, or the space of a deep, hollow well. When they run to converge, in between the two rulers—seize the means by their boundary-ends.

In the body of the letter Eratosthenes indicates his solution's use for the construction of altars and temples which would appeal to the institutions involved in such building projects; royal households and religious organisations. He speaks in terms that prospective patrons would understand. In contrast, the (assumed to be) publicly viewable epigram turns the reader's focus solely onto the practical uses which Eratosthenes subsequently mentioned: cattle enclosures, corn-pits, and wells.[45] Set upon a votive monument the epigram presents the solution, and the physical mechanism accompanying it, as a cog in the machine of state's crucial, yet quotidian, operations.

[45] This is not necessarily, after Netz 2004, 298 n.182, a "georgic touch."

The second section develops this rhetoric with particular attention to earlier attempts (Eratosthenes, "Letter to Ptolemy" 112.19–114.2 H = fr.35.7–12 *CA*):

> μηδὲ σύ γ' Ἀρχύτεω δυσμήχανα ἔργα κυλίνδρων
> μηδὲ Μεναιχμείους κωνοτομεῖν τριάδας
> διζήσῃ, μηδ' εἴ τι θεουδέος Εὐδόξοιο
> καμπύλον ἐγ γραμμαῖς εἶδος ἀναγράφεται·
> τοῖσδε γὰρ ἐν πινάκεσσι μεσόγραφα μυρία τεύχοις
> ῥεῖά κεν ἐκ παύρου πυθμένος ἀρχόμενος.[46]
>
> Do not seek the impractical works of Archytas' cylinders, nor the three conic-cutting Menaechmics; and not even that shape which is curved in the lines that divine Eudoxus constructed. By these plates, indeed, you may easily fashion—starting from a small base—even thousands of means.

Archytas, Menaechmus and Eudoxus are all knocked down a peg, while Plato has completely fallen out of the picture. Most effective is the layering of polysyllabic technical vocabulary. While the first section contextualises the solution in terms of the pragmatic, those solutions the reader is told not to seek are made to be both verbally and conceptually complex. The section's final line provides the *coup de grâce*. The ease and abundance of his own method makes a sharp contrast with others' solutions.

The third and final section turns political and personal (Eratosthenes, "Letter to Ptolemy" 114.3–114.8 H = fr.35.13–18 *CA*):

> εὐαίων, Πτολεμαῖε, πατὴρ ὅτι παιδὶ συνηβῶν
> πάνθ', ὅσα καὶ Μούσαις καὶ βασιλεῦσι φίλα,
> αὐτὸς ἐδωρήσω· τὸ δ' ἐς ὕστερον, οὐράνιε Ζεῦ,
> καὶ σκήπτρων ἐκ σῆς ἀντιάσειε χερός.
> καὶ τὰ μὲν ὣς τελέοιτο, λέγοι δέ τις ἄνθεμα λεύσσων
> τοῦ Κυρηναίου τοῦτ' Ἐρατοσθένεος.
>
> O Ptolemy, happy! Father as youthful as son; you have given him all that is dear to the Muses and to kings. In the future—O heavenly Zeus!—may he also receive sceptres from your hand. May this come to pass, and may anyone seeing this votive offering say: "This is the dedication of Eratosthenes of Cyrene."

The subject of the accompanying mechanical device is set to one side, and Eratosthenes addresses Ptolemy, while also referencing the Muses,

[46] In v. 8 Heiberg 1883.3, 112.20 reads Μενεχμείους. I follow Mugler 1972, 69 in printing Μεναιχμείους in the epigram, on the evidence of Proclus (see below).

Zeus, and himself. Each section, however, reflects the structure of the letter and contributes to the specific political import of the mechanism.

Before looking deeper into the ways the grasping motif is developed it is worth briefly considering the material possibilities of the mechanical device, which Eratosthenes is keen to emphasise. In moving from the mathematical exposition to the construction of a mechanism which enables the taking of mean proportionals, he makes suggestions about its appearance: διαπήγνυται πλινθίον ξύλινον ἢ ἐλεφάντινον ἢ χαλκοῦν ("may a frame be fashioned of wood, or ivory, or bronze," 110.3–4 H). As part of his instructions, the reader can construct this mechanism from whatever they like. His device erected on the *stele*, though, is fashioned from bronze and fitted to the *stele* with lead (ἐν δὲ τῷ ἀναθήματι τὸ μὲν ὀργανικὸν χαλκοῦν ἐστιν καὶ καθήρμοσται ὑπ' αὐτὴν τὴν στεφάνην τῆς στήλης προσμεμολυβδοχοημένον, 110.12–14 H). The physical material of the mechanism, to be chosen by the reader, was nevertheless important enough to be specified by Eratosthenes. In light of this material focus, a productive way to approach the epigram is to see the text (whether literary or inscribed) as supplementing the proof and, more specifically, the experience of operating the mechanism on the supposed *stele*. Whereas often epigrams toy with the idea of allowing one to read a view, Eratosthenes' epigram has the tactile materiality of his mechanism in mind.[47]

Indeed, Eratosthenes plays with the idea of physically grasping the mechanism through vocabulary choice in both the epigram and letter, and so aligns the action to holding the text. He measures the mean proportionals with his easy new "take" on the problem: ἐπινενόηται δέ τις ὑφ' ἡμῶν ὀργανικὴ λῆψις ῥᾳδία ("But we have conceived of a certain easy mechanical taking," 106.9 H).[48] This adds further point to the criticism of his Academic competitors (Eratosthenes, "Letter to Ptolemy" 106.1–8 H):

> τῶν δὲ φιλοπόνως ἐπιδιδόντων ἑαυτοὺς καὶ ζητούντων δύο τῶν δοθεισῶν δύο μέσας λαβεῖν, Ἀρχύτας μὲν ὁ Ταραντῖνος λέγεται διὰ τῶν ἡμικυλίνδρων εὑρηκέναι, Εὔδοξος δὲ διὰ τῶν καλουμένων καμπύλων γραμμῶν. συμβέβηκε δὲ πᾶσιν αὐτοῖς ἀποδεικτικῶς γεγραφέναι, χειρουργῆσαι δὲ καὶ εἰς χρεῖαν πεσεῖν μὴ δύνασθαι πλὴν ἐπὶ βραχύ τι τοῦ Μενέχμου καὶ ταῦτα δυσχερῶς.[49]

[47] In recent years much has been written on ekphrastic epigrams. Indispensable are Goldhill 1994; Bing 1995; Stewart 2005; Sens 2005; and Squire 2010, all with considerable bibliography. For another *ekphrasis* of a mechanism, see Hedylus 4 *HE*, below.

[48] I accept Serafina Cuomo's point to me that λαμβάνειν is the traditional verb of taking proportions, although I think the physical sense of the word would still have had semantic force when considered cumulatively.

[49] Mugler 1972, 65 reads "τὸν Μέναιχμον." Heiberg 1883.3, 106.8 prints "τοῦ Μενέχμου." The genitive is more likely after πλήν (cf. LSJ *s.v.* πλήν A.1). Turning the second vowel into

> Of those who dedicated themselves to this diligently, and investigated how to take two mean proportionals between two given lines, it is said that Archytas of Tarentum solved this with the aid of semicylinders, while Eudoxus did so with the so-called curved lines; as it happens, all of them wrote demonstratively, and it was impossible practically to apply this by hand—except Menaechmus, by the *shortness*,[50] and this with difficulty.

His claim that Archytas' and Eudoxus' methods cannot be constructed or "executed by hand" (χειρουργῆσαι) and that Menaechmus' solution was applicable beyond geometry only with difficulty (δυσχερῶς, lit. "hard to take in hand"), sets them against the easily operable and manoeuvrable solution of Eratosthenes. In the epigram, which Eratosthenes attaches at the end of his letter so that Ptolemy might "have/hold" it also as a text—ἵνα ἔχῃς καὶ ὡς ἐν τῷ ἀναθήματι, ("so that you also have it, as in the dedication," 110.17 H)—the mechanism's manipulability is again highlighted. If you wish to double a cube, Eratosthenes' epigram announces, you can measure whatever you like when you take (ὅτε . . . ἕλῃς, 5–6) the proportionals between the twin rulers. The immediacy of this efficient solution might have been greater for those present at the *stele* who could reach out and grasp the device, but Eratosthenes emphasises this also for the reader who gains a similar sense when grasping the letter and epigram in their own hand.

With the mention of the Muses, Ptolemy and himself in the final lines, Eratosthenes further sets this grasping—whether in front of the *stele* or simulated through the holding of the text—in the context of his relationship with, and the readership of, the king. As Agosti 1997 has noted, line 14 echoes the opening of Hesiod's *Theogony*. In a famous passage (80–103) Hesiod sums up the interrelation between the gods, rulers and poets: ἐκ δὲ Διὸς βασιλῆες· ὁ δ' ὄλβιος, ὅντινα Μοῦσαι /φίλωνται ("from Zeus come kings, but he [sc. the poet] is blessed whomever the Muses love," Hesiod *Th*. 96–7). Before Eratosthenes, Callimachus had already engaged with Hesiod's triangulation of the Muses, kings and poets. Passages echoing Hesiod's language appear both in the *Aetia* at the end of his *Reply to the Telchines* (37–8) and epigram 29 *HE*, although since these two echoes, and their possible interrelation or interpolation, are a

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a diphthong would match with Mugler's attractive suggestion for the epigram (see above). I hesitate to correct Heiberg here since this point does not affect my larger argument.

[50]This comes from Netz 2004, 295, and is meant to suggest a method of solution called the *shortness*. The confusion stems from the manuscripts, though it in no way affects my argument.

strongly debated area, they are to be handled with caution.[51] In the case of Eratosthenes' Hesiodic prediction—πάνθ' ὅσα καὶ Μούσαις καί Βασιλεῦσι φίλα /αὐτὸς ἐδωρήσω (14–5)—Ptolemy bestows gifts on his son and these relate to providing his son with an education and the necessary training for kingship. The following lines—τὸ δ' ἐς ὕστερον, οὐράνιε Ζεῦ /καὶ σκήπτρων ἐκ σῆς ἀντιάσειε χερός ("in the future—o heavenly Zeus—may he also receive sceptres from your hand," 15–6)—develop this focus on inheritance. The σκῆπτρον is the archetypal object of power, and here Eratosthenes describes the future point of inheritance of power through their transfer (cf. *Il.* 1.279, 2.86 for kings, *Il.* 1.28 for priests, and *Od.* 11.90 for prophets). Ptolemy gifts his son first education, and then the rule.

The epigram's σκῆπτρα also set Ptolemaic power in relation to the didactic poet. In the *Theogony* the sceptre becomes the symbol of Hesiod as a poet—καί μοι σκῆπτρον ἔδον ("and they [the Muses] gave me a rod," *Th.* 30)—one whose skill in singing is authorized by the Muses under the hegemony of Zeus; that is to say, it is the symbol of the ruler-ordained poet. It is worth considering a Hellenistic epigram on Aratus' *Phaenomena*, reportedly written by King Ptolemy, which sheds light on contemporary poetic representations of a didactic poet's relation to a ruler (King Ptolemy 1 *FGE*):[52]

> πάνθ' Ἡγησιάναξ τε καὶ Ἕρμιππος <τὰ> κατ' αἴθρην
> τείρεα καὶ πολλοὶ ταῦτα τὰ φαινόμενα
> βίβλοις ἐγκατέθεντο, †ἀπὸ σκοποῦ δ' ἀμφάρτον†
> ἀλλ' ὅ γε λεπτολόγος σκῆπτρον Ἄρατος ἔχει.
>
> Hegesianax and Hermippus and many others put the heavenly bodies, those phaenomena, into books and they missed the mark. But Aratus, the subtle-speaker, holds the sceptre.[53]

Along with Callimachus (56 *HE*) and Leonidas of Tarentum (101 *HE*), Ptolemy chose to respond to Aratus' astronomical didactic poem with his own epigrammatic composition.[54] Each of these rough contemporaries admires Aratus and his poem by employing compounds of λεπτός, not only because it was a common aesthetic term, but precisely to echo

[51] Cf. Harder 2012, volume 1, 83–6.

[52] It is unclear which Ptolemy is meant. Fraser 1972.2, 1090 n.459, is inclined to see it postdate Aratus by some time, while Cameron 1995, 323, argues for Ptolemy Philadelphus. The dating does not largely affect my argument.

[53] Adapted from Klooster 2011, 155.

[54] For a balanced analysis of the other epigrams, see Klooster 2011, 154–61.

Aratus' ΛΕΠΤΗ acrostic (783–7) set into the *Phaenomena* for the discerning reader.[55] Ptolemy's specific estimation and response by handing the sceptre to Aratus, strategically engages with the Hesiodic influence on Aratus' didactic poem.[56] By judging Aratus to hold the sceptre Ptolemy figures him as a second Hesiod, but more importantly, positions himself as a Zeus able to effect such a sanction; perhaps even over and against Aratus' supposed Antigonid patrons.[57]

Eratosthenes' configuration of the sceptre image works in a similar way. Ptolemy gifts his son sceptres (likely a poetic plural for a single "sceptre"), and the invocation of Zeus (15), following the address to Ptolemy (13), aligns the king to the god just as in the epigram attributed to Ptolemy. Ptolemy's conferring of power to his son in this epigram simulates a divine action of authorisation. Equally, with the sceptre as representing the didactic poet, this can be understood as a synecdochic elaboration of Ptolemy's gift of "those things dear to the Muses," in other words, the gift of education by the didactic poet, Eratosthenes. In this epigram, the holding of power becomes co-extensive with the ability to confer poetic authority and more broadly to make use of poetic productions. And in a very real way, the grasping of the sceptre parallels the holding of this didactic poetic text. Holding the text in one's hands, grasping the instruction manual for mechanical augmentation, the reader is "divinely empowered" (cf. 15).[58] In the same way that for Hesiod, "ease" is associated with divine actions (*Th*. 442–3) and those of god-like kings (*Th*. 90), the epigram lays out how ῥεία ("easily," 12) one would operate the mechanism.

A significant consequence of this association is that the parallel of holding the text and grasping the sceptre extends to the operating of the mechanism. This intersection of power and mechanics strikes at the heart of Ptolemaic concerns. The central concept of the mean proportional—the underlying problem for doubling the cube (see Hippocrates above)—is the demand to create something of equal proportions but of a greater magnitude: similar but different. The motif of proportional increase as a specific dynastic augmentation appears in Theocritus' *Encomium of*

[55] On reading the *Phaenomena*, see Hunter 1995.

[56] On Hesiod's influence on, and presence in, the *Phaenomena*, see now Van Noorden 2015, 168–203 with further bibliography.

[57] For his working under Antigonus cf. e.g. *Vit. Arat.* I.8.1–10.

[58] On the rhetoric of ease in Hellenistic and Imperial Greek literature, see Hunter 2004, 223–7.

Ptolemy Philadelphus (*Idyll* 17), where, following the enumeration of the cities under his control (82–4), the poet outlines each Ptolemies' responsibility to the dynasty: ἐπίπαγχυ μέλει πατρώια πάντα φυλάσσειν οἳ/ ἀγαθῷ βασιλῆι, τὰ δὲ κτεατίζεται αὐτός ("there is care to protect entirely all things inherited from his father, as is right for a good king, and he increases the store himself," 103–5). He adds that such royal wealth is not hoarded, but dedicated: πολὺν μὲν ἔχοντι θεῶν ἐρικυδέες οἶκοι ("much do the glorious house of the gods receive," 108). Hunter 2003a, 158–78, has underscored how this is not only poetic encomium; enumeration and expansion was a political mode of expression in both Greek and Egyptian. This tension maps onto the father-son dynamic in the final lines of the epigram. The father as ὅτι παιδὶ συνηβῶν (13) not only reflects the prevailing co-regency of the dynasty, but the idea of succession which demands the Ptolemaic line emphasise continuity of kingship with each new Ptolemy. So too, it corrects the father-son failure in the opening tragic quotation. A mechanical device which, when grasped and operated, makes objects the same but larger, parallels the grasping of the sceptre, and the hope that Ptolemaic rule and empire will continue and grow with every succession. (Indeed, the use of the plural "sceptres" may in fact respond to the two rulers of the mechanism, v. 6.) The image of the sceptre, then, makes clear that having this text in your hand is to possess a blueprint for mechanical expansion, and imperial expansion, which in turn ensures the continuity of the dynasty.

The second half of the letter with its epigram, in sum, certainly provide a hands-on solution. The intersection of a text which the reader holds, the mechanism which is manoeuvred on the *stele in situ*, and the sceptre which confers power when grasped, is a striking activation of the pragmatic nature of reading texts. The implication of this intersection would change with the context and the reader. A royal reader holding onto the mechanical solution in textual form simulates operating the mechanism, as well as the greater action of augmenting the empire through Eratosthenes' break-through. For the reader faced with the *stele*, however, the epigram would have presaged the transition and negotiation of power by the royal family, while each administrative application of the mechanism—when increasing wet and dry measures, and ballistics—actually co-opts the reader-operator into augmenting the empire. In other words, the mechanism is so significant because it aids imperial expansion, and Eratosthenes' combination of Hesiodic allusion and focus on the materiality of the text underscores how every gripping of the mechanism helps to secure the Ptolemies' grip on power.

4. THE MOBILE MESSAGE

The experience of reading, importantly, is dependent on the epigram's context of encounter and so it is worth considering the various means of broadcasting Eratosthenes' solution beyond a royal readership. The epigram, Eratosthenes explains, is written on a dedication (ἐν δὲ τῷ ἀναθήματι, 110.12 H) below the mechanism and a condensed version of the proof. Significantly, he does not say where. It is at least clear that such scientific inscriptions were not uncommon in the Hellenistic world. Cicero, for example, claims to have encountered Archimedes' tomb which preserved a verse inscription (*quosdam senariolos*) and a sphere together with a cylinder either engraved on, or a mechanism above, the monument (*Tusc. Disp.* 5.23).[59] This section considers the extent to which the epigram as an inscribed document would have embedded these political and mechanical concerns into the Ptolemaic landscape. But also, since the epigram is attached to the letter, it will address the potential significance of reading a (purportedly) inscribed epigram beyond its intended spatial context. My claim is that, regardless of whether or not the text was inscribed, Eratosthenes was aware of the potential mobility of his epigram and its message.

A roughly contemporary Alexandrian epigram by Hedylus (active 240–280 B.C.E.) provides a point of comparison for the intersection of poetics, politics, and mechanics that could be achieved by setting up a mechanical device amidst the Egyptian public (Hedylus 4 *HE* = Ath. 11.497d):

> ζωρόποται, καὶ τοῦτο φιλοζεφύρου κατὰ νηὸν
> τὸ ῥυτὸν εὐδίης δεῦτ' ἴδετ' Ἀρσινόης,
> ὀρχηστὴν Βησᾶν Αἰγύπτιον· ὃς λιγὺν ἦχον
> σαλπίζει κρουνοῦ πρὸς ῥυσὶν οἰγομένου,
> οὐ πολέμου σύνθημα, διὰ χρυσέου δὲ γέγωνεν
> κώδωνος κώμου σύνθεμα καὶ θαλίης,
> Νεῖλος ὁκοῖον ἄναξ μύσταις φίλον ἱεραγωγοῖς
> εὗρε μέλος θείων πάτριον ἐξ ὑδάτων.
> ἀλλὰ Κτησιβίου σοφὸν εὕρεμα τίετε τοῦτο,
> δεῦτε, νέοι, νηῷ τῷδε παρ' Ἀρσινόης.[60]

[59] On the significance of Cicero's encounter of the tomb see Jaeger 2008, Chapter 2.

[60] The text is an adaption of *HE* by Sens 2015. For the use of εὐδίης here instead of Athenaeus' εἰδείης in v.2 and σύνθεμα instead of σύνθημα in v.6, see Sens 2015, 42 n.5 and 11. For further literary context, see Bing 2003.

> Hard drinkers, look even at this *rhyton* in the temple of mild Arsinoe who loves the west-wind—it's the Egyptian dancer Bes, who trumpets out a shrill sound when the spout is opened for pouring, a call not to war, but from his golden trumpet he cries out a call to revelry and festivity, just as the lord Nile discovered an ancestral song, dear to his rite-bearing initiates, from his divine waters. But come honour this clever invention of Ctesibius, young men, by the temple of Arsinoe.[61]

Hedylus was the last of an illustrious group of epigrammatists writing about dedications in the temple of Aphrodite-Arsinoe at Zephyrium, and Ctesibius' machine was no doubt one of its main attractions.[62] Ctesibius is known for his work in pneumatics and the development of the hydraulic organ.[63] The peculiarities of this dedicatory machine are unclear, but it appears that when water was forced through the *rhyton*, it produced a melodious sound. The epigram plants the religious theme of celebration and plenty firmly into the Egyptian spatial context. Not only is the *rhyton* in Arsinoe's sanctuary reproducing the music of festival, as the figure of Besas, it fashions a synchresis of the Greek and the Egyptian. The Egyptian water forced through the Greek rhyton with an Egyptian figure calling men to the Greek κῶμος and θαλία is favourably compared to the sonorous Nile's call to the autochthonous celebrants of its own mysteries; the underlying force of all Egypt's power and fertility is co-opted into an image of Greek festivities. The juxtaposition of innovative machine and timeless life-source co-exist and co-operate under the protection of Aphrodite-Arsinoe.[64] Its record in Hedylus' epigram becomes a tool of propaganda for the Ptolemaic message of "plenty" being brought to Egyptian lands.

An appealing proposal by Berrey (forthcoming, Chapter 4) likewise locates Eratosthenes' epigram in an Egyptian context. He amasses evidence from Egyptian administrative sources in arguing that Eratosthenes synchronises his concerns with traditional Egyptian preoccupations such as water-supply, cattle and corn, which are recorded, for example, in the list of duties of the vizier on the tomb of Rekhmire at Egyptian Thebes.[65] These suggestions are convincing, although I would question the extent to which such concerns were identified as solely "Egyptian" in Eratosthenes'

[61] The translation is adapted from Sens 2015.

[62] Posidippus 39 A-B (possibly 37 A-B); Callimachus 14 *HE*.

[63] On his life, see Vitruvius *De arch*. 9.8.2 and Philo of Byzantium *Bel.* 67. On his various machines, cf. Philo *Pneum.* 1, *Belo*. 77 and Vitruvius *De arch*. 9.8.4–7; 10.8; 10.7.1–3.

[64] Sens 2015, 50–1.

[65] On the tomb of Rekhmire in Thebes, see Breasted 1906, 698–745.

time. His situating the epigram (and to some degree the entire text) as embedded in the economy of the native Egyptian village, however, leads him to suppose a particular site for an actual *stele* and mechanism. Even in the case of Hedylus the idea of place is toyed with, rather than being a fact asserted by the epigram. The emphatic καὶ τοῦτο ("even this," 1) sets the *rhyton* among all the other objects dedicated in the temple, but equally sets the ekphrastic epigram in a tradition of such *ekphrases* of dedications collected on the page.[66] So too, the closing address—δεῦτε, νέοι νηῷ τῷδε ("come . . . young men, by the temple," 10)—seems to have more efficacy outside its fixed and inscribed context; perhaps redundant when one encounters the epigram *in situ*, in a circulated text it becomes a clarion call, summoning readers to that Ptolemaic centre of worship and its festivities. However, my point is not to disprove Berrey's suggestion, since his arguments are highly persuasive. Similar to Hedylus' epigram, whether or not it was in fact inscribed, Eratosthenes' epigram is also composed to have impact beyond a specific locale. Thus an under-played aspect which ought to be explored further is how the epigram works as a text embedded in the letter that a subsequent reader encounters.

Focussing on the epigram as an embedded text, accordingly, can set the spatial aspect of the genre in a more constructive framework. For epigrams, extracting the text from its original location—or representing it as extracted—introduces ideas of inscriptional mobility, which necessarily re-frame how the epigram is read. Broadly, all epigrams intend to transmit across time information that is deemed important. In the Hellenistic period this information was collated in a systematic way with, for example, the collections of Philochorus' Ἐπιγράμματα Ἀττικά (*Attic Inscriptions*) and Polemon's Περὶ τῶν κατὰ Πόλεις Ἐπιγραμμάτων (*On Inscriptions by City*) (Athen.10.436d and 442e). Unsurprisingly, this extraction ignored the spatial and material experience of reading these inscriptions. At the same time, a new idea of epigrammatic contextuality was developing; the growing genre of literary epigram, and epigram collections, meant that these short texts were purposefully selected, extracted, combined and reconfigured into new and often programmatic sequences.[67] Just like the

[66] Sens 2015, 43 n.8.

[67] The bibliography on Hellenistic epigram is immense. Particularly useful, all with extensive discussion and bibliography, are Gutwiller 1998, 2005; Acosta-Hughes, Kosmetatou and Baumbach 2004; Fantuzzi and Hunter 2004; Bing and Bruss 2007, Höschele 2010. Ideas of editorial arrangement will be found throughout. On the textual mobility of epigrams, Anderson 2014 is illuminating, again with further bibliography.

epistolary genre, epigrams, both inscribed and literary, were subject to increased mobility in the Hellenistic period.

The result of this inscriptional mobility, the claim that an epigram in a text records an inscription located elsewhere, can provide a view of epigram's potential status as "evidence" about a specific location. This "evidentiary" nature can be seen in an epigram recorded by Strabo (Anonymous 133 *FGE* = Strabo 2.1.16):

> εἴ τις ἄρ' ἀνθρώπων μὴ πείθεται οἷα παρ' ἡμῖν
> γίγνεται, εἰς τήνδε γνώτω ἰδὼν ὑδρίαν·
> ἣν οὐχ ὡς ἀνάθημα θεῷ καλόν, ἀλλ' ἐπίδειγμα
> χειμῶνος μεγάλου θῆχ' ἱερεὺς Στρατίος.
>
> If any man does not believe what happens in our country, let him look at this water-jar and know; which, not as a fine dedication to the god, but as an illustration of severe winters, has been dedicated by Stratios the priest.[68]

The epigram, Strabo notes (2.1.16), accompanied a bronze water-jar burst by the cold, located in Panticapaion.[69] With ἐπίδειγμα replacing the traditional ἀνάθημα, material as monumentality is exchanged for material as evidence. The term's nuance in relation to display in an evidentiary or expository sense—think Herodotus' ἀπόδειξις (e.g. 1.1, 1.207)—is hard to ignore.[70] Yet the crucial objection to the epigram proclaiming itself as evidence is its spatial fixity: a readership in Panticapaion would likely have no need for its climatological claims. Emancipation from stone fulfils the genre's potential, transmitting a memory or "evidence" to anyone anywhere, but the expectations of readers encountering a spatially fixed inscription clearly differ from those encountering a mobile text. Regardless of whether the epigram was ever inscribed, what is important is that Strabo handles this generic form in order to advance a factual—even scientific—assertion. More significant still is that Strabo's source is Eratosthenes, geographer, as well as mathematician. If this epigram is not in fact Eratosthenes' (I am more than a little suspicious), it at least highlights the contemporary practice of extracting (or appearing to extract) and recording inscribed epigrams within texts as persuasive evidence. Eratosthenes had, in fact, been accused by the "inscription-glutton" Polemon (στηλοκόπας, Athen. 6.234d, above) of having not visited the places he

[68] The translation is my own.
[69] Modern day Kerch at the mouth of the Sea of Azov.
[70] In this sense, the LSJ's gloss, "memorial," is not helpful. Cf. LSJ *s.v.* ἐπίδειγμα II.

claimed.[71] The point I want to impress with the Stratios epigram is that, while Hellenistic epigrams like Hedylus' play with the fiction of their inscriptionality and location within a landscape, Hellenistic prose writers also co-opted such works, regardless of their original inscriptional nature, in advancing their own knowledge claims.

I want to propose, by way of conclusion, that Eratosthenes' letter handles its epigram in a similar way, as further evidence of the proof's validity ("if you don't believe, go read the *stele* . . ."), but in addition that it opens up the possibility of subsequent copying of the text. Here Eratosthenes' terminology for describing the proof, diagram and epigram on the *stele* becomes significant. He addresses the reader saying the following: ὑπογεγράφθω οὖν σοι καὶ ταῦτα, ἵνα ἔχῃς καὶ ἐν τῷ ἀναθήματι ("So let these be written below as well, for you, so that you have them also, just as on the *stele*," 110.16–7 H).[72] The semantic field of ὑπογράφω includes both "append below to a text," as well as "inscribe below" (LSJ *s.v.* ὑπογράφω I, 1 and 2.). Following his description of the mechanical device one may be forgiven for initially thinking he is referring to the proof and epigram on the *stele*. Eratosthenes' comments blur the boundary between inscribing a version of the proof and writing it into the letter, and hints at how the form of his text is related to an inscriptional original. Straddling the textual and inscriptional media of recording information, his words point towards and encapsulate the potentials of the epigrammatic genre as one which can be extracted from its original site of encounter and have a second life in textual copy.

The capitalisation of such potential might well be inferred with the appending of the epigram. Embedding the epigram within a letter underscores more overtly the textual mobility of epigrams (literary and inscribed), in comparison to other forms of prose, such as the Stratios epigram used in a geographical treatise. Eratosthenes' epigram is "data in transit." If the Stratios epigram could be extracted by Strabo, and probably by Eratosthenes, then he was surely aware that his epigram could equally be extracted. And, in fact, one later reader did just that. In evidencing Menaechmus' use of conic sections in his commentary to Euclid's *Elements*, Proclus quotes from the epigram (Proclus *In Euc.* p.111.20–23 Freidlein):

> ἐπινενοῆσθαι δὲ ταύτας τὰς τομὰς τὰς μὲν ὑπὸ Μεναίχμου τὰς κωνικάς, ὃ καὶ Ἐρατοσθένης ἱστορῶν λέγει· "μὴ δὲ Μεναιχμίους κωνοτομεῖν τριάδας·"

[71] He appears to level similar accusations at the historian Timaeus according to Athenaeus (14.695c).

[72] I thank Rebecca Lämmle for alerting me to this point.

> And, with respect to sections [of a solid], conic [sections] were discovered by Menaechmus, which Eratosthenes, observing, also says: "nor the three conic-cutting Menaechmics."[73]

He goes on to quote from another epigram by one Perseus which proclaims his discovery of spiral sections (Proclus *In Euc.* p.111.23–p.112.2 Freidlein). Writing an epigram about your mathematical achievements really could become a tag of authorship and intellectual authority. By placing his epigram at the end of the letter, then, Eratosthenes is able not simply to imply it as physically inscribed in a Ptolemaic landscape (and then subsequently "appended below" into his letter), he sets up the possibility for its further broadcasting beyond his own text: an extractable, "take-home" message, about his solution and its Alexandrian significance. And, for a royal reader, it might also be thought that copying the epigram, multiplying the contexts for encountering the message, is Eratosthenes doubling the potential impact of his solution and broadcasting the Ptolemaic hold on power.

5. THE EMPIRE ENCAPSULATED

The suggestion that the epigram is an extractable text, of course, brings with it the assumption that it sufficiently represents the contents and aims of the letter and, while I hope that the preceding sections have gone some way in highlighting the shared themes, the very idea that an epigram could compress the information of the letter into its lines responds to a number of Hellenistic and Alexandrian literary trends. As part of his instructions for operating the mechanism, Eratosthenes explains how the plates must be "as thin as possible" (ὡς λεπτοτάτους, 110.5 H) and that "taking the means in the most accurate way is to be done with great care for skill" (πρὸς δὲ τὸ ἀκριβέστερον λαμβάνεσθαι τὰς γραμμὰς φιλοτεχνητέον, 110.8–10 H).[74] Each of these terms—the language

[73] It is also highly likely that Pappus of Alexandria (first half of the 4th c. C.E.) knew the letter, cf. Cuomo 2000, 134–40.

[74] The idea of the expansion being carried out φιλοτεχνητέον ("requiring great care for skill") appears to be a particularly Ptolemaic attitude towards construction. In the *Belopoeica* ("*Manufacture of Cannons*") of Philo of Byzantium (2nd c. B.C.E.), Alexandrian craftsmen discovered first the ideal diameter for the hole which holds an artillery spring—for a catapult, say—due to a large subsidy "because they had ambitious kings who loved craftmanship" (διὰ τὸ φιλοδόξων καὶ φιλοτέχνων ἐπειλῆφθαι βασιλέων, Philo *Belo*. 50.25–6). See Marsden 1971, 156–7. Philo here and Eratosthenes' letter appear to influence similar sentiments about the Ptolemies' care for skill and ambition found in the *Letter of Aristeas* (chapters 51–6 and 79–82), a second century B.C.E. text about the translation of the Pentateuch from Hebrew into Greek. I intend to explore these ideas elsewhere.

of "fineness" or "thinness," of accuracy, and of "art" or "skill"—is also part of the Hellenistic critical vocabulary of poetry, and their cognates are often found in relation to ekphrastic epigrams on works of art;[75] the handling of the mechanism is to be done almost in the manner of Hellenistic aesthetics, an aesthetics of poetry as much as of material.

Whereas traditionally these terms of "fineness" and "accuracy" were seen to relate to a Hellenistic literary rejection of grandeur, as seen most emblematically in Callimachus' *Reply to the Telchines* (23–4),[76] recent scholars have produced a more nuanced view of epigram's application of these ideas. Porter 2011, 285, in particular, has argued that an aesthetics of smallness is only one side of the story, and that in fact many epigrams involve an "organized aesthetics of *contrastive opposites*"; Hellenistic poetic skill is about capturing big themes in small compositions. This Hellenistic "poetics of scale" has subsequently allowed for the unlocking of numerous works' operations; Squire 2011, Ch. 6, has fruitfully applied this to representations of Homeric epic in image and text, and I have recently argued (2015, 215–9) for a similar play with scale in another Hellenistic mathematical poem, Archimedes' *Cattle Problem*. Turning from Eratosthenes' description in the letter of how to operate the mechanism, to the epigram's description of the same, the Hellenistic aesthetic touch required to operate the mechanism is followed by an emphatic claim expressed through "contrastive opposites." It is worth considering Eratosthenes' declaration—τοῖσδε γὰρ ἐν πινάκεσσι μεσόγραφα μυρία τεύχοις /ῥεῖά κεν ἐκ παύρου πυθμένος ἀρχόμενος ("By these plates, indeed, you may easily fashion—starting from a small base—even thousands of means," 11–2)—not only as characterising the amazing operations of the mechanism through a poetics of scale, but as a claim which encapsulates the production of the epigram, its relationship to the letter, and the symbolic significance of Eratosthenes' solution as presented in the text.

Most immediately, a contrastive opposition of size, a poetics of scale, informs the text as a whole, since the structure of the epigram is writ large in the structure of the letter; the Academic history of the solution, its applicability for the architectural as well as the everyday, and an address

[75] For *leptotes*, the idea of things being λεπτός ("fine"), see Aratus 783–7 and the epigrammatic response of Callimachus and Leonidas (see above) with Cameron 1995, 321–8. For ἀκρίβεια ("accuracy"), cf. Hunter 2003b, with many texts discussed. For τεχνή ("skill"), see Callimachus fr. 1.23–4 Harder with discussion in Fantuzzi and Hunter 2004, 66–76. For the particular use of these terms in ekphrastic epigrams, cf. Squire 2011, 247–8, with the most up-to-date bibliography for each critical term, too.

[76] There is large bibliography on this. To start, see Gutzwiller 2007, 30–6.

to the ruling Ptolemies, all find correspondences. Moreover, Eratosthenes sets the final citation of the epigram in response to the opening tragic quotation: the fragment about a monumental object has been reworked into a text inscribed *on*, or indeed *as*, a monumental object. The interrelation operates even on the verbal level. The epigram's initial suggestion that a μάνδρα (lit. "cattle enclosure," "fold") could be constructed keys into the σηκός of the quotation, a "pen" or "animal enclosure" as well as a "precinct" or "sacred enclosure."[77] A generic nod can also be detected in Eratosthenes' address to Ptolemy with εὐαίων, a markedly tragic exclamation sending the reader back to the initial scene of royal misfortune.[78] The reported speech embedded within the epigram—λέγοι δέ τις ἄνθεμα λεύσσων/τοῦ Κυρηναίου τοῦτ' Ἐρατοσθένεος ("may anyone who sees this dedication say 'it is Eratosthenes of Cyrene's.'" 17–8)—then takes on further resonance, offering a rather different exclamation from the initial tragic scene. A "cry" of authorship, it signals what, or rather whom, Minos was missing. These correspondences between the epigram and the letter, importantly, make Eratosthenes' textual manoeuvres comparable to the operations of the device itself. The ability to enlarge or miniaturise while maintaining the proportions, is a literary as well as a mechanical Hellenistic trend.

As well as the relationship between the epigram and letter in literary terms embodying the function of the device in mechanical terms, the text stands as a testament to the skill with which Eratosthenes handles the resources of the Alexandrian Library and Museum. The text's very generic hybridity reflects the intellectual processes at work in Alexandria, the absorption of sources which are then redeployed in line with the cultural programme of the Ptolemies. Eratosthenes' letter has made use of resources from many areas of study: research on tragedy (an early focus of the scholars),[79] history and biography,[80] and mathematics.[81] These aspects of the intellectual project of the Library and Museum ultimately coalesce in Eratosthenes' text, in resolving a problem which has practical

[77] I thank Gary Vos for this observation.

[78] Particularly lyric, e.g. Euripides *Ion*. 126, *Iph.Aul.* 550. It was also a favourite of Callimachus, Hymns 4.292 and 5.117. This may be a watch-word of political significance since the adjective elsewhere in Callimachus refers to Berenice (15.3 *HE*) and is also applied to Ptolemy Philopator in an anonymous, roughly contemporary epigram (*SH* 979.2).

[79] Cf. Fraser 1972.1, 618–21, and for comedy and its relation to tragedy, with an outline of Eratosthenes' role, see Lowe 2013. Strecker 1884 is still fundamental on Eratosthenes' work *On Old Comedy*.

[80] Such works were numerous but are now fragmentary, cf. e.g. Momigliano 1993, 65–92.

[81] Fraser 1972, 2, 376–446, and Netz 2009, *passim*.

ramifications for the mechanics of empire. The request, though apocryphal, that Ptolemy wanted a shorter route (ὁδὸς συντομωτέρα, *In Euc.* p.68.15 Freidlein) to geometry than Euclid's *Elements* finds a response in Eratosthenes' letter when he describes the proof on the *stele*: ἡ ἀπόδειξις συντομώτερον φραζομένη ("the proof is more concisely phrased," 110.15 H). While this technically refers to the proof, the epigram as the genre typically characterised as purposefully short and able to encapsulate themes in only a few lines also provides a more concise explanation.[82] It too offers a short-cut, condensing not only the mathematics, but a history of the problem, its importance as a solution, and the identity of Eratosthenes and his patron. The literary skill of writing about science is part of the mechanics of this text, and it is through this that the work of the Museum and Library is compressed into Eratosthenes' letter, which is condensed still further into the epigram.

In short, by concluding the letter, encapsulating the history of the mechanism and his own solution, Eratosthenes' epigram stands as an enduring monument to his skill, perhaps in the landscape as well as on the page, but also as an enactment of it. In concluding this section, I want to make a tentative suggestion which ties the operating of the plates more closely to the Ptolemaic library project. Key for the mechanism's condensing or expanding are the plates (πινάκισκοι), which enable the sliding of dimensions proportionally from the small to the large or *vice versa*. In the epigram, significantly, Eratosthenes employs instead πίναξ, and in the plural πίνακες. In third-century Alexandrian literary circles, the mention of πίνακες could bring to mind Callimachus' archival work and his production of a roster of all texts within the Library, the *Pinakes*.[83] An allusion by Eratosthenes, the third head of the Library and a supposed student of Callimachus, is quite possible and the echoes of Callimachus' works in Eratosthenes' poem strengthen the case.[84] Eratosthenes' allusion would be playful, but the point could be serious. Callimachus' *Pinakes* are a textual manifestation of the literature flowing into, and being seized for, the Library, and it being processed by the scholars in the Museum. The *Pinakes* enabled an increasing mastery over Greek literary culture

[82] See, for example, Callimachus' playful epigram 35 *HE*. For a full round up of the themes of "the grand in the small" in epigram—in Greek *and* Latin—see Squire 2011, 274–83.

[83] Blum 1991, 124–81 and *passim*; Pfeiffer 1968, 128–34.

[84] Eratosthenes may not have been his actual student, but they would certainly have known each other. Blum 1991, 124–33; Geus 2002, 18–26. See also Athenaeus' punning use of *pinakes* to denote both the dishes and the texts which circulate in the *Dinner-sophists* with Jacob 2013, 45.

and the production of works informed by a greater body of literature at hand, and were no doubt utilized by Eratosthenes in his geographical, chronological, philosophical and mathematical studies. Eratosthenes alludes to the origin of his plates—enlarging the physical matter of the Ptolemaic empire from a small base (ἐκ παύρου πυθμένος)—as indebted to Callimachus' *Pinakes* which catalogued and miniaturised the Library's content and enabled countless further works; the ambitious Ptolemaic project of compression which the *Pinakes* represent has led to Eratosthenes' project of Ptolemaic expansion.

CONCLUSION

For most readers, the text offers a glimpse of the inner workings of the Ptolemaic dynasty and how diverse aspects of the cultural project fit together to produce a device with an impact on the practicalities of life: a mobile transcript of the various cultural and scientific projects of empire packaged within a letter. So too, they may be impressed by Eratosthenes' carnival of learning as he recalls the history of the problem, provides a solution, then commemorates it with an epigram, all with generic versatility. Addressed and presented to Ptolemy, though, the text documents the pay-off of investment in his research centre, and presents the solution as resolving perennial kingly concerns—extending and increasing power both materially, and temporally through the succession of a dynasty. Likewise, Eratosthenes figures himself as the inheritor of an intellectual tradition with origins in fifth-century Athens, something which the letter would broadcast far, and which his epigram would situate firmly in the Alexandrian landscape. Eratosthenes does not simply place in Ptolemy's hands a mathematical solution, a mechanical invention, or a tool of expansion and succession. He hands the king—and indeed any reader—an image of the capital's potential and the potential of cultural capital. On opening up the letter, Eratosthenes takes hold of tradition and places in the reader's hands a mobile message encapsulating the mechanics of empire.[85]

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