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Technical Terminology in Greco-Roman Treatises on Artillery Construction

Mark J. Schiefsky

1. Introduction

This paper is concerned with the technical terminology of a well-developed ancient art or τέχνη, the building of artillery engines. By technical terminology I mean the specific terms or phrases used by practitioners of an art or τέχνη in connection with their professional activity. For my purposes in this paper, a term or phrase qualifies as a technical term if there is good reason to think that it was used in a reasonably standardized way by practitioners of a given τέχνη to refer to objects, concepts, or procedures connected with that τέχνη. My primary aim is to consider technical terminology in relation to the knowledge that practitioners possessed and utilized in their professional activity.

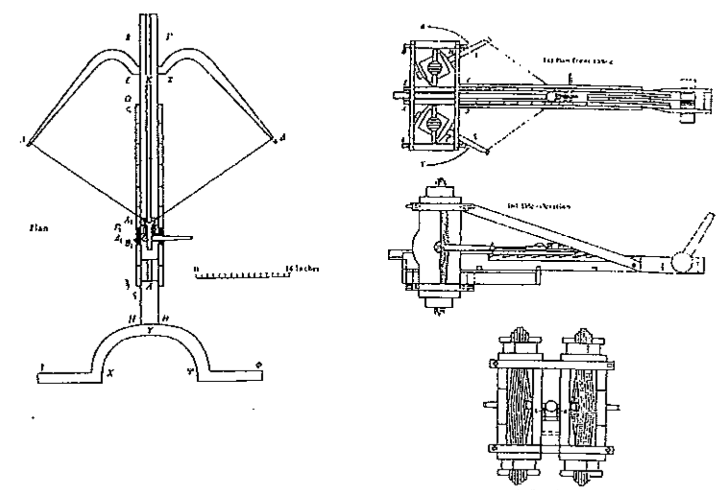

Figure 1: Non-torsion and torsion artillery (Marsden 1971: 47, 56)

I begin with a brief description of the technical tradition reflected in the ancient texts on artillery construction (cf. Marsden 1969; Landels 1978: 99-132). While the use of the bow can be documented from the beginnings of Greek civilization, the invention of artillery engines may plausibly be dated to 399 B.C., when the tyrant Dionysius of Syracuse brought together a large number of craftsmen with the specific goal of developing new military technology (Diodorus Siculus 14.41; Marsden 1969: 48-64). The earliest artillery was based on the idea of extending the power of the traditional bow, as in the so-called "belly-bow" or γαστραφέτης (figure 1, left). This could be drawn back by resting the curved beam (marked ΤΧΥΨΦ in the figure) against the belly; once ready, the bow would remain locked in position until the string was released by a sophisticated trigger mechanism. At some point in the mid-fourth century B.C. it was realized that the resilient properties of animal sinew or hair could provide much more power than the traditional bow. A typical example of this type of artillery engine (known as torsion artillery) is shown in figure 1 on the right. Long strands of animal sinew were wound through the frame, and the arms of the engine were thrust into the bundles of strands (see especially the front elevation "c" in figure 1). The pull-back and trigger mechanisms were similar to those of the γαστραφέτης, but had to be stronger because of the greater forces involved. After its invention in the mid-fourth century B.C., torsion artillery spread rapidly through the Mediterranean world, and remained standard well into the Roman empire. Within torsion artillery, two types of engines were distinguished: the straight-shooting engines or euthytones (εὐθύτονοι), and "back-turned", "V-spring" engines or palintones (παλίντονοι). As illustrated in figure 2, these names were based on resemblance to the shapes of two different kinds of standard bow. The key difference between them was that the arms in palintone engines could be pulled back farther, making them more powerful. For this reason euthytones could shoot arrows only, whereas palintones could shoot both arrows and stones.

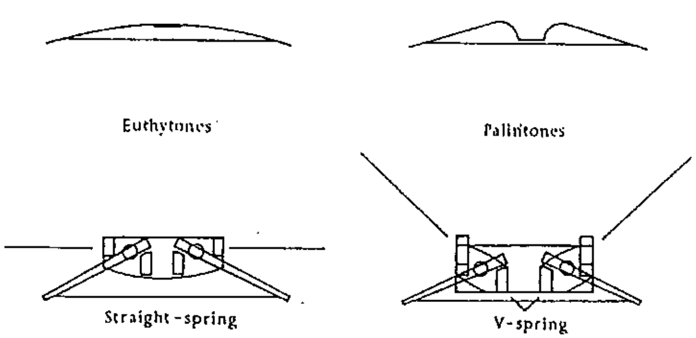

Figure 2: Euthytones and palintones (Marsden 1971: 45)

The construction of both torsion and non-torsion artillery depended on the existence of practitioners with highly specialized skills and knowledge. In particular, two types of information were of crucial importance. First, lists of dimensions were given, specifying the precise size of all components of an artillery engine down to the smallest detail. In the case of torsion artillery, the fundamental unit in which these dimensions were specified was the diameter of the hole through which the spring cords were strung. A larger hole meant a larger spring and thus a more powerful engine. Second, precise quantitative relationships were set out, correlating the size of the stone or the length of the arrow the engine was designed to shoot with the diameter of the spring hole. In the case of arrow-throwing engines, the diameter of the hole was specified as one-ninth the length of the arrow. For stone-throwers a much more complicated formula was developed: the diameter of the hole was obtained by taking the cube root of the weight of the shot, then adding one-tenth of that root. According to Philon of Byzantium, an important source to whom I will return below, these calibration formulae were discovered in Ptolemaic Alexandria as the result of an extensive program of systematic investigation and experimentation fostered by royal patronage.[1]

How was this knowledge transmitted? Oral instruction was no doubt of great importance. Philon's remarks about the patronage of the Alexandrian kings suggest a thriving community of researchers in close contact with one another; Rhodes too was an important center for the development of military technology.[2] But written texts also played an important role in the standardization and dissemination of the technical knowledge of artillery construction.[3] Three sources in particular provide extensive information about the technical terminology employed in the discipline: two treatises by Heron of Alexandria and Philon of Byzantium (both entitled *Belopoeica*), and three chapters of the tenth book of Vitruvius' *De architectura* (10-12). In what follows I shall consider each of these sources in turn, with special emphasis on their treatment of

1 Philon, *Bel.* 50.24-26: τοῦτο δὲ συμβαίνει ποιῆσαι τοὺς ἐν Ἀλεξανδρείᾳ τεχνίτας πρώτους μεγάλην ἐσχηκότας χορηγίαν διὰ τὸ φιλοδόξων καὶ φιλοτέχνων ἐπειλῆφθαι βασιλέων. In the following all references to Heron and Philon are to the text of Marsden's edition (1971).

2 Cf. Philon's remarks (*Bel.* 51.10-14) that the construction methods he reports in the *Belopoeica* are based on personal association with engineers in both Alexandria and Rhodes: ἱστορήσομεν οὖν σοι, καθότι καὶ αὐτοὶ παρειλήφαμεν ἔν τε Ἀλεξανδρείᾳ συσταθέντες ἐπὶ πλεῖον τοῖς περὶ τὰ τοιαῦτα καταγινομένοις τεχνίταις, καὶ ἐν Ῥόδῳ γνωσθέντες οὐκ ὀλίγοις ἀρχιτέκτοσι καὶ παρὰ τούτοις κατανοήσαντες τὰ μάλιστα τῶν ὀργάνων εὐδοκιμοῦντα σύνεγγυς πίπτοντα τῇ μελλούσῃ μεθόδῳ λέγεσθαι οὕτως. For other references to the oral transmission of knowledge in Philon's *Belopoeica* see 68.1-2, 72.24-6. Cf. also *Bel.* 67.30, where Philon indicates that the constructional details of the bronze-spring engine invented by Ctesibius had not been "passed on" to his time: τῆς δὲ κατασκευῆς οὔπω διαδεδομένης.

3 Both Heron (*Bel.* 73.6-11) and Philon (*Bel.* 49.4-11) refer to numerous writers on the topic of artillery construction, without mentioning any by name.

technical terminology. How self-conscious are these authors about the technical character of the terminology that they use, and what can we infer from this about the audiences for which their texts are intended? What information do these texts provide about the range of this terminology, the degree to which it was standardized, and the way in which it developed? I shall conclude with some brief remarks on the relationship between technical terminology and technological and scientific development.

2. Heron of Alexandria

Heron of Alexandria's *Belopoeica*, probably written in the first century A.D., describes the construction of various kinds of non-torsion and torsion artillery. These descriptions are set in the context of an account of how the latter developed out of the former as a response to difficulties arising from the need to achieve ever more powerful impact and longer range. A number of considerations indicate that the text's intended audience was not limited to practitioners of artillery construction. The *Belopoeica* opens with a striking passage arguing that the study of mechanics in general, and especially the branch of it known as artillery construction (βελοποιία), can provide the tranquility (ἀταραξία) that was the ultimate goal of philosophical study (*Bel.* 71.1-73.5).[4] Heron then goes on to take issue with predecessors who allegedly wrote only for those with extensive knowledge of the subject (*Bel.* 73.6-74.4):

> Ἐπεὶ οὖν οἱ πρὸ ἡμῶν πλείστας μὲν ἀναγραφὰς περὶ βελοποιικῶν ἐποιήσαντο, μέτρα καὶ διαθέσεις ἀναγραψάμενοι, οὐδὲ εἷς δὲ αὐτῶν οὔτε τὰς κατασκευὰς τῶν ὀργάνων ἐκτίθεται κατὰ τρόπον οὔτε τὰς τούτων χρήσεις, ἀλλ' ὥσπερ γινώσκουσι πᾶσι τὴν ἀναγραφὴν ἐποιήσαντο, καλῶς ἔχειν ὑπολαμβάνομεν ἐξ αὐτῶν τε ἀναλαβεῖν καὶ ἐμφανίσαι περὶ τῶν ὀργάνων τῶν ἐν τῇ βελοποιίᾳ, ὡς μηδὲ ἴσως ὑπαρχόντων, ὅπως πᾶσιν εὐπαρακολούθητος γένηται ἡ παράδοσις. ἐροῦμεν οὖν περὶ κατασκευῆς τῶν ὅλων τε καὶ τῶν ἐν αὐτοῖς κατὰ μέρος τοῖς ὀργάνοις, καὶ περὶ τῶν ὀνομάτων, καὶ περὶ τῆς συνθέσεως αὐτῶν καὶ ἐξαρτίσεως, ἔτι δὲ καὶ περὶ τῆς ἑκάστου χρείας καὶ μέτρων, προειπόντες περὶ τῆς τῶν ὀργάνων διαφορᾶς καὶ ὡς τὴν ἀρχὴν ἕκαστον αὐτῶν προεβιβάσθη.

4 While the sentiment *si vis pacem, para bellum* is a commonplace in ancient writings on military technology (Marsden 1971: 44), the opening of the *Belopoeica* is far more radical, in that it not only claims that mechanics is *superior* to philosophy, but also attempts to appropriate the term φιλοσοφία itself (72.3-8): μηχανικὴ δὲ ὑπερβᾶσα τὴν διὰ τῶν λόγων περὶ ταύτης διδασκαλίαν ἐδίδαξε πάντας ἀνθρώπους ἀταράχως ζῆν ἐπίστασθαι δι' ἑνὸς καὶ ἐλαχίστου μέρους αὐτῆς, λέγω δὴ τοῦ κατὰ τὴν καλουμένην βελοποιίαν, δι' ἧς οὔτε ἐν εἰρηνικῇ καταστάσει ταραχθήσονταί ποτε ἐχθρῶν καὶ πολεμίων ἐπανόδοις, οὔτε ἐνστάντος πολέμου ταραχθήσονταί ποτε τῇ παραδιδομένῃ ὑπ' αὐτῆς διὰ τῶν ὀργάνων φιλοσοφίᾳ.

> Writers before me have composed numerous treatises on artillery dealing with measurements and designs; but not one of them describes the construction of the engines in due order, or their uses; in fact, they apparently wrote exclusively for experts. Thus I consider it expedient to supplement their work, and to describe artillery engines, even perhaps those out of date, in such a way that my account may be easily followed by everyone. I shall speak about the construction of complete engines and the individual parts thereof, about nomenclature, composition, cord-fitting, and, furthermore, their individual use and measurements – after first remarking on the difference between the engines and the original development of each engine. (Translation: Marsden 1971)

The deficiencies criticized here are partly a matter of content (discussion limited to "measurements" and "designs"), partly of form or mode of expression (lack of an orderly, methodical, and clear exposition). In contrast to these authors, Heron promises a discussion of the construction, use, and terminology of the various engines that will present the subject in a way that is clear to anyone. The concern with nomenclature is signaled throughout the text by the frequent use of the verb καλέω to mark technical terminology (Fögen 2003: 45). Often Heron describes the construction of a component of an artillery engine in general terms, and only then indicates that it is "called" such and such, viz. by the practitioners of the τέχνη itself.[5] Moreover, in keeping with the criticisms made in the above passage, Heron refrains from giving specific dimensions for the various parts of the engines that he describes. Such dimensional lists, as noted above, were central to the technical tradition of artillery construction and are an important feature of both Philon's and Vitruvius' accounts. But they are irrelevant if the goal is to communicate the general methods and terminology of the discipline. Finally, as the passage above suggests, there is good reason to suppose that the *Belopoeica* reflects the technological level of a time several centuries before Heron's own (Marsden 1971: 1-2); again this is understandable if the text is intended to communicate general principles rather than the latest in specialized design. A clear contrast with the *Belopoeica* in this regard is provided by another of Heron's treatises, the *Cheiroballistra*, which is indeed subject to many of the criticisms leveled in the above passage (Marsden 1971: 206-233). It describes the construction of a piece of artillery that was probably quite up to date in Heron's time, including precise specifications of dimensions, but in a way that could hardly be understood

5 For a typical example see *Bel.* 77.7-78.4, after the description of the construction of the γαστραφέτης (figure 1, left): ἐκάλουν δὲ τὸν μὲν ΕΖΗΘ κανόνα σύριγγα, διώστραν δὲ τὸν ἐπικείμενον αὐτῷ κανόνα· τὸ δὲ δεχόμενον τὸ βέλος κοίλασμα ἐπιτοξίτιδα· τὸ δὲ μεταξὺ τῶν ΞΟ μέρος τοῦ ἐπικειμένου κανόνος χελώνιον (ἦν γὰρ καὶ ὑψηλότερον τοῦ ἐπικειμένου κανόνος)· τὸν δὲ ΝΞΟ δάκτυλον χεῖρα· τὰ δὲ εἰρημένα στημάτια κατοχεῖς· τὸ δὲ ΠΡ κανόνιον σχαστηρίαν· τὸν δὲ ΤΥΦΧΨ κανόνα καταγωγίδα· τὰ δὲ ΑΒ, ΓΔ ἄκρα τοῦ τόξου ἀγκῶνας. See also *Bel.* 81.1-2, 83.3-5, 89.2-5, 93.7, 97.10, 99.10-100.1, 100.5-7, 101.7.

without extensive familiarity with both the methods and terminology of artillery construction.[6]

Heron provides extensive evidence of a specialized terminology for the different types of artillery engines (both torsion and non-torsion) and their parts. A sample of these terms, most of which are marked by the presence of καλέω in the text, is given in table 1 below. The range and detail of this terminology is striking. In the case of non-torsion engines, Heron's terminology covers not just large-scale components such as the case (σῦριγξ) and slider (δίωστρα), but also fine details such as the χείρ or "claw", a part of the trigger mechanism, and κατακλείς or "clicker", a key component of the pull-back system. For torsion engines, we have a whole series of terms connected with the spring or τόνος and its frame or πλινθίον, such as περίτρητον or "hole-carrier" (the part of the frame containing the holes through which the spring cords passed), παραστάτης or "side-stanchion" and ἀντιστάτης or "counter-stanchion" (the vertical supports holding the two hole-carriers together), ἐπιζυγίς or "tightening-bar" (an iron rod placed over the holes to hold the springs in place and to tighten them when necessary), χοινικίς (washer placed under the tightening bars), and ὑπόθεμα (a strengthening plate placed between the washer and hole-carrier). A further series of terms concerns the base or βάσις of the engine: these include τράπεζα "table", κλιμακίς "ladder", ἀντηρείδιον "stay", ἀναπαυστηρία "rest", and the καρχήσιον or "universal joint" on which the case of the engine was mounted. Finally we have a series of terms connected with the stretching of the spring cords, a crucial procedure in the construction and use of a torsion engine: ἐντόνιον "stretcher" (a machine to perform the initial stretching of the springs), ἐξάρτησις "stretching" (the initial stretching itself), περιστομίς ("clip" used in the stretching procedure), and ἐπιστροφή ("extra twist" given to the spring cords to retighten them after some use).

A. Non-torsion artillery:

γαστραφέτης	belly-bow
σῦριγξ	case
δίωστρα	slider
ἐπιτοξῖτις	groove
ἀγκών	arm
χελώνιον	block
χείρ	claw
κατοχεύς	holder
σχαστηρία	trigger
καταγωγίς	withdrawal-rest
κατακλείς	clicker

B. Torsion artillery:

εὐθύτονον	straight-spring engine (also called σκορπίος)
παλίντονον	V-spring engine (also called λιθόβολος)
πλινθίον	frame
τόνος	spring; also called ἐνάτονος, ἡμιτόνιον
χοινικίς	washer
ἐπιζυγίς	tightening-bar
βάσις	base
καρχήσιον	universal joint
ἀντηρείδιον	stay
ἀναπαυστηρία	rest
παραστάτης	side-stanchion
ἀντιστάτης	counter-stanchion; μεσοστάτης for euthytones
περίτρητον	hole-carrier
ὑπόθεμα	strengthening plate placed under washer
ὑποπτερνίς	heel-pad
τριβεύς	flange
τράπεζα	table
κλιμακίς	ladder
ἐντόνιον	stretcher (machine for stretching spring cords)
περιστομίς	clip (used in stretching spring cords)
ἐξάρτησις	initial stretching of spring cords
ἐπιστροφή	supplemental stretching by twisting

Table 1: Heron's terminology.

6 Marsden (1971: 208-209) draws attention to the similarity between Heron's *cheiroballistra* and the artillery engines depicted on the Column of Trajan.

Heron's terminology includes a number of everyday words with a particular specialized meaning, such as χείρ "claw", τράπεζα "table", and κλιμακίς "ladder". On the other hand, some terms are new coinages that have no relevance outside the field of artillery construction. The term περίτρητον ("hole-carrier") is a case in point. Again, this refers to the beams on the top and bottom of the wooden frame that contained the holes through which the spring cords passed. As Hermann Diels was the first to suggest, the term περίτρητον is connected to the shape of the part to which it refers: in the hole-carrier, the main hole or τρῆμα was surrounded by a ring of smaller holes into which the washer was fitted; hence the name περίτρητον, "holes around".[7] Terms such as περίτρητον provide clear evidence of the importance of technological development in stimulating the creation of technical terminology: the new objects created in a τέχνη called for new, specialized names.[8] Heron sometimes remarks on the ways in which new terms were coined: euthytone engines, he says, are also called scorpions (σκορπίους) "from the similarity of shape" (*Bel.* 74.6: ἀπὸ τῆς περὶ τὸ σχῆμα ὁμοιότητος), and the γαστραφέτης or "belly-bow" got its name from the method used to draw it back, by resting it against the belly (*Bel.* 81.1-2: ἐπειδήπερ διὰ τῆς γαστρὸς ἡ καταγωγὴ τῆς τοξίτιδος ἐγίγνετο).[9] Finally, we may note that Heron draws attention to a certain amount of variation in the usage of particular terms; thus he remarks that some people call the single spring of a torsion engine τόνος, while others refer to it as ἐνάτονος or ἡμιτόνιον.[10] But despite such variation, the overall picture conveyed by Heron's *Belopoeica* is of a stable terminology precisely matched to the fine detail and complexity of its subject matter.

3. Philon of Byzantium

Philon of Byzantium's *Belopoeica*, which probably dates from the late third century B.C., originally made up the fourth book of an eight-book compendium of mechanical knowledge, the μηχανικὴ σύνταξις.[11] Like Heron, Philon takes issue with previous writers on the subject at the opening of his work (*Bel.* 49.4-11):

> εἰ μὲν οὖν συνέβαινεν ὁμοίᾳ μεθόδῳ κεχρῆσθαι πάντας τοὺς πρότερον πεπραγματευμένους περὶ τοῦ μέρους τούτου, τάχα ἂν οὐθενὸς ἄλλου προσεδεόμεθα πλὴν τοῦ τὰς συντάξεις τῶν ὀργάνων ὁμολόγους οὔσας ἐμφανίζειν. ἐπεὶ δὲ διενηνεγμένους ὁρῶμεν οὐ μόνον ἐν ταῖς πρὸς ἄλληλα τῶν μερῶν ἀναλογίαις, ἀλλὰ καὶ ἐν τῷ πρώτῳ καὶ ἡγουμένῳ στοιχείῳ, λέγω δὲ τῷ τὸν τόνον μέλλοντι δέχεσθαι τρήματι, καλῶς ἔχον ἐστὶ περὶ μὲν τῶν ἀρχαίων παρεῖναι, τὰς δὲ τῶν ὕστερον παραδεδομένας μεθόδους δυναμένας ἐπὶ τῶν ἔργων τὰ δέοντα ποιήσειν ταύτας ἐμφανίζειν.
>
> Had it been the case that all who previously dealt with this section [sc. of mechanics] used the same method, we should have required nothing else, perhaps, except a description of the artillery designs which were standard. But, since we see that they [sc. previous writers] differ not only in the proportions of interrelated parts, but also in the prime, guiding factor, I mean the hole that is to receive the spring, it is only right to ignore old authors and to explain those methods of later exponents that can achieve the requisite effect in practice. (Translation: Marsden 1971)

Whereas Heron's stated purpose in the *Belopoeica* is to explain the procedures and terminology involved in the discipline of artillery construction to a reader not yet familiar with them, Philon is motivated by the need to resolve the disagreement among his predecessors and to present a method that will enable a practitioner to attain a successful result.[12] After some remarks on the discovery of the fact that the diameter of the spring hole is the "prime, guiding factor" (*Bel.* 49.8: τὸ πρῶτον καὶ ἡγούμενον στοιχεῖον) in artillery construction, Philon goes on to give an account of the construction of standard-design torsion artillery of the sort that Heron describes; as noted above (n. 2), this account is explicitly based on personal association with engineers in both Alexandria and Rhodes. Philon begins with the method of calculating the size of the spring hole using the calibration formulae, then goes on to explain in detail the construction of the various parts of a torsion engine; he includes a complete dimensional list specifying the size of each part in units of the diameter of the spring hole (*Bel.* 53.8-55.11). In the rest of the treatise (from *Bel.* 56.8 on) Philon makes a number of criticisms of standard torsion artillery and discusses several alternative designs, some of which he claims to have developed himself. Unlike Heron, Philon shows little concern to explain the terminology of artillery construction; rather, he seems to presuppose that his readers are already familiar with it. This suggests that his *Belopoeica* is intended for a somewhat more specialized audience that Heron's – an impression confirmed by the presence of a table correlating the weight of shot of a stone-throwing engine with the diameter of the spring hole for a number of commonly used weights (*Bel.* 51.15-27). Such a

7 Marsden (1971: 52-53); Diels (1924: 101-103). Cf. Heron, *Bel.* 96.2-3: ἐπεὶ οὖν τὸ περίτρητον ἀσθενὲς ὑπάρχει διὰ τὸ πάντη ἐκτετρῆσθαι [...].

8 For a similar new coinage cf. ὑποπτερνίς, which referred to a small pad placed under the πτέρνα, the heel or butt-end of the arm (ἀγκών) of a torsion engine (*Bel.* 93.6-7).

9 Cf. *Bel.* 74.7-8: τὰ δὲ παλίντονα ἔνιοι καὶ λιθοβόλα καλοῦσι διὰ τὸ λίθους ἐξαποστέλλειν. Cf. also *Bel.* 101.7, where Heron remarks that the name πτέρυξ "wing" was given to a complete torsion engine; Marsden (1971: 55) interprets this as a nickname, and translates "protector" (cf. *LSJ*, s.v. "πτέρυξ" III).

10 *Bel.* 83.3-4: ἐκάλουν δὲ τὰ μὲν συνέχοντα τοὺς ἀγκῶνας νεῦρα τόνον· ἔνιοι δὲ ἐνάτονον· ἔνιοι δὲ ἡμιτόνιον. Cf. *Bel.* 74.7-8 (quoted in the previous note).

11 On Philon's dates see Marsden (1971: 6-8); on the contents of the μηχανικὴ σύνταξις see Marsden (1971: 156 n. 2). The *Belopoeica* is addressed to one Ariston, about whom nothing else is known (*Bel.* 49.1-4).

12 The term μέθοδος occurs some 16 times in the *Belopoeica*, and Philon repeatedly insists on the need for a method; see 50.15-17 (ταύτην δ' ἔδει μὴ ἀπὸ τύχης μηδὲ εἰκῇ λαμβάνεσθαι, μεθόδῳ δέ τινι ἑστηκυίᾳ), 52.21-2 (οὐκ εἰκῇ καταγραπτέον, ἀλλὰ καὶ τοῦτο μεθόδῳ τινί), 55.12 (δεῖ δὲ καὶ μέθοδόν τινα ὑπάρχειν), 69.26 (προσεδεῖτο δὲ ἄλλης μεθόδου). "Method" does not mean "theory": at 50.26-9 Philon insists that not everything in artillery construction can be discovered "by reason and the methods of mechanics" (τῷ λόγῳ καὶ ταῖς ἐκ τῶν μηχανικῶν μεθόδοις); some things are also discovered by testing (πεῖρα).

table would enable a practitioner to avoid the extraction of a cube root, a necessary step if the calibration formula for stone throwers is applied directly.[13]

In general Philon's terminology is quite similar to Heron's.[14] There are a number of minor differences (see table 2): cases in which Philon uses the same term as Heron in a slightly different sense (as with χελώνιον and ὑπόθεμα) or uses a different term to refer to the same thing (thus Philon's ἀπόληψις corresponds to Heron's περιστομίς, both of which mean "clip").[15] With these differences in terminology go minor differences in technique on such matters as the construction of the περίτρητον or hole-carrier (*Bel.* 52.20-53.7; cf. Heron, *Bel.* 94.1-96.5). As Marsden has suggested (1971: 9), these differences can plausibly be ascribed to Philon's association with Rhodian engineers, in contrast to Heron's presumably Alexandrian connections. But despite these differences, the overall impression conveyed by a comparison of Heron's and Philon's terminology is nonetheless one of consistency and agreement.

χελώνιον	slider (= Heron's δίωστρα)
ὑπόθεμα	strengthening plate fitting *under* hole-carrier
ἀπόληψις	clip (= Heron's περιστομίς)
καταζυγίς	under-lever (cf. Heron's ἐπιζυγίς)
ἐπιστροφή	supplemental stretching by twisting
ἡμιτόνιον	half of a torsion spring

Table 2: Philon's divergences from Heron.

The view must be qualified, however, when we come to Philon's criticisms and modifications of standard-design torsion artillery (*Bel.* 56.8-78). Here he proposes a number of significant terminological innovations in the course of an attempt to overcome certain perceived defects in the standard design. I shall consider three examples.

(1) A recurrent problem with torsion artillery was the tendency for the spring cords to slacken after continued use. This required re-tightening them, a process that was difficult to accomplish in the heat of battle. The so-called "tightening

13 Philon does, however, set out a method for what is in effect the extraction of a cube root, by solving the traditional problem of doubling the cube (*Bel.* 51.28-52.19). Heron gives a very similar method at the end of his *Belopoeica* (114.8-119.2).

14 Among the technical terms used in the same sense by Philon and Heron are: ἀγκών "arm", ἐντόνιον "stretcher", ἐπιζυγίς "tightening-bar", ἐπιτοξῖτις "groove", καρχήσιον "universal joint", κλιμακίς "ladder", παραστάτης "side-stanchion", περίτρητον "hole-carrier", πλινθίον "frame", πτέρνα "heel", σῦριγξ "case", σχαστηρία "trigger", τόνος "spring", τριβεύς "flange", τράπεζα "table", τρῆμα "hole", ὑποπτερνίς "heel-pad", χείρ "claw", and χοινικίς "washer".

15 On these differences see Marsden (1971: 161 n. 28 on χελώνιον; 160 n. 20 and 164 n. 47 on ὑπόθεμα; 164 n. 48 on ἀπόληψις).

bars" or ἐπιζυγίδες, which rested on washers on top of the hole-carrier or περίτρητον, would be used to impart a twist to the spring cord and increase its tension. Philon criticizes this procedure strongly, claiming that such a twist is contrary to the nature of animal sinew and weakens it (*Bel.* 58.7-16):

> In the heat of shooting and pulling-back, the spring experiences a slackening and needs tightening again. The range of the shooting deteriorates because of the relaxation. But those who wish to tighten it cannot apply the re-stretching vertically and in a straight line, but do it by extra-twisting (ἐπιστρέφοντας), imparting an extra-twist (ἐπιστροφή) unnaturally greater than is suitable [...]. The engine loses its springiness because the strands are huddled up into a thick spiral and the spring, becoming askew, is robbed of its natural force and liveliness through the excessive extra-twisting (ἐπιστροφή). (Translation: Marsden 1971)

Philon therefore proposes a new kind of engine in which the tightening can be accomplished by means of wedges (figure 3). In this design, the spring cord is wrapped around an "upper-lever" or ἐπιζυγίς and an "under-lever" or καταζυγίς. When it becomes slack, a wedge lying between the two levers is driven in, thus pushing them apart and increasing the tension in the springs. The term καταζυγίς is new coinage, corresponding to this technological innovation; at the same time, the term ἐπιζυγίς is redefined to mean a bar sitting on top of the wedge rather than the washer.[16]

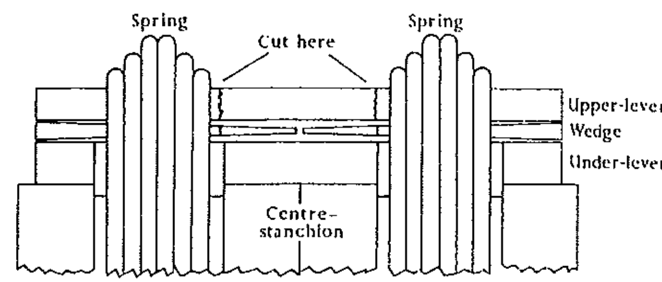

Figure 3: Detail of Philon's wedge engine (Marsden 1971: 174).

16 For the normal meaning of ἐπιζυγίς and its placement on top of the washer, see Heron, *Bel.* 83.4-11; Philon himself uses the term in this sense in discussing standard-design artillery (*Bel.* 53.23). The terminological innovation is signaled at *Bel.* 65.17. Having just explained the construction and placement of the καταζυγίδες, Philon stipulates that the bars resting on top of them are to be called ἐπιζυγίδες: καλείσθωσαν δ' ἡμῖν οἱ προειρημένοι κανόνες ἐπιζυγίδες. Somewhat earlier, at *Bel.* 60.3-4, καλεῖσθαι is again used to mark a terminological innovation: Philon remarks that "the so-called under-levers" (αἱ καλούμεναι [...] καταζυγίδες) are placed over the washers, i.e. in the place where the ἐπιζυγίδες would normally be placed. The point is clearer if we adopt Schöne's plausible emendation: μέσαι δ' ἐπ' αὐταῖς [sc. χοινικίδαις] αἱ καλούμεναι τίθενται <ἐπιζυγίδες, ἡμῖν δὲ κληθησόμεναι> καταζυγίδες σιδηραῖ.

(2) In arguing for the superiority of his wedge engine, Philon also uses the term ἐπιστροφή in a polemical manner. This is a technical term used by Heron for the "extra twist" imparted to the spring cords by turning the ἐπιζυγίδες (e.g. *Bel.* 83.5-6). Philon's claim, again, is that such a twist is unnatural, and that his own design makes it unnecessary. But at one point he claims that in his wedge engine the spring cords will receive a natural "extra-twist" (ἐπιστροφή) by means of the wedges, *even though no twisting is involved* (*Bel.* 61.6-23):

> I maintain that [...] I shall impart a very strong, natural extra-tension (ἐπιστροφή), which will be enduring throughout and can in no way fail. I maintain that, while there is a tendency in continuous shooting, as we have shown, for relaxation of the spring to occur on account of frequent pullings-back, I can produce additional stretch immediately, not by extra-twisting (ἐπιστροφή) (for we have shown this to be injurious), but by stretching naturally and vertically all the strands at once, just as they were originally stretched when the machine was being strung. That a more than suitable extra-twist (ἐπιστροφή) produces great trouble, all others agree and we have clearly proved above. (Translation: Marsden 1971)

In the first sentence of this passage, Philon extends the range of the term ἐπιστροφή to include *all* stretching of the spring cords; he then goes on to use the term in its more usual sense of "extra-twist", where this is understood as harmful and contrary to the nature of the spring cords. The effect of extending the meaning of ἐπιστροφή in this way is to forestall a possible objection, viz. that the wedge engine provides nothing like the "extra-twist" of the standard design (Marsden 1971: 169 n. 69).

(3) Finally, in discussing the so-called bronze-spring engine (χαλκότονος) of Ctesibius of Alexandria (early third century B.C.), Philon uses the term ἡμιτόνιον to refer to one half of a spring cord, rather than a single spring cord as a whole (as Heron suggests was the standard usage, *Bel.* 83.3-4).[17] Philon argues that for each arm of a torsion engine, only one of the ἡμιτόνια contributes to its movement, and that it would therefore be better if one ἡμιτόνιον could be removed. But this is impossible, since then there would be nothing to hold the arm in place (*Bel.* 69.20-30). From such considerations, Philon suggests, Ctesibius was led to the notion of employing springs constructed from bronze plates to provide the motive power to the arms. As well as being a remarkable assertion of the dependence of a technological development on theoretical considerations, this provides yet another example of the connection between technological development and shifts in terminology.[18]

17 Once again Philon also adopts the standard usage when he is not discussing a technological innovation (*Bel.* 53.17).

4. Vitruvius

In chapters 10-12 of book 10 of the *De architectura*, Vitruvius discusses the construction of two types of torsion artillery: arrow-shooting engines or *scorpiones* and stone-throwers or *ballistae*. For the former he gives the standard calibration formula: the diameter of the hole is one-ninth the length of the arrow (*De arch.* 10.10.1). In the latter case he refrains from giving the exact cube root relation, but instead provides a list correlating sizes of shot with the corresponding spring hole diameters translated into Roman units of measure (*De arch.* 10.11.3); this, he says, is to make it possible for practitioners without knowledge of geometry to construct artillery engines even in the desperate circumstances of war.[19] Vitruvius gives detailed lists of dimensions for both scorpions and *ballistae*; these are similar to Philon's, though they also reflect a number of technical improvements made in the intervening centuries (Marsden 1969: 41-47). Vitruvius claims to have knowledge of artillery both from teachers (*praeceptores*) and his own experience (*De arch.* 10.11.2); according to his own account in the preface of the *De architectura*, he served Octavian as a military engineer concerned with the construction and repair of scorpions and *ballistae*.[20] The impression that on the subject of artillery Vitruvius is writing as an expert and for experts is confirmed by the absence of any explanatory remarks on technical terminology in these chapters; they are clearly intended

18 For a further example of a technological modification based on theoretical considerations cf. *Bel.* 59.30-31, where Philon explains that in his wedge engine the spring cords "do not converge, but run parallel" (τοὺς τόνους μὴ καταλλήλους, ἀλλὰ παραλλήλους πίπτειν). The rationale for this modification depends on an elaborate analysis of the arms of the engine as levers working at a mechanical disadvantage (*Bel.* 59.11-22). The appeal to a precise distinction between κατάλληλος and παράλληλος reflects the kind of concern with terminological precision that we have noted elsewhere in Philon's text.

19 *De arch.* 10.11.2: *Itaque ut etiam qui geometricen non noverunt habeant expeditum, ne in periculo bellico cogitationibus detineantur, quae ipse faciundo certa cognovi quaeque ex parte accepi a praeceptoribus finita exponam.* Cf. *De arch.* 10.11.1: *Igitur de ratione earum* (sc. *ballistarum*) *non est omnibus expeditum, nisi qui geometricis rationibus numeros et multiplicationes habent notas.*

20 *De arch.* 10.11.2 (quoted in the previous note) and 1 *praef.* 2: *Itaque cum M. Aurelio et P. Minidio et Gn. Cornelio ad apparationem ballistarum et scorpionum reliquorumque tormentorum refectionem fui praesto et cum eis commoda accepi, quae, cum primo mihi tribuisti recognitionem, per sororis commendationem servasti.* Though Marsden (1971: 3-5) is inclined to doubt that Vitruvius' chapters on artillery are based on his personal experience, he nonetheless concludes that "Vitruvius' designs for catapults and *ballistae* were right up to date, incorporating important modifications introduced between Philon's time and his own" (1971: 5).

for a reader thoroughly familiar with the technical discourse of artillery construction.

A striking feature of Vitruvius' account of artillery is the extent to which he makes use of Greek terms without providing any gloss on their meaning or drawing attention to linguistic borrowing (table 3A). In the case of some of these terms Vitruvius' usage deviates from that of Heron and/or Philon. For example, whereas both Heron and Philon use ἐπιτοξῖτις of the "groove" in which the arrow is placed (Heron, *Bel.* 77, 79; Philon, *Bel.* 73, 75), Vitruvius uses *epitoxis* of the "claw" of a trigger-mechanism (χείρ in the Greek sources: Heron, *Bel.* 78, 100, 111; Philon, *Bel.* 68). For Vitruvius the term *carchesium* means a drum, instead of "universal joint" (καρχήσιον) as in Heron (*Bel.* 88) and Philon (*Bel.* 74). In 10.10.5 Vitruvius refers to the *posterior minor columna, quae graece dicitur* ἀντίβασις; in fact Heron had called this part ἀναπαυστηρία (*Bel.* 89).[21] Like the discrepancies between Heron's and Philon's terminology noted above, these differences probably reflect Vitruvius' association with particular engineering traditions.[22] While some of the Greek terms used by Vitruvius display a certain amount of variation in usage, this variation is not greater than that present in the Greek sources themselves. Thus Vitruvius sometimes uses *chelonium* (χελώνιον) for a small block on the trigger mechanism (so Heron, *Bel.* 77), but sometimes for the slider itself (Philon, *Bel.* 54).[23] In the case of some Greek terms Vitruvius supplies an explanatory paraphrase or gloss (table 3B). Yet even here we have a Greek term (*peritretos*) whose meaning is assumed to be familiar to the reader elsewhere in the text (*De arch.* 10.11.4), and a case in which one Greek term is used to specify the meaning of another (*De arch.* 10.11.9: *basis, quae appellatur* ἐσχάρα). In the case of *chele* and *chelonium,* Vitruvius gives a Latin gloss only for certain usages ("trigger"

21 The ἀντίβασις or ἀναπαυστηρία was a movable rod that served to regulate the inclination of the scorpion. Cf. *De arch.* 10.11.9, where *antibasis* refers to the "counter-base", or stationary piece that is placed opposite the base in a *ballista*.

22 See Marsden (1971: 4-5) on the possibility that Vitruvius' account is based on the writings of a single Greek engineer, Agesistratus.

23 Cf. *De arch.* 10.10.5, where *chelonium* refers to a small block that serves as a stop for the *posterior minor columna* or ἀντίβασις of a scorpion. Vitruvius also uses *chelonium* for similar blocks in the crane; see *De arch.* 10.2.2, 10.2.5 and Callebat & Fleury (1995: 310). The wide range of meanings is hardly surprising, since χελώνιον could be applied to anything that resembled a tortoise shell (the term's basic sense); cf. Heron, *Bel.* 93.7, where it refers to a "pad" meeting the heel of the arm, whose technical designation is ὑποπτερνίς. Similarly, the term *chele* (χηλή) has two distinct senses in Vitruvius: in the scorpion it refers to a trigger (*De arch.* 10.10.4, corresponding to σχαστηρία in the Greek sources) and in the *ballista* to the slider (*De arch.* 10.11.7b, 10.11.8). Like χελώνιον, χηλή could be used in a variety of ways, all of them connected with the basic sense of an animal's hoof or claw (Callebat & Fleury 2003: 233). For explicit indications of terminological variation in Vitruvius' account, see *De arch.* 10.10.3: *Regularum, quas nonnulli bucculas appellant* [...], and 10.10.3: *vocitatur scamillum, seu, quemadmodum nonnulli, loculamentum.*

and "pillow" or "bolster", respectively; cf. n. 23); the meaning "slider" for χηλή is assumed to be familiar to the reader at *De arch.* 10.11.7 (*Ex his dentur duae partes ei membro, quod Graeci* χηλήν *vocant*).[24] In light of this, the passages in which Vitruvius expands on the meaning of a Latin term using a phrase of the form "a, which in Greek is called β" (table 3C) are best interpreted not as attempts to clarify the meaning of Greek terminology in Latin, but rather as efforts to make the reference of the *Latin* phrase in question clear and unambiguous by giving the precise Greek equivalent. This is certainly the case with the expression *ei membro, quod Graeci* χηλήν *vocant* (*De arch.* 10.11.7); similarly in the case of *cuneoli ferrei, quos* ἐπιζυγίδας *Graeci vocant* (*De arch.* 10.12.1), we have a Greek term whose meaning is assumed to be familiar to the reader on its first occurrence earlier in the text (*De arch.* 10.11.4: *Foramen autem oblongius sit tanto quantam epizygis habet crassitudinem*). The phrase *posterior minor columna* hardly qualifies on its own as a technical term with an unambiguous reference; moreover both *scutula* and *canaliculus* are used by Vitruvius in new senses, which are made clear by their Greek equivalents (περίτρητος and σῦριγξ, respectively).[25] Naturally Vitruvius does employ a number of Latin terms without giving any Greek equivalents (table 3D). But these tend to be either straightforward translations of a corresponding Greek term (such as *foramen* for Greek τρῆμα, *mensa* for Greek τράπεζα, and *bracchium* for Greek ἀγκών), or terms whose meaning is reasonably self-evident (such as *antefixum, subiectio*, or *canalis fundus*). Thus, despite the fact that artillery had been introduced into the Roman world several centuries before the time at which Vitruvius wrote, his account suggests that its terminology remained thoroughly Greek.[26]

24 On the choice of reading here (χηλήν rather than the χελώνιον preferred by some editors, for the MSS *chelon*), see Callebat & Fleury (2003: 233).

25 Both *scutula* and *canaliculus* are classified by Callebat & Fleury (1995: 329, 334) as "mots de sens nouveau". For further examples from other Latin authors of the expression "a, which the Greeks call β", and a similar evaluation of their significance as reflecting a desire to achieve precision and clarity, see Fögen (2002: 264-265, 271).

26 Cf. the introduction to the discussion of harmonic theory at *De arch.* 5.4.1: *Harmonice autem est musica litteratura obscura et difficilis, maxime quidem quibus Graecae litterae non sunt notae. quam si volumus explicare, necesse est etiam graecis verbis uti, quod nonnulla eorum Latinas non habent appellationes.*

A. Greek terms used without explanatory gloss:

epitoxis	claw (10.10.4; Heron's χείρ)
parastata	side-stanchion (10.11.5; cf. *parastatica* in 10.10.2, 10.11.6 and *parastas media* in 10.10.2, 10.10.3)
carchesium	drum (10.10.5; cf. καρχήσιον "universal joint")
anteris	stay (10.11.9)
climacis	ladder (10.11.7-8)
pterygoma	ridge (10.11.7; Philon's πτερύγιον, *Bel.* 54.12)

B. Greek terms with explanation or gloss:

peritreti	*tabulae, quae sunt in summo et in imo capituli peritretique vocantur* (10.10.2; cf. 10.11.4)
chele	*cheles, sive manucla dicitur* (10.10.4 "trigger"; but knowledge of meaning "slider" assumed at 10.11.7: *ei membro, quod Graeci* χηλήν *vocant*)
chelonium	*supra minorem columnam chelonium, sive pulvinus dicitur* (10.10.5 "pillow", "bolster"; but no gloss at 10.10.4 "block", or 10.11.8 "slider")
anatonus	*si capitula altiora quam erit latitudo facta fuerint, quae anatona dicuntur* (10.10.6)
catatonus	*si minus altum capitulum fuerit, quod catatonum dicitur* (10.10.6)
basis	*quae appellatur* ἐσχάρα (10.11.9; cf. 10.10.4)

C. Latin terms with Greek equivalent or gloss:

cuneoli ferrei	*quos* ἐπιζυγίδας *Graeci vocant* (10.12.1; cf. 10.11.4)
canaliculus	*qui graece* σῦριγξ *dicitur* (10.10.3)
posterior minor columna	*quae graece dicitur* ἀντίβασις (10.10.5; cf. 10.11.9 for the sense "counter-base")
scutula	*quae graece* περίτρητος *appellatur* (10.11.4)

D. Latin terms without explanatory gloss:

capitulum	frame
foramen	hole
antefixum	cross-piece (10.10.4)
subiectio	stay (10.10.5; Heron's ἀντηρείδιον)
bracchium	arm
modiolus	washer
canalis fundus	slider (10.10.4)
mensa	table

Table 3: Vitruvius' terminology (*De arch.* 10.10-12).

5. Conclusion

Let me now attempt to sum up the results of this study and draw some general conclusions. First, the sources we have considered provide ample evidence of the role of technological development in stimulating the creation of technical terminology. The invention of artillery, and of torsion artillery in particular, prompted the creation of an extensive and detailed terminology that was transmitted by practitioners over several centuries both orally and in written form. Terminological developments – whether the coining of new terms such as περίτρητον or shifts in the meaning of existing terms (such as Philon's use of ἐπιστροφή or ἡμιτόνιον) – tend to be correlated with actual technological innovations or attempts to introduce them. Second, it is remarkable that, despite a certain amount of variation, the terminology of artillery construction remained relatively stable and consistent from the third century B.C. through the time of Vitruvius (cf. Marsden 1971: 157). Here there is a contrast with other fields such as medicine, where the situation down to the first century A.D. has been characterized as one "bordering on terminological anarchy".[27] The stability of the terminology of artillery construction is in part a reflection of the lack of any fundamental technological advances during the period we have considered: there was certainly no new discovery comparable to that of torsion artillery between the third century B.C. and the first century A.D. But another factor was also important: a consistent, stable terminology facilitates communication between practitioners and the transmission of knowledge, by making it possible to refer to the objects of a τέχνη in a precise way with just a single word or combination of words. Technical terminology is, above all, a means of communication, and the relative lack of variation in the terminology of artillery construction is an indication of just how useful such a means could be in the ancient world. Finally, while the sources we have considered provide ample evidence of the freedom with which Greek engineers coined new terms and gave new senses to old ones to refer to the objects and practices of their τέχνη, they do not offer any examples of the creation of *theoretical* terms, i.e. terms referring to abstract concepts or entities whose scope of reference is stipulated by precise definitions or by their role in a system of explanations. The creation of such terminology, though sometimes inspired by technological developments, was not a direct response to them; rather, it was a response to the need to communicate new concepts that had been created in a context of theoretical investi-

27 So Lloyd (1983: 163) on the development of Greek anatomical terminology down to the beginning of the second century A.D. In this case, of course, there was controversy not only about what names to give to certain structures, but also about what structures should be given names at all; see the next note.

gation.[28] For insight into the motives leading to the creation of this kind of technical terminology and its modalities we must turn to sources other than those considered in this study.[29]

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28 As an example of the use of a term drawn from the technological sphere in anatomy we may consider Herophilus' application of a the term ληνός ("vat", "press") to refer to a particular structure in the brain known as the *torcular Herophili* (Russo 2004: 150-151). As Russo remarks (2004: 153): "When Herophilus picks from the continuous and enormously complex structure that is the circulatory system those particular features that warrant a specific name (such as *calamus* or *torcular*) in view of his physiological and pathological purposes, he is creating new concepts. He is in fact inaugurating a new discipline in which not only the words but even the corresponding concepts are conscious creations". On the importance of theoretical terms in Hellenistic mathematics and science, and the ways in which they were coined, see Russo (2004: 179-185).

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Das römische Agrarhandbuch als Medium der Selbstdarstellung

Silke Diederich

Ein Fachtext, seine Form und seine Sprache haben nach modernem Anspruch objektiv und sachbezogen zu sein; die persönliche Weltanschauung des Autors hat darin nichts verloren. Doch die römischen Agrarschriftsteller Cato, Varro, Columella und Palladius waren offenbar ganz anderer Ansicht. Für sie war die Landwirtschaft, die ja für Senatoren die einzige offiziell erlaubte Einnahmequelle darstellte, ein wesentlicher Teil ihres Selbstverständnisses und ein Politikum ersten Ranges. Diese gesellschaftlichen und persönlichen Implikationen des Faches blieben nicht ohne Wirkung auf Sprache und Gestaltung der römischen Agrarhandbücher.

1. Cato

Dies läßt sich bereits bei M. Porcius Cato feststellen: Durch die militärische Expansion im 3. und 2. Jh. v. Chr. erlebte die römische Republik einen rasanten Wandel. Dabei führte der Zustrom von Beutegut, Sklaven und griechischem Fachwissen in der Landwirtschaft einen Umschwung herbei, der eine Landkonzentration in größere Höfe nach sich zog. Zugleich geraten die alten senatorischen Eliten in Legitimationsdruck: Neue Philosophien stellen die tradierten gesellschaftlichen Muster in Frage (Meißner 1999: 170); snobistische Abweichler aus den eigenen Reihen entfernen sich unter griechisch-orientalischem Einfluß immer weiter vom traditionellen römischen Lebensstil; die Schicht der Ritter, durch Krieg und Handel reich geworden, gewinnt ständig an Einfluß, zumal die *Lex Claudia* von 218 v. Chr. den Senatoren Handelsgeschäfte verbot (Kienast 1979: 27, 71-80).

Damit schlug die Stunde des *homo novus* M. Porcius Cato. In einer Epoche, in der die Wertehaltung der konservativen Führungsschicht, zu denen er gehören wollte, in Gefahr geriet, trat er als deren Retter auf. Da die Senatorenschaft sich traditionell als ein Bauernkriegertum definierte, richtete auch Cato sein Talent auf diese Gebiete, galten doch Fähigkeiten in der Gutsverwaltung als Schlüsselqualifikation für die Verwaltung öffentlicher Ämter (Kienast 1979: