Philo of Byzantium | Encyclopedia.com

(*fl*. *ca*. 250 b.c)

physics, *mechanics*, *pneumatics*.

Little is known of Philo's life. Vitruvius includes him, with Archytas, Archimedes, Ctesibius, and others, in a list of inventors,[1] while Hero of Alexandria mentions a work on an automatic theater by him[2] and Eutocius cites his work on the duplication of the cube.[3] These constitute the only references to Philo in antiquity; what else is known of him must be infered from the hints that exist in his few extant writings. These writings, are fragments of a large book on mechanics, Philo's only known work. Form reference to the bronze-spring catapult, recently invented by Ctesibius (*fl*. *ca*. 270 b.c.), it is possible to reach an approximate date for Philo's career. It is also clear that Philo was able to travel to Rhodes and Alexandria to study catapults, which suggests that he may have been wealthy, or have had a wealthy patron—perhaps his friends Arison, to whom each of the surviving books of the larger mechanics is dedicated. (Nothing else is known of Ariston, who would seem to have been a man of position and of some mathementical sophistication; in Arabic versions of the text his name is rendered as Maristun).[4] Diels states that, like Hero, Philo was a mere artisan, but he gives no reason for his opinion.[5]

Philo chose to write his textbook on mechanics, the Σύνταξις τής μηχανικής in κοινή, the vernacular common to the whole Greek-speaking world of the time. Certainly this straightforward language is better suited to his practical purpose than is the intricate Attic literary prose; the book is full of technical detail that would be of service to an architect, contractor, or—in its sections on war machines and fortifications—a general, and perhaps Ariston was one of these.

It is possible, through studying the extant parts of Philo's *Mechanics*, to surmise what the contents of the whole work must have been, especially since Philo often refers both to what he has already written and to what he intends to write. One can thus reconstruct a list of nine books:

1. Introduction

2. On the lever (Μοχλικά)

3. On the building of seaports (Λψενοποικά)

4. On catapults (Βελοποικά)

5. On pneumatics (Πνευματικά)

6. On automatics (Αὐτοματοποικά)

7. On the building of fortress (Παρασκευατικά)

8. On besigingand defending towns (Πολιορκετικά)

9. On stratagems

Of these, book 4 (the *Belopoeica*), book 5 (the *Pneumatica*), book 7 (the *Paraskeuastica*), and boook 8(the *Poliorcetica*) are extant. The Greek text exists for the *Belopoeica* and for parks of the *Paraskeuastica* and *Poliorcetica*; the *Pneumatica* was for many years known only thought a Latin translation of an Arabic verstion of the first sixteen chapters. At the beginning of the twentieth century, however, B.Carra, de Vanx found three manuscrips (one in the Bodleian Library and two in the library of Hagia Sophia), which provided a fuller Arabic text; previous to this discovery the Paraskeuastica and the Poliorcetica were together known as book 5.

Book 4, the *Belopoeica*, is concerned with the construcation of catapults. It is from this book that Philo's travels may be discovered. In chaper 3, he remarks that his application of mathematics to the building of these weapons resulted from the interest that the Alexandrian kings took in the technical arts. (This would indicate that he was in Alexandria in the time of the first Ptolemies). In chaper 4, Philo states that he has talked with catapult experts in Alexandria, and has examined catapults in Rhodes; in chaper 39, he goes on to mention that although he himself has not seen Ctesibius' bronze-spring catapult, it has

been described to him in detail by people who have. He display a great interest in experimention, and would seem to have invented improved catapults himself.

Philo gives the rules for constructing a catapult from a module derived from either the lengh of the arrow or the weight of the projectile, a method first worked out by Alexandrian technicians. Philo then approaches the problem of designing a catapult that will deliver a missile of twice the weight of one launched by another catapult; in established the module by which such a catapult should be constructed it is necessary for him to double the cube, since the respective weights of the two missiles are in the proportion of the cubes of their diameters.

This cannot be done by a Euclidean construction with ruler and compass alone; the method is to find two mean proportionals. Philo writes (chapter 7):[6] "the reduplication of the cube, which I have explained in the first Book but which I do not hesitate to write here also" (see fig.1). "Let there then be given a certain straight line. A. for which for example, we have to find the double cube; I then place the double of it, B at right angles to it, and from the other end of B 1 drew at right angles a straight line of indefinite lengh

towards Γ <and from the end of A I draw at right angles a straight line of indefinite length towards Δ>; from the angle marked Θ <to the angle marked E> I draw the staight line K, and with K as centre and K as centre and $K\Theta$ as radius I draw a half circle, which goes also through the point Z. Then I take an accurately fashioned ruler and place it so that it cuts both the straight lines, taking care that one point of it touches the angle (Z) and turing it till I get the part of the ruler from the intersection marked Γ to the part that falls on the intersection with the circle, marked $H(Z)$ to be equal to the equal to the length from the ineresection marked to that which falls on the angle marked Z. And then ΔE is the double of the cube of EZ, $\Theta\Gamma$ of that of $E\Delta$, ΘZ of that of $\Theta\Gamma$. The diameter of the circle, which has to take the spring is found in this way." Additions to the text have been made by August Brinkmann, and they are so obvious that it is possible that Phillips himself omitted them since this is just an example an application of the proof given in the first book.

Eutocius (in his commentary on Archimedes, De spaera, Book 2)[7] reviews the different ways of reduplicating the cube. He gives Hero's solution, and then proceeds to Philo's figure but with lettering of his own and adding two lines from Hero's figure from K to Δ and Z (see fig. 2).

The construction is the same as that of Philo, but Eutocius uses fewer words. When he has placed the ruler, he writes: "Let it then be assumed that the ruler has the position taken by ΔBEZ, where, as stated, ΔB is equal to EZ. I say then that $A\Delta$ and ΓZ are middle proportions to AB and $B\Gamma$.

He then gives the proof in this way: "Let us assume

that A and $Z\Gamma$ are prolonged and intersect at Θ; then it is evident that, since BA and $Z\Theta$ are parallel, the angle at Θ is right, and that the half-circle $AE\Gamma$ if it is filled out also will go through Θ. Now since ΔB and EZ are equal, $E\Delta$ by EB will be equal BZ by BE, But $E\Delta$ by ΔB is equal to ΘA by ΔA, for both are equal to the square of the tangent from Δ; but BZ by ZE is equal ΘZ by $Z\Gamma$, for both are equal to the tangent from Z; so also $\Theta\Delta$ by ΔA is equal to ΘZ by $Z\Gamma$, and from this it follows that $\Delta\Theta$ to ΘZ is equal to $B\Gamma$ to ΔA. But as $\Delta\Theta$ is to ΘZ so, is both $B\Gamma$ to ΓZ and ΔA to AB, for in the triangle $\Delta\Theta Z$ $B\Gamma$ parallel to $\Delta\Theta$, and BA is parallel to ΘZ. So then, as $B\Gamma$ to ΓZ so ΓZ to ΔA and ΔA to AB, which was to be proved."

This construction is almost the same as that of Hero; for the $B\Theta$ parallelogram is the same as that assumed in Hero's construction, and also the prolonged sides ΘA and $\Theta\Gamma$, and the ruler turned on the point B. The only difference is that (in Hero) we move the ruler around B until the lines from the middle of $A\Gamma$ that is K become equal as they are intersected by it where they reach $\Theta\Delta$ and ΘZ, as $K\Gamma$ and KZ, but here (in Philo) till ΔB becomes equal to EZ. In either construction the same thing follows, but the latter is more easy in practice, for to see that ΔB and EZ are equal can be done if the ruler is divided into equal parts, and very much more easily than by trying to find out by compasses from K if the lines from K to Δ and to Z are equal."

It appears that the first part of this construction was written by Eutocius in his own way, but the middle part, the proof, may be copied from Philo. The comparision of the two constructions is Eutocius own contribution; when the figures are drawn Hero's method is easier.

Philo goes on to describe a method of improving catapults by using wedges to tighteen the sinews. He also gives a design for a catapult with bronze spring, which he notes was inspired by the report that Ctesibius had made such a machine. Philo did not know the details of Ctesibius' catapult at the time he devised his own, and when he was able to compare the two weapons, he discovered that they were different in several respects. Philo also describes Ctesibius' airdriven catapult, and discusses an automatic catapult invented at Rhodes by a man named Dionysius, about whom nothing else is known. None of these devices is mentioned by either Vitruvius (in 25 b.c) or Hero (in a.d.62)

Philo's fifth book, the Pneumatica, begins with a series of introductory chapters that incorporate a number of examperiments almost certainly taken from Ctesibius, the founder of the science of pneumatics. These chapters were copited by Hero. The rest of the book (like Hero's work on the same subject) consists of descriptions of pneumatic toys-trick jars, inexhaustible bowls,

and other apparatus for parlor magic. Many of these were probably reconstructed or reinvented by Hero adn others.[8] All the chapters are illustrated in the extant Arabic manuscripts, but the illsutrations have never been pubilshed.

The surviving parts of books 7 and 8, the Paraskeuastica and the Poliorcetica, indicate that each book consisted of a large number of short chapters. These were considered together as one book in earlier editions of Philio's work, and may be divided into four sections, of which the first two constitute the Paraskeuastica, and the second two the *Poliorcetica*. The first section contains eighty-seven chapters devoted to the techniques of fortifying a town—constructing walls and towers, digging moats, setting up palisades, and placing chapters on provisioning a town against siege. In it Philo describes the proper construction of storerooms and lists the foodstuffs to be kept therein, together with methods for keeping stored foods fresh. He gives several recipes for "iron rations" for the besieged and recommends poisoning supplies that might otherwise be used by the enemy. He promises a full treatment of poisons in a later book (presumably one of the lost chapters of book 8). Philo also gives a list of materials and tools to be prepared or procured against a siege, and describes an optical telegraph, which employs a clepsydra as a mechanism, for maintaining communications with allies beyond the perimeter of the besieging forces.

Section 3 has seventy-five chapters, primarily devoted to a number of different ways of defending town walls against attack and to the means of defense against an attack from the sea. Philo also discusses the importance of the availability of good doctors during time of war, and states that invalids should be made certain of pensions, that the dead should be buried with honor, and that widows should be provided for.

The last section is 111 chapters long; it deals with how to lay siege to a town, how to use catapults, testudos, and other engines of war, and how to capture a town through starvation or bribery. There are also discussions of secret messages (Philo promises a more detailed discussion of this subject in a following book that is now lost) and cryptography, and an account of how to attack a town from the sea. Philo again mentions his longer treatment of poisons, this time as something that he has already written; it may therefore be assumed that this chapter is one of the missing fragments of book to[8]. He further states that he has drawn figures to illustrate all of the kinds of fortifications that he has discussed,[9] but these drawings have also been lost.

Since only fragments remain, it is impossible to judge Philo's textbook on mechanics as a whole. His thoroughness and attention to detail, however, are evident in every part that remains. He is not identical with a later Philo of Byzantium who wrote a work on the seven wonders of the world.

NOTES

1. Vitruvius, *De architectura*, VII, intro., 14

2. Hero, *Automata*, xx, 1 and 3. *Heronis Alexandrini Opera quae supersunt omina*, W. Schmid, ed I (Leipzig 1899).

3. Eutocius, in *Achimedis Opera omina cum commentariis Eutocii*, J. L. Heiberg, ed. III(Leipzig, 1915), 60.

4. B. Carra da Vaux,"L'invention de l'yydraulis," in *Revue des etudes grecques*, **21** (1908), 332–340

5. Hermann Diels,"Uber das physikalische system des Straton," in *Sitzugsberiche der Preussischen Akademie der Wissenschafen zu Berlin*, **9** (1893), 110, n. 3.

6. Philo, *Belopoeica* VII

7. Eutocius, *loc cit., n. 3 above*.

8. A. G. Drachmann, *ktesibios, Philon adn Heron*, no 4 in the series Acta Historica Scientiarmu Naturalium et Medicinalum (Copenhagen, 1948).

9. Philo, *Mechanics*, 7–8 sec. 1, ch. 87.

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