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Hero of Alexandria’s *Automata*. A Critical Edition and Translation, Including a Commentary on BOOK ONE

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Submitted in fulfilment of the requirements for the degree of Doctor of Philosophy (Ph.D.)

School of Humanities
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ABSTRACT

This thesis is a critical edition, with introduction, translation and partial commentary, of the Automata, a two-book mechanical treatise written by Hero of Alexandria (first century CE). It provides the first commentary on BOOK ONE, dealing with the construction of a mobile, as opposed to a stationary, automaton.

The preface summarises the significance, aims and limitations of the work. The opening section gives a summary of some of the conventions and abbreviations used in the thesis, and is followed by a list of figures.

The introduction provides a context for an informed reading of the text. It consists of six parts. Part One discusses the ‘Heronian question’, with particular attention to the chronology of the Automata and the Pneumatica. Part Two evaluates previous editions and translations, and summarises the main novelties of this study. Part Three assesses the manuscript tradition, including a stemmatic analysis of a large number of manuscripts. Part Four mainly discusses the various forms of the title of the treatise, which is reconstructed as Περὶ αὐτομάτων (On Automata). Greater uncertainty surrounds the heading of BOOK TWO, Περὶ στατῶν αὐτομάτων (On Stationary Automata), which may have been derived from Hero’s source, Philo of Byzantium (third-century BCE). Part Five focuses on the work itself. It starts with an overview of the structure of the text, with remarks on previous editorial practices. This is followed by a critical description of the contents of the treatise and by a discussion of the historical, literary and cultural background. This, in turn, allows for consideration of the performative context of Hero’s automata. Attention is then paid to the purpose and intended audience of the treatise, followed by an exploration of Hero’s relationship with his sources. A stylistic comparison with the Pneumatica sheds new light on Hero’s degree of originality, removing suspicions of interpolation. Finally, discussion turns to the status of the text. Internal inconsistencies are best explained as the result of incomplete authorial editing. Part Six addresses the principles of the edition.

The text, apparatus criticus and translation form the centre of the thesis. To maximise readability, the layout of the English translation mirrors the layout of the Greek text. The elucidation of the manuscript sigla and abbreviations used in the apparatus criticus precedes the text.

The commentary is mainly philological and text-critical in nature. However, it also addresses stylistic, interpretive and reconstructive issues, without failing to consider the oldest manuscript diagrams.

Following the commentary are six appendixes: (1) a concordance of editions; (2) addenda et corrigenda to Schmidt’s edition; (3) three stemmata codicum; (4) illustrations; (5) a review of Masià (2015); (6) an index of technical terms. Appendix (4) includes manuscript diagrams and reconstruction drawings of the mobile automaton. The thesis closes with a bibliography.
The *Automata*, our only extant treatise on the design and construction of ancient automata, was probably written sometime between the second half of the first century and the beginning of the second century CE by Hero of Alexandria, one of the most well-known technical and mathematical writers of antiquity. The treatise, which in all likelihood was published (posthumously?) in an incompletely revised form, is divided into two books, each devoted to a different type of automaton, one mobile (ὑπαγων) and the other stationary (στατόν). We know little about Hero’s sources, except that he drew directly on a lost treatise by the third-century BCE mechanical writer Philo of Byzantium for the second part of his work. In fact, it has been suggested that the greater portion of BOOK TWO repeats *verbatim* Philo’s earlier text,¹ and there are indications, including linguistic and stylistic differences between the two books, which tend to confirm this suggestion. Apart from this, a stylistic comparison with the *Pneumatica*, a treatise on pneumatic devices, suggests that Hero made eclectic use of multiple sources, often improving pre-existing technology.

The *Automata* is of particular importance for our understanding of both the history of science and technology and Hellenistic and Imperial entertainment culture. Thus far, scholars have tended to focus on particular aspects of the work, such as its continuities and discontinuities with mathematical prose,² the mechanisms of movement of the mobile automaton,³ or the theatrical relevance of the stationary model.⁴ However, since the appearance of Schmidt’s standard edition in 1899 (with notes, but without a commentary), very little attention has been paid to text-critical problems,⁵ and the sole English translation of the treatise, published by Murphy in 1995, is neither widely available nor unproblematic.

¹ Schöne (1891: 77).
² Cambiano (2011).
⁵ The most notable exception is the exchange on interpolations between Olivieri (1901) and Schmidt (1903).
This thesis has been undertaken as the philological component of a larger research project, ‘Hero of Alexandria and his theatrical automata’, headed by Professor Isabel Ruffell (School of Humanities, Classics) in collaboration with Dr. Euan McGookin (School of Engineering). The purpose of this project was to investigate the historical, technical and theatrical context of the treatise, the practical and technical viability of the automata (in particular, of the mobile type), and their influence on developments in Renaissance automata and robotics. As part of the project, the present thesis aims to provide a new critical edition of the text, accompanied by apparatus criticus, an English translation, a detailed introduction and a full-scale commentary on BOOK ONE. In particular, it sets out to offer a fresh interpretation of the text, giving special attention to the following aspects: (1) the language and style of Hero; (2) the nature and (philological) status of the text; (3) the manuscript tradition of the text; (4) the situation of the work within the ancient tradition of automata-making; (5) whether and how Hero’s devices functioned; (6) Hero’s degree of originality.

As with any study, this work has limitations. First, although the edition is based on the collation of a larger number of manuscripts than the previous edition, it has not been possible to access all manuscripts nor to collate all the available manuscripts fully (see further Introduction, §§3.1-2). Because of this, and in the absence of an apparatus fontium,6 no attempt has been made to use sigla for the consensus of all complete manuscripts or between groups of manuscripts. Second, the introduction does not include full discussion of the instructional mode in the treatise both because this requires a separate and detailed treatment and because there is no commentary on BOOK TWO.7 Third, the thesis does not purport to offer a technological history of the automata or to investigate the text in direct relation to broader technological discourses. Technical and technological issues are addressed in a number of places but do not constitute the main approach of the thesis.

6 This will be added at the stage of revising the thesis for publication. The need for an apparatus fontium depends on the fact that some manuscripts are fragmentary.

7 Reasons of word-count and time prevented me from writing a commentary on BOOK TWO. This is of course not to say that the text of BOOK TWO has not been studied. See my remarks in Introduction, §6.1. I intend to produce a full commentary when preparing the thesis for publication.
I would have never embarked on the study of Greek science were it not for my former supervisors, Professor Camillo Neri and Professor Valentina Garulli. My Master’s dissertation, which I defended at the University of Bologna, Italy, in November 2013, started out with the intention of investigating the whole of book fourteen of the Palatine Anthology, thus covering three different epigrammatic genres – arithmetic problems, riddles and oracles. Because of time constraints, and because of the overly ambitious scope of the project, it was agreed that I would confine my study to arithmetic epigram, a choice made all the more apropos by the structure of the book itself. All of a sudden, then, I found myself developing a particular interest in the playful side of Greek mathematics. This provided a springboard for expanding my interests and venturing into the study of Greek mechanics. I thank my former supervisors for enabling me to take the leap.

I am very grateful to The Leverhulme Trust, who funded the research project ‘Hero and his theatrical automata’ during the years 2014–2017 and without whose support this thesis could not have been undertaken.

I owe a very special debt to Professor Isabel Ruffell, who supervised my doctoral work and patiently advised on every aspect of the thesis. Without her constant encouragement, critical insight and careful guidance, this study could not have been completed in its present form. Her style of mentoring taught me many precious lessons. It challenged me to push my intellectual boundaries, clarify my arguments, and strive for logical coherence. Most of all, perhaps, it empowered me to trust my intuitions. I am also extremely thankful to my second supervisor, Professor Costas Panayotakis. He taught me the real meaning of rigor, precision and accuracy. I am very much indebted to him for showing me how to make the apparatus criticus come to speak to the reader. The presentation of the material in the section on ‘Conventions and abbreviations’ owes much to his edition of the fragments of the Roman mimographer Decimus Laberius (Panayotakis 2010).

I also wish to thank Dr. Duncan Keenan-Jones, who has participated in the experimental strand of the project and reconstructed Hero’s mobile
automaton. He kindly allowed me to access and use the reconstruction drawings of the automaton. Figs. 3, 24b and 26b are based on his work. A similar debt of gratitude goes to Riccardo Ravecca, friend and architect, who explained to me the basic conventions of architectural drawing and who drew some of the more challenging illustrations appended in the thesis (Figs. 2 and 6b).

Parts of the thesis were delivered at conferences and seminars in Glasgow, Madrid, St. Andrews and Canterbury. I am grateful for comments and suggestions received on these occasions.

I wish to express my thanks to the following libraries that provided me with reproductions of manuscripts: Biblioteca Angelica, Rome; Biblioteca Nazionale Centrale, Florence; Biblioteca Nacional de España, Madrid; Biblioteca Nazionale Marciana, Venice; Biblioteca Nazionale Universitaria di Torino, Turin; Bodleian Library, Oxford; Det Kongelige Bibliotek, Copenhagen; Herzog August Bibliothek, Wolfenbüttel; Österreichische Nationalbibliothek, Vienna; Real Biblioteca del Monasterio de El Escorial, San Lorenzo de El Escorial; Universiteitsbibliotheek van Amsterdam, Amsterdam; Veneranda Biblioteca Ambrosiana, Milan. I am also particularly grateful to the librarians of the Universiteitsbibliotheek Leiden and the Bibliothèque National de France, Paris, for granting me access to their manuscript collections.

Mr. Christopher Ashill, from the Joint Library of the Institute of Classical Studies and the Hellenic and Roman Societies, has been kind enough to send me scans of Vicente Bécares Botas’ Diccionario de terminología gramatical griega, Salamanca 1985, and I gratefully acknowledge his help.

I extend my warmest thanks to Dr. Natalia Tsoumpra, Dr. Elena Giusti and Dr. Arianna Gullo, for their friendship and support, and to all my other friends, both in Glasgow and elsewhere, who endured my anxieties and frustrations.

My last words of gratitude go to my partner Enrico and my mother Donatella, for without them I would have never made it this far. It is to them that I dedicate this thesis.
At the stage of revising the thesis I obtained copies not only of the most recent edition of Hero’s *Metrica* (Acerbi-Vitrac 2014) but also of two less frequently cited studies which deal with, or touch upon, the delicate and complex question of Hero’s date (Reinhardt 1930; Sakalis 1972). I have been unable to incorporate these studies into the present thesis. It is worth noting that, while Acerbi-Vitrac (2014: 16-22) offer a valuable discussion of the most important pieces of evidence which are generally used for dating Hero, they are overly pessimistic about the possibility of establishing a fairly secure chronology for the author. The study by Sakalis (1972: 158-60), primarily on linguistic grounds, makes Hero contemporary with Nero, thus lending further precision to Reinhardt’s (1930) previous linguistic and stylistic analysis (first century BCE/first century CE). I therefore encourage the reader to consider the opening section of the Introduction only as a preliminary foray into a much-needed reassessment of the *status quaestionis* on the chronology of Hero and his works. For discussion of the problems associated with Masià’s (2015) argument that the eclipse of *Dioptr.* ch. 35 cannot be used for dating Hero, see Appendix 5.
## CONTENTS

ABSTRACT ........................................................................................................ iv
PREFACE ........................................................................................................ v
ACKNOWLEDGMENTS ...................................................................................... vii
CAVEAT TO THE READER ............................................................................... ix
CONVENTIONS AND ABBREVIATIONS ....................................................... xii
  1. Ancient authors ....................................................................................... xii
  2. References ............................................................................................... xiv
  3. Periodical and reference works ................................................................. xiv
  4. Editions and translations .......................................................................... xvii
  5. Secondary sources .................................................................................... xix
LIST OF FIGURES ............................................................................................ xx
INTRODUCTION ............................................................................................... xxii
  1. The author ............................................................................................... xxii
  2. Editions and translations of the *Automata* ............................................ xxviii
     2.1 Editions ............................................................................................... xxix
     2.2 Translations ........................................................................................ xxxiii
     2.3 The present edition .............................................................................. xli
  3. The history of the text of the *Automata* ............................................... xlii
     3.1 List of manuscripts .............................................................................. xliii
     3.2 Schmidt’s account of the tradition ...................................................... xlvii
     3.3 Stemmatic analysis .............................................................................. l
        3.3.1 The β branch ................................................................................ li
        3.3.2 The γ branch ................................................................................ lvi
     3.4 Conclusions and future research ........................................................ lxxxiii
  4. Titles ........................................................................................................... lxxiv
     4.1 Earlier emendations .............................................................................. lxvi
     4.2 The original main title ........................................................................ lxvii
     4.3 Περὶ στατῶν αὐτομάτων ..................................................................... lxx
  5. The work ................................................................................................... lxxxi
     5.1 Internal arrangement ........................................................................... lxxxiii
     5.2 Contents ............................................................................................. lxxvi
CONVENTIONS AND ABBREVIATIONS

1. ANCIENT AUTHORS

Abbreviations of ancient authors and their works follow the conventions of Liddel’s and Scott’s A Greek English Lexicon, revised and augmented by Jones (henceforth LSJ), of Glare’s Revised Supplement to LSJ (henceforth LSJ, Supplement) and of the Oxford Latin Dictionary (henceforth OLD), with the following additions:

Anon. Vit. Aesch.  Anonymus Vitae Aeschyli
Gal. Al. Fac.  Galenus, De alimentorum facultatibus
           —— Foet. Form.  Id., De foetuum formatione libellus
           —— Meth. Med.  Id., De methodo medendi libri
           —— San. Tu.  quattuordecim
Georg. Torn. Or. Georg. Xiph.  Id., De sanitate tuenda
Hero, Mech. Frag.  Georgius Tornices, Orationes in
                  honorem Georgii Xiphilini
Hero Byz.  Hero Alexandrinus, Mechanicorum
Jos. Genes.  fragmenta
Max. Conf. Amb.  Josephus Genesius, Regum libri
Paraphr. rec. in Lycophr.  quattuor
Maximus Confessor, Ambigua ad
Joannem  Paraphrasis recentior in
Lycophronem
Ph. Parasc.

Philo Byzantinus, *Parasceuastica et poliorcetica*¹


Plutarchus, *Aetia Romana et Graeca*

—— Cur.

Id., *De curiositate*

—— Ser. Num.

Id., *De sera numinis vindicta*


Id., *Praecepta gerendae reipublicae*


Pseudo-Nonnus, *In quattuor orationes Gregorii Nazianzenii commentarii*

Ps.-Plu. Lib. Ed.

Pseudo-Plutarchus, *De liberis educandis*


Scholia in Aristophanis *Nubes* (scholia recentiora Eustathii, Thomae Magistri et Triclinii)


Ead. (scholia anonyma recentiora)


Ead. (scholia recentiora Tzetzae)

Theoph. Cont.

Theophanes Continuatus, *Chronographia*

I also occasionally abbreviate Biton’s *Kataskeuai* (*Constr.*), Pappus’ *Synagoge* (*Syn.*) and Oribasius’ *Collectiones medicae* (*Coll. Med.*).

References to Greek authors are made according to the standard citation systems of the *Thesaurus Linguae Graecae* (henceforth *TLG*), with the following exceptions:

(i) Hero’s *Dioptra, Geometrica, Metrica* and *Pneumatica* are cited by page and line of the pertinent volumes of *Heronis Alexandrini opera quae supersunt omnia* (Leipzig 1899–1914; repr. Berlin 2011) unless reference is made to the whole chapter (abbreviated as ‘ch.’, pl. ‘chh.’);

(ii) Hero’s and Philo’s *Belopoeica* and Bito’s *Kataskeuai* are cited according to the edition of Marsden (1971: 66–77), which has been reformatted compared to

¹ As noted by Whitehead (2016: 9 n. *), LSJ erroneously abbreviate all of Philo’s extant works as ‘Bel.’
the previous editions of Wescher and Thévenot. So, for example, Hero, Bel. 73.6 refers to page 73 in Wescher and to line 6 in Marsden (so also in the case of Bito’s \textit{Kataskeuæ}), whereas Ph. Bel. 73.22 refers to page 73 in Thévenot and to line 22 in Marsden.

2. REFERENCES

References to the text are by chapter (Roman numeral) and section (Arabic numeral), with page and line numbers of the present edition given in square brackets (for an exception, see Introduction, §3 with n. 70). Citations of whole chapters or sections are made without reference to page and line number, unless the context otherwise requires (see Introduction, §5.1, and the synopsis headings in the Commentary on BOOK ONE). Cross-references to notes in my commentary follow the same citation system. When there is more than one commentary entry for the same line, cross-references to different notes are distinguished by citing the relevant portion of text in bold style. References to illustrations in this edition are shown in bold (e.g. \textbf{Fig. 1}).

3. PERIODICALS AND REFERENCE WORKS

Abbreviations of periodicals follow the conventions of \textit{L’Année philologique}. The following abbreviations are used for standard reference works:

- \textbf{CID} \textit{Corpus des inscriptions de Delphes}, Paris 1977–.
- \textbf{CODM} \textit{The Concise Oxford Dictionary of Mathematics}, Oxford 2014\textsuperscript{2} (1990\textsuperscript{1}).
<p>| IG         | <em>Inscriptiones Graecae</em>, Berlin 1873–. |</p>
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG</td>
<td>Patrologia Graeca, Paris 1857–.</td>
</tr>
<tr>
<td>SEG</td>
<td>Supplementum Epigraphicum Graecum, Leiden 1923–.</td>
</tr>
<tr>
<td>TGL</td>
<td>Thesaurus Graecae linguae, Paris 1831–1865.</td>
</tr>
<tr>
<td>TLL</td>
<td>Thesaurus linguae Latinae, Leipzig 1900–.</td>
</tr>
</tbody>
</table>
4. EDITIONS AND TRANSLATIONS

In the apparatus criticus and in the commentary the abbreviation ed. princ. refers to the first edition of Hero’s *Aut* and *Spir* (also referred to as Thévenot). The following editions and translations (listed chronologically) are cited by the name of the editor and/or translator only:

**Baldi**
B. B. (trans.), *Di Herone Alessandrino de gli automati, overo machine se moventi, libri due*, Venice 1589.

**Thévenot**

**Couture**
D. C. (trans.), *Heronis Alexandrini de automatorum fabrica*, in Thévenot 243-274.

**Prou**

**Schmidt**

**Schmidt, Supplementum**

**Murphy**

All emendations, deletions and transpositions have been cited in the apparatus critici and in the commentary by the name of their proposer only. J.F.
Boissonade’s and B.J. Rozema’s (proposed) supplements in AP 11.185.4 have been cited from Floridi (2014: 356, 360), whereas the reference to Commandino in my app. crit. to Papp. 1024.24-1026.2 is to Commandino (1588: 305). The conjectures of A. Brinkmann, H. Diels, F. Haase, P. Hildebrandt, H. Schöne, R. Schöne have been cited from Schmidt’s edition of Hero’s Aut, except when it was possible to locate their original (or intermediary) source (see below).\(^2\) F. Susemihl’s supplement has been cited from Susemihl (1891: 744 n. 190). M. Egger’s conjectures have been cited from Prou’s edition of BOOK TWO of Hero’s Aut., although it is not clear whether the emendation at XXX.6 has been proposed by M. Egger or by É. Egger. (In his Index, Prou 255 refers to É. Egger, “Coup d’œil sur l’histoire des acteurs dans l’antiquité”, in Id., Mémoires de littérature ancienne, Paris 1862, 409-423, but I was unable to find any mention of the conjecture there.) Schmidt’s and Prou’s have been cited from their respective editions. Weil’s have been cited from his review of Prou’s original 1881 edition (Weil 1882: 420, 421, 422, 423), while Olivieri’s critical observations have been cited from Olivieri (1901: 432, 433, 434). E.S. Förster’s supplement (see Comm. on II.6 [10.4-8]) has been cited from Nussbaum (1976: 152). J.G. Schneider’s correction (see Comm. on IV.1 [18.6]) has been cited from Schmidt’s edition of Hero’s Spir., whereas G. Murray’s conjecture (see Comm. on VI.3 [24.16-20]) has been cited from Biehl (1970: 47); for the emendations of C. Wescher and L. Dindorf, see Introduction, §4.1. The following abbreviations should be particularly noted:

\begin{itemize}
  \item Diels for XXI.1 [68.12] and XXII.6 [72.20]: Schöne (1891: 75 n. 3, 76 n. 5)
  \item Haase for II.8 [12.1], XV.2 [52.16], XV.3 [54.2], XVI.2 [54.16-17], XX.3 [66.6], XXII.5 [72.13], XXIII.6 [78.3]: ‘schedae Schoenianae’; for XX.1 [64.7]: Haase (1847a: 432 n. 34)
\end{itemize}

\(^2\) Some of Haase’s and R. Schöne’s emendations were in turn cited by Schmidt from the so-called ‘schedae Schoenianae’ (on which, see Schmidt, Supplementum 12 n. 2), which I have been unable to locate (for these emendations, see below).
R. Schöne

for XX.1 [64.5-6], XXIII.1 [74.7] and XXX.2 [106.14]: ‘schedae Schoenianae’; for XX.4 [66.17], XXI 2 [68.15], XXII 4 [72.3], XXII 6 [72.20], XXVIII 3 [102.1], XXIX 1 [104.17]: Schöne (1891: 75 with n. 4, 76 n. 5)

5. SECONDARY SOURCES

Secondary sources other than those listed in §§3-4 above are cited by author and date. Publications by two or three authors are referred to by the last names of all authors, separated by a hyphen. If a name contains a hyphen, an en dash is used instead. For works by more than three authors, only the name of the first author is cited, followed by et al. Multiple publications by the same author in the same year are distinguished by lowercase letters (a, b) after the year. For forthcoming works by the same author, Arabic numerals (1, 2) are used for the same purpose. English-language titles of cited works are capitalised headline-style, whereas titles in other languages are capitalised sentence-style.
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Fig.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hero’s mobile automaton</td>
</tr>
<tr>
<td>2</td>
<td>Drive mechanism of Hero’s mobile automaton</td>
</tr>
<tr>
<td>3</td>
<td>Bearing arrangement of the axle of Hero’s mobile automaton</td>
</tr>
<tr>
<td>4</td>
<td>Configuration for straight-line motion (plan view)</td>
</tr>
<tr>
<td></td>
<td>(a) manuscript diagram</td>
</tr>
<tr>
<td></td>
<td>(b) modern reconstruction</td>
</tr>
<tr>
<td>5</td>
<td>Bobbin and cord arrangement for straight-line motion</td>
</tr>
<tr>
<td></td>
<td>(a) forward</td>
</tr>
<tr>
<td></td>
<td>(b) forward and backward</td>
</tr>
<tr>
<td></td>
<td>(c) forward and backward with pause</td>
</tr>
<tr>
<td>6</td>
<td>Side elevation of case and tube</td>
</tr>
<tr>
<td></td>
<td>(a) manuscript diagram</td>
</tr>
<tr>
<td></td>
<td>(b) modern reconstruction</td>
</tr>
<tr>
<td>7</td>
<td>Circular motion</td>
</tr>
<tr>
<td></td>
<td>(a) manuscript diagram</td>
</tr>
<tr>
<td></td>
<td>(b) modern reconstruction</td>
</tr>
<tr>
<td>8</td>
<td>Configuration for rectangular motion (plan view)</td>
</tr>
<tr>
<td></td>
<td>(a) manuscript diagram</td>
</tr>
<tr>
<td></td>
<td>(b) modern reconstruction</td>
</tr>
<tr>
<td>9</td>
<td>Configuration for rectangular motion (side view)</td>
</tr>
<tr>
<td>10</td>
<td>Mechanism for raising and lowering wheel $\pi\rho$</td>
</tr>
<tr>
<td>11</td>
<td>First configuration for snake-like motion (plan view)</td>
</tr>
<tr>
<td></td>
<td>(a) manuscript diagram</td>
</tr>
<tr>
<td></td>
<td>(b) modern reconstruction</td>
</tr>
<tr>
<td>12</td>
<td>Wheel $\pi\rho$ mounted on hub and close-up of hub with cord wound around it</td>
</tr>
<tr>
<td>13</td>
<td>Second configuration for snake-like motion (plan view)</td>
</tr>
<tr>
<td>14</td>
<td>Third configuration for snake-like motion (plan view)</td>
</tr>
<tr>
<td></td>
<td>(a) manuscript diagram</td>
</tr>
<tr>
<td></td>
<td>(b) modern reconstruction</td>
</tr>
<tr>
<td>15</td>
<td>Kindling altar of Dionysus (front view)</td>
</tr>
</tbody>
</table>
Fig. 16  Piping system for libation of milk and wine (front view)
Fig. 17  Modern gas tap vs ancient water tap
Fig. 18  Hero’s double-piped tap
Fig. 19  Trigger mechanism for Hero’s belly-bow (γαστραφέτης)
Fig. 20  Trigger mechanism for weight μ
Fig. 21  Parapet(s) for descending garlands
(a) manuscript diagram (plan view)
(b) modern reconstruction (side view)
Fig. 22  Stylobate, ring (ἴτυς) and base of the shrine (plan view)
(a) manuscript diagram
(b) modern reconstruction
Fig. 23  Transmission system for dancing Bacchantes
Fig. 24  Single σύριγξ
(a) manuscript diagram (plan view)
(b) modern reconstruction
Fig. 25  Transmission system for extending the range of the mobile automaton
(a) manuscript diagram (side view)
(b) modern reconstruction
Fig. 26  Double σύριγξ
(a) manuscript diagram (plan view)
(b) modern reconstruction
Fig. 27  Bottom of double σύριγξ with slides (front view)
Fig. 28  Door mechanism for Hero’s stationary automaton (front view)
Fig. 29  Starwheel and ὄσπλήγγιον assembly for moving arms (side view)
Fig. 30  Papyrus scroll for sailing ships (front view)
Fig. 31  Axle and pulley assembly for plunging dolphin (plan view)
Fig. 32  Mechanism for Nauplius’ torch (front view)
INTRODUCTION

1. THE AUTHOR

Nothing is known for certain about Hero's life except that he lived and worked in Alexandria, Egypt, in the mid-first century CE. A highly erudite scholar, he wrote numerous mechanical and mathematical treatises, most of which are extant either entirely or in part. His corpus includes works on pneumatics (On Water-clocks, Pneumatica), artillery (Belopoeica), land-surveying (Dioptra), geometry (Definitions, De Mensuris, Geometrica, Metrica, Stereometrica),

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1 The geographical location is inferred from the epithet Ἀλεξανδρινός. For the evidence and discussion, see Giardina (2003: 6-7 nn. 5-6). See also below, §4.
2 On Hero's erudite profile, see Vitrac (2009: esp. 191-5).
3 For a full account of Hero's works, see Giardina (2003: 31-74), who distinguishes between 'mathematical works' and 'technological works', the latter being further subdivided into 'technologico-theoretical' and 'technologico-practical'. As Giardina (2003: 34) herself notes, her classification is based on modern epistemological assumptions. See Vitrac (2009: 156) for some cautionary remarks about the inadequacy of application of the distinction between mathematical and technical to the ancient situation.
4 The Pneumatica was intended as a sequel to a four-volume work on water-clocks (Spir. 2.12-15), of which only scanty fragments are preserved in Pappus' commentary on Ptolemy's Almagest and Proclus' Hypotyposis. These fragments have been edited by Schmidt (below, §2.1). On the title of this work, see below, n. 108.
5 I do not include in my study the fragmentary treatise attributed to Hero and commonly known as Cheiroballistra, since the general scholarly consensus regards it as spurious. The Heronian authorship has been accepted by Prou (1877) and Marsden (1971: 206-33), who both edited, translated and commented on the work. For a more recent edition, translation and discussion, see Wilkins (1995). The most recent reconstruction of the cheiroballistra, a hand-held arrow-shooter, has been proffered by Iriarte (2000), who also carefully discusses previous reconstructions.
6 The De Mensuris, Geometrica and Stereometrica underwent alterations at the hands of later writers, but it is difficult to distinguish between original and interpolated material. Likewise, in Byzantine times the Definitions was augmented with material from other sources, but in this case it is easier to draw a line of demarcation (Deff. 1-132 vs 133-8). There has been some debate about the authenticity of this work (Giardina 2003: 83-4), which has culminated in Knorr's (1993) suggestion that its author was the mathematician Diophantus of Alexandria, traditionally dated to the mid-to-late third century CE (but see Knorr 1993: 184-5, 187 for the suggestion that he lived either in the early-mid third century or in the first century CE; as noted by Klein 1968: 248, a first-century CE date was first proposed by Bachel 1621 in his Epistolae ad Lectorem). The grounds for this attribution are as follows: (1) both the Definitions and Diophantus' Arithmetic are dedicated to a Dionysius; (2) the prefaces to these treatises show similarities in content and style. Neither (1) nor (2) proves conclusively that Diophantus wrote the Definitions both because Dionysius was a very common name (in either case he is addressed with a different title) and because both authors represent to a certain extent a common 'Oriental' Hellenistic tradition; see Neugebauer (1969: 178-9). The similarities between the prefaces
catoptrics (Catoptrica),\textsuperscript{7} and applied and theoretical mechanics (Automata, Baroulcos, Mechanica).\textsuperscript{8} The date of his activity has been long debated, with suggestions ranging from the first century BCE to the third century CE.\textsuperscript{9} A consensus was reached after Neugebauer (1938: 22-3) demonstrated that Hero was earlier than Ptolemy (fl. 127-148 CE), and that the lunar eclipse (not a ‘Sonnenfinsternis’, Asper 2001: 136) mentioned in ch. 35 of his Dioptra is an actual eclipse that occurred on 13 March 62 CE.\textsuperscript{10} The so-called ‘Heronian question’ has received renewed attention in more recent years, and Sidoli (2011) took pains to show that the date of 62 CE can only be taken as a terminus post quem for Hero’s activity. Although many of his observations remain valid, it is worth examining the question in some detail.

Sidoli’s (2011) main argument is that the eclipse data in Dioptr. ch. 35 do not correspond to an accurately recorded observation that can be attributed (at least with any certainty) to Hero. His aim, therefore, is to partly refute Neugebauer’s (1938: 23) earlier argument, which he contends depends upon three claims: (1) the mathematical methods of Dioptr. ch. 35 are purely nomographic and the eclipse of 62 CE, being ‘ill-suited’ to such methods, must have been used as an appeal to the recent memory of his readers;\textsuperscript{11} (2) the data stated in Dioptr. ch. 35 refer to an eclipse that Hero himself observed, despite the fact that he does not explicitly state this; (3) the lunar eclipse of 13 March 62 CE

suggest to me a relation of direct dependence between the two. On the addressee of the Definitions, see, more recently, Asper (2001), who proposes to identify him with the first-century CE grammarian Dionysius of Alexandria (Suda ο 1173; Matthaios 2015: 226, with further bibliography).

\textsuperscript{7} The Catoptrica, which was previously attributed to Ptolemy, is preserved in a – probably abridged – Latin translation by William of Moerbeke. For a recent edition and English translation, see Jones (2001), who (pp. 150-51) raises doubts about the authorship.

\textsuperscript{8} The Mechanica survives in Arabic translation, as well as in fragments preserved in Pappus’ Mathematical Collection. The Baroulcos, which was originally a separate work, has been transmitted as part of both the Mechanica (Mech. 1.1) and the Dioptra (ch. 37); see Drachmann (1963a: 22-32).

\textsuperscript{9} For a summary of the main positions, see Giardina (2003: 8-25). These chronological limits were set by the fact that Hero cites several times Archimedes and is cited by Pappus.

\textsuperscript{10} In a recent article, Masià (2015) argued that the eclipse has no evidential value for the purposes of dating Hero. The problems associated with Masià’s argument are discussed in Appendix 5.

\textsuperscript{11} Neugebauer (1975: 846) amplifies this point, suggesting alternatively that Hero might have appealed to his own memory. Sidoli (2011: 60) defines nomographic methods as ‘some tradition of using techniques of ancient geometry to produce line segments or arc lengths on an instrument in such a way that they could then be measured by an analog measuring tool’. 

xxiii
is the only one in the range of dates in which Hero might possibly have been active that gives a good fit for the data provided in the text.\(^\text{12}\) In order to prove his argument, Sidoli (2011: 57-8) points out that the eclipse data in Dioptr. ch. 35 are too vaguely formulated (contra, Giardina 2003: 18), which, as he maintains, accords neither with the standards of precision found in other ancient technical works nor with the method of finding the great-arc distance between two locations (in Hero’s own example, Alexandria and Rome) set out in that chapter. From these and other observations, he concludes that the reason why that particular eclipse was chosen is that it had been seen in both cities by the contemporaries of Hero or his source, and that Hero might in fact have drawn the eclipse data from the latter (Sidoli 2011: 59). While this argument is cogent, it only indicates that the year 62 CE is a terminus post quem for Hero’s Dioptra, not for his activity as such. There are at least two problems with it. First, it misattributes claim (2) to Neugebauer (1938: 23).\(^\text{13}\) Hero’s autopsy of the eclipse was first inferred by Drachmann (1948: 76),\(^\text{14}\) and was later independently suggested as a possibility by Neugebauer (cf. above, n. 11). In his earlier study, Neugebauer (1938: 24) only concluded that ‘man Heron entweder an das Ende des ersten Jahrhunderts n. Chr. setzen muss oder alle Daten zwischen etwa – 100 und + 200 als gleichwahrscheinlich ansehen kann’.\(^\text{15}\) Second, it fails to take account of other pieces of internal evidence used for dating Hero. The evidence can be summarised as follows:

(a) Hero, Mech. 3.20 describes a direct screw press with a female screw cut into its beam, a device which Plin. Nat. 18.317 says was invented twenty-two years before his time. This, together with Hero’s description of the screw-cutter (Mech. 3.21),\(^\text{16}\) establishes a terminus post quem of 55 CE for the Mechanica.\(^\text{17}\) This date has been corroborated by Drachmann (1932: 125-8), who called

\(^\text{12}\) These three claims are quoted, almost unaltered, from Sidoli (2011: 55).

\(^\text{13}\) The same mistake has been made by Vitrac (2009: 155).

\(^\text{14}\) This has already been noted by Keyser (1988: 218 with n. 5).

\(^\text{15}\) In subsequent studies, Neugebauer (1969: 178; 1975: 846) decisively opted for the former alternative.

\(^\text{16}\) Drachmann (1963a: 140) finds it likely that the screw-cutter, a device for cutting female screw threads, was Hero’s own invention.

\(^\text{17}\) Schmidt XIX, XXII-III. Keyser (1988: 218) cautions that Schmidt’s argument is valid only if the screw-cutter was published for the first time in the Mechanica (which would indeed be the case had Hero invented it; see above, n. 16) and if Pliny had found out about it only through published works.
attention to the fact that another instrument described by Hero, Mech. 3.16-17, the so-called galeagra,\textsuperscript{18} is referred to by Plin. Nat. 15.5 as nuper invenitur;\textsuperscript{19}

(b) Suet. Nero 41.2 and D.C. 63.26.4 both mention a new type of water-organ that was demonstrated in 68 CE in Rome. A comparison with Hero’s water-organ (Spir. ch. 1.42) has led Keyser (1988: 219-20) to suggest that the new model was Hero’s own invention, which, in turn, would provide an approximate date for the publication of the Pneumatics.\textsuperscript{20} ‘Composition’ is more correct than ‘publication’, given that the Pneumatics was in all likelihood published posthumously (cf. below, §5.7);

(c) In ch. 25 of his Dioptra, Hero employs Eratosthenic, rather than Posidonian, measurements of the circumference of the Earth. This gives a terminus ante quem of c.114 CE for the Dioptra, since it was then that the mathematician/geographer Marinus of Tyre introduced the Posidonian measurements in Alexandria;\textsuperscript{21}

(d) The first Hebrew treatise on mensuration, the Mishnat ha-Middot, which was composed no later than 150 CE, shows a strong Heronian influence in terms of subject matter (Gandz 1940). This provides a terminus ante quem for the Metrica.

This evidence alone suffices to show that Hero was active between the years 55 and 114-150 CE, and so there seems to be no reason to doubt that the eclipse of 62 CE, whether Hero observed it or not, occurred during his lifetime. As far as (b) is concerned, it should be noted that while the water-organ was first invented by Ctesibius, who lived in the early to mid-third century BCE,\textsuperscript{22} Hero’s model was most probably based on an earlier prototype by Ctesibius’ successor Philo of Byzantium.\textsuperscript{23} Unfortunately, we have no means of knowing what Philo’s device looked like, and Drachmann (1948: 100) believes that the differences between the Ctesibian and the Heronian versions are so slight that it is of little importance that we cannot distinguish between Philonian and Heronian

\textsuperscript{18} The galeagra was a wooden bin used for holding the olive pulp. Hero describes two versions of it; see Drachmann (1963a: 122-6).
\textsuperscript{19} Drachmann’s argument is summarised in Drachmann (1948: 75). Sidoli (2011: 59 n. 2) is aware of Schmidt’s and Drachmann’s arguments.
\textsuperscript{20} Keyser’s argument has been accepted by Raïos (2000: 35) and Giardina (2003: 27-8).
\textsuperscript{22} On Ctesibius, see further below, §5.3.
\textsuperscript{23} On Philo, see further below, §§2 and 5.3.
improvements. What is certain, however, is that the improved version of the
device had only recently been introduced in Rome, as one can infer from
Suetonius’ words (organa hydraulic a novi et ignoti generis, Suet. Nero 41.2). The
date of 68 CE, therefore, must be regarded as a terminus ante quem for the
introduction of the new model into imperial circles rather than for either its
invention or, for that matter, the publication of the Pneumática.

An attempt to narrow down the chronological range of Hero’s activity has
been made by Raïos (2000). He adduces two main pieces of evidence in support
of a Neronian date (Raïos 2000: 29-31, 34-6). The first is the inauguration of
two (unfinished) construction projects, namely, the canal from Lake Avernum to
the mouth of the Tiber (probably started in 64 CE) and the canal through the
Isthmus of Corinth (67 CE). In particular, the construction of the latter would
provide a more secure terminus ante quem for the Dioptra on the basis of the
assumption that the Egyptian geometers forming Nero’s entourage (Ps.-Luc. Ner.
4 = 221.27 Kayser) included Hero. Clearly, this is highly speculative, and the
fact that some of Hero’s problems deal with hypsometric differences and the
digging of a tunnel cannot be taken as a definitive indication of Hero’s
involvement in either project. And even if he did take part in the design and/or
construction process, it does not follow that he composed his Dioptra before the
years 64–67 CE. The second piece of evidence is the fact that Nero sung the role
of Nauplius (Suet. Nero 39.3), whose myth, as will be seen, is displayed in
Hero’s stationary automaton. The value of such evidence depends on the
interpretation of a poem by the first-century CE epigrammatist Lucilius (AP
11.185) as alluding to Nero’s performance, a performance which would have
taken place during his journey to Greece (67 CE). This would establish either a
terminus ad quem or a terminus ante quem for the composition or even the
publication of the Automata. But let us look at Lucilius’ epigram:

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24 For the differences between Ctesibius’ and Hero’s water-organs, see Drachmann (1948: 7-9). Keyser (1988: 219) is inclined to think that, in addition to using horn for the valve-springs instead of iron, Hero introduced several improvements in technical details.
25 On the former, see Arata (2014); on the latter, see Werner (1997: 114-16).
26 Pace Raïos (2000: 30-1 with nn. 54-6), who refers to Dioptr. 204.25-8 (hypsometric
differences), 234.19 (height of a ditch) and 238.3-4 (digging of a tunnel). On tunnels, see also
Dioptr. chh. 16 and 20.
27 For the tentative suggestion that the Automata was published posthumously, see below,
§5.7.
Hegelochus, my Lord Caesar, once relieved a city from the Greeks by coming on stage to sing of Nauplius. Nauplius is always an evil to the Greeks, either bringing a great wave or bringing a citharist.

The reference to a performance centred around the character of Nauplius has led most scholars to think that Lucilius is satirising Nero through the figure of the tragic actor Hegelochus,28 and hence that the words Ἐλλήνων ἀπέλυε πόλιν (line 1) refer to Nero’s proclamation of freedom and tax immunity for Greece (67 CE; Suet. Nero 24.2; IG 7.2713.12-14).29 This interpretation has been rightly challenged on the following grounds: (1) the myth of Nauplius was a rather popular subject in the early Imperial period, and we know that Nero performed other traditional tragic roles (Suet. Nero 21.2-3);30 (2) the repeated addresses to Καῖσαρ in the Lucillian corpus should be understood as reminders that Nero is the primary addressee of the book rather than as clues to a hidden satire;31 (3) the inclusion of the poem among epigrams about incompetent singers and actors (AP 11.186-9; cf. lemma to AP 11.185 [B] εἰς κιθαρῳδοὺς, ἄλλα μὴν καὶ τραγῳδοὺς καὶ κομῳδοῦς) indicates that Ἡγέλοχος (line 2) is not a fictive name.32 Thus, the epigram should simply be read as a satire of Hegelochus, and there

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28 Hegelochus was famous for having mispronounced E. Or. 279 in the first performance of the tragedy in 408 BCE. The episode is famously ridiculed by Ar. Ra. 303-4; for a discussion of Hegelochus’ error and other testimonia, see Csapo-Slater (1994: 267-8).
29 For Nero’s philhellenic agenda behind the event, see Enos (2013: 47); contra, for instance, Alcock (1993: 16).
30 Floridi (2014: 357-8).
31 Gutzwiller (2005); cf. also Floridi (2014: 78-9), with references. The most common interpretation is that the address δέσποτα Καῖσαρ in AP 11.185.1 refers to Vespasian rather than to Nero; see Floridi (2014: 357).
32 Gutzwiller (2005), whose position has been endorsed by Floridi (2014: 358).
would be no reason to connect Nero’s performance with the mythical display of Hero’s stationary automaton. The year 67 CE, as a result, does not constitute a chronological indication for the Automata.  

2. EDITIONS AND TRANSLATIONS OF THE AUTOMATA

The history of the editions and translations of the Automata is a complex one. The reasons for this are threefold. First, it is intimately connected with questions concerning the history of the text. The surviving manuscripts of the treatise, most of which are late and of ancillary importance for the constitutio textus, show a disruption of the order of chn. XXII-XXV.  

This issue was not recognised as such until 1882, when H. Weil (1818–1909) published a review of Prou’s original edition of Book Two which, among other things, constitutes a valuable source of emendations (Weil 1882). Second, the first translations of the work antedate the editio princeps by more than a century and were based on Greek exemplars that have not yet been identified. This means that these translations should be treated as a source of critical information. Third, Hero’s debt to Philo of Byzantium (fl. c.200 BCE), from book 6 of whose work (now mostly lost) our author derived much of his material on the stationary automaton, has been acknowledged not before the end of the nineteenth century (Schöne 1891; cf. below, § 5.6). The obvious implication of this is that the first attempts to edit the second part of the treatise (which is more problematic textually when compared with the first) did not take into account the surviving portions of Philo’s work: of his eight- or nine-book compendium of mechanics entitled Μηχανικὴ σύνταξις (Mechanical Collection) there survives, in the original Greek, only the fourth book on artillery construction (Βελόποικα),

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33 Marshall (2003: 263 with n. 9) feels that the treatise postdates more strictly technical works such as the Dioptra, and hence he tentatively suggests an early Flavian date.

34 On such disruption, and on the attempts to restore the original chapter order, see below, §3.2, and esp. nn. 84 and 86.
along with substantial excerpts from the seventh and eighth books, concerning, respectively, fortifications (Παρασκευαστικά) and siegecraft (Πολιορκητικά).\textsuperscript{35}

2.1 Editions

The treatise was edited for the first time by M. Thévenot (1620–1692), Ph. de la Hire (1640–1718) and J. Boivin de Villeneuve (1663–1726) in Thévenot 243–74. The text of their edition, which contains facing Latin translation by D. Couture (dates unknown), is largely unsatisfactory, because it is based on three relatively late and inferior manuscripts: \textit{Pa}, \textit{PD} and \textit{PF}. However, despite his marked reluctance to emend (see Thévenot VI), Thévenot has corrected the text in a few places (II.9 [12.13], VII.2 [26.13], IX.1 [30.6] and [30.9]), while in others he appears to have derived his (variant) readings (or corrections) from the equally late manuscripts \textit{PC}, \textit{PE} and \textit{PG}.\textsuperscript{36} The illustrations are copied from Baldi’s drawings, occasionally modified in small details and reversed horizontally.

A little more than a century and a half later, in 1847, F. Haase (1808–1867) announced a complete re-edition that was part of a larger project consisting of a six-volume collection of works by military and mechanical

\textsuperscript{35} The arrangement of Philo’s Mechanical Collection was first elaborated by Haase (1847a) and later by Orinsky-Neugebauer-Drachmann (1941). These reconstructions, which are mainly based on the presence of cross-references in the extant portions of the work, agree on the order of the books. Curiously, Whitehead (2016: 20-1) does not mention either of these reconstructions, but he (p. 21 n. 19) does refer to Garlan (1973: 16-18; 1974: 283-4) for the controversies concerning the order of books 5–9. Although there is some variation in the titles of individual books, most notably in the title of book 6 (below, n. 123), the generally accepted arrangement is as follows (asterisked titles are not attested in Philo): 1. Εἴσαρχον, 2. Μοχλικά, 3. Λεμεσοποιικά, 4. Βελουποιικά, 5. Πνευματικά, 6. *Αὐτοματοποιικά* Αὐτοματοποιικά, 7. Παρασκευαστικά, 8. *Πολιορκητικά, 9. Περὶ ἐπιστολῶν (unless this was a separate treatise). Book 5 is preserved in Arabic translation (translated into French and English, respectively, by Carra de Vaux 1902 and Prager 1974) and in a partial Latin translation of another (lost) Arabic version (fully translated into German by Schmidt: see below, §2.1; for a selective English translation, see Prager 1974: 79-91, 127-233). Further references in Rance (2016). On the subject-matter of book 6, see below, n. 126.

\textsuperscript{36} Some of these readings are correct (ἀνισορροίαν, V.2 [20.14]; ἀναιγμὸν, XIV.1 [50.21]); ἐν, XXVI.1 [90.14]), but of course it is debatable whether Thévenot (or either of the other two editors) took all of them from the manuscripts. In at least two cases (V.2 [20.14] and XXVI.1 [90.14]), they may be due to conjectural emendation. See, by contrast, the erroneous readings περιφρής (III.2 [16.8]) and ἀνεξίσθοντα (XXIII.5 [76.17]).
writers.⁵⁷ Although none of the projected volumes ever appeared, the announcement remains valuable as an indication of a renewed interest in the works by Hero. Haase intended to use manuscripts (\textit{Ae}, \textit{Mc}, \textit{Pa}, \textit{Pe}, \textit{Pf}, \textit{Pg} and \textit{Ph}) as the basis for his edition.⁵⁸

In 1881 the civil engineer V. Prou (1831–1884) re-edited the second part of the treatise on the basis of seven Paris manuscripts (\textit{P₁–P₇} = \textit{Pa}, \textit{Pb}, \textit{Pd}, \textit{Pe}, \textit{Pf}, \textit{Pg} and \textit{Ph}): “Les théâtres d’automates en Grèce au IIᵉ siècle avant l’ère chrétienne d’après les \textit{AUTOMATONIIKA} d’Héron d’Alexandrie”, Mémoires présentés par divers savants à l’Académie des inscriptions et belles-lettres de l’Institut de France, s. 1, 9.2 (1881); reprinted, apparently unaltered, as part of an enlarged issue of the same publication in 1884 (erroneously catalogued under the year 1878 at BNF, Gallica, http://gallica.bnf.fr/ark:/12148/cb32813503c/date18780101).⁵⁹ This publication has a quadripartite structure. In the introduction (‘Introduction historique’), Prou reviews Magnin’s (1852) book on the history of European puppetry (which he criticises for not mentioning Hero’s work) and discusses previous and contemporary scholarship on the Automata, most notably the first two translations of the treatise (respectively, by Baldi and D’Auria; see below), the edition princeps and the contribution of Martin (1854). Immediately following the introduction, Part One (‘Première partie’) provides observations on the manuscripts used in the edition, addresses the issue of the disrupted chapter order (albeit without understanding it) and discusses the two types of automaton distinguished by Hero – ‘mobile’ (\textit{υπάγων}) and ‘stationary’ (\textit{στάτων}) – against their mythical and theatrical background. Part Two (‘Deuxième partie’) furnishes a technical examination of the mechanisms described, or alluded to, in the treatise, and formulates an engineering theory of how (repeated) motion is imparted by means of the counterweight (‘théorie des cordons moteurs des automates d’Héron d’Alex-

⁵⁷ See Haase (1847b: esp. 9-10). In addition to the Automata, Haase planned to publish (vol. 3) the following Heronian or pseudo-Herolian works: Baroulos, Belopeica, Chérobalista and Dioptia.

⁵⁸ Of these, he fully inspected (\textit{Ae}, \textit{Pa}, \textit{Pe}, \textit{Ph}) and partially collated \textit{Mb}, \textit{Pf} and \textit{Pg}. Schmidt’s account (Supplementum, 138) is not only incomplete but also incorrect: in addition to omitting \textit{Mb}, it includes \textit{Pe} among the partially collated manuscripts.

⁵⁹ Murphy 8 is wrong in claiming that Prou’s edition was republished as a book in 1884. Both COPAC and Google Books records suggest instead that it is the original edition that was published as a separate volume.
Part Three ('Troisième partie') contains the Greek text with French translation underneath it and footnotes mainly devoted to linguistic and philological matters. The edition closes with an analytical index of topics, persons and Greek words; Part Two and Part Three comprise modern illustrations (some of which appear more than once), whereas Part One and Part Two include partial quotations and translations of BOOK ONE. The main contribution of Prou's edition to scholarship lies in the emphasis he places on the relevance of Hero's automata both to the history of theatre and to the history of technology. All too often, however, he has a very poor understanding of Hero's mechanisms (for two notable exceptions, cf. Comm. on V.3 [22.2-3] and IX.5 [32.8-9]), offers implausible or even absurd reconstructions, and fails to provide evidence to support them. As a result, despite a relatively good number of improvements and corrections, Prou did not lay solid foundations for an adequate understanding of the text. Some of his conjectures are ungrammatical, while others are either unconvincing (for instance ἐλπίδα, XXV.5 [88.4]) or altogether wrong (for instance παραφθέντα, XXIII.8 [78.16]). His footnotes do not always specify whether the readings adopted in the text and not found in the editio princeps derive from the manuscripts. The availability of Prou's 1881 edition is very limited. In Europe I know of copies of the original edition in only three university libraries: Freie Universität Berlin (borrowable), University College London (not borrowable) and Université Paris-Sorbonne (not borrowable).

The decisive turning point in the editorial history of the Automata came in 1899, when W. Schmidt (1862–1905) published the first volume (divided into

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40 This theory has not been taken into account in the present study because it requires advanced mathematical skills which I do not possess.

41 See already Schmidt, Supplementum 139, who cites as examples of Prou's misunderstanding of the Heronian principles his emendations of the text of II.2 [6.14-15] and VI.1 [22.22-24.3]. In addition to my observations on these passages, see my Comm. on XIV.2 [52.5-6] and XVI.3 [56.1-2], as well as my synopses on XLI.I-7 [44.15-48.13] and XIII.7-9 [48.13-50.15].

42 An opinion already held by Schmidt, Supplementum 139.

43 These are προσκαλάται (VI.2 [24.13]), ἤγοιγμένον (XIV.1 [50.21]), περιγγοῖς (XXIV.6 [84.10]), ἀποτελοῦσθαι (XXVI.1.3 [92.8]) and ἀποτελοῦσθαι (XXVI.4 [92.12]).

44 Only internal members of the university are eligible to borrow the item, but anyone can consult it in loco. I thank I. Kirsch, librarian of the Philologische Bibliothek of the Freie Universität Berlin, for the information (personal communication, January 7, 2019).

45 In the present edition, I refer to Prou's 1884 reprint. Unfortunately, because I also refer to Weil's 1882 review of Prou's original edition, this creates an inconvenient anachronism.
two parts) of the Heronian opera omnia (Teubner). The first part includes, in addition to the Pneumatics and the Automata, the text, with apparatus criticus, facing German translation and footnotes, of (a) the exiguous fragments of Hero's four-volume work on water-clocks as preserved in Pappus' commentary on Ptolemy's Almagest (in Ptol. 87.9-88.10 and 89.4-5) and Proclus' Hypotyposis (Hyp. 4.74-7), (b) the Latin version of Philo of Byzantium's Pneumatics, and (c) Vitruvius' De Arch. 1.6.2, 9.9.2-5 and 10.12-13 (all relating to pneumatics). The second part (Supplementum) is mainly devoted to the manuscript tradition of Hero's twin treatises, and contains an extensive word index to the entire edition. Schmidt's edition can be considered as the only serious attempt to approach the text in a systematic and scholarly fashion. He consulted manuscripts which were apparently unknown to his predecessors (in his apparatus criticus and throughout his discussion of the history of the text sigla are used only for those manuscripts which he considered to be superior, on which see below, §3), made use of almost all of Haase's collations (which had been made available to him through R. Schöne and were previously unknown to Prou), and printed the text of chh. XXII-XXV in the correct order (though, lamentably, he was not aware of Weil's reconstruction, which is clearly preferable to that of R. Schöne). He greatly improved the readability and presentation of the text (to wit, he punctuates far better than Thévenot and Prou and adopts a text layout that is not just more faithful to that of the manuscripts but also more perspicuous), although his approach to conjectural emendation appears to have been rather erratic: at times he does not emend where emendation is required (see, for instance, the retention of the manuscript reading ἐξειλησόμεθα, VI.2 [24.12]), at other times he intervenes too rashly (see, for instance, the emendation ὠν ἂν for ὀσα, II.3 [8.3]), and at yet other times he proposes emendations that are unsupported (see, for instance, the conjecture ἐν τῷ for ἐν τῷ, XVI.3 [56.1]) or poorly supported (see, for instance, the suggested addition of θυμάζονταν at XXI.2 [68.19]).

His apparatus criticus records emendations by previous scholars whose first source may be difficult to locate, but contains errors, oversights and omissions (for example, he does not acknowledge readings found in Prou's edition and

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46 See Schmidt, Supplementum 12 n. 2.
47 On the text layout of previous editions, see below, §5.1.
instead treats them as his own conjectures). Schmidt was the first to discuss the
text in relation to (at least some) manuscript diagrams and to comment on the
modern illustrations included in his edition (see his “Anmerkungen zu den
Automaten, insbesondere zu den Figuren”, pp. LI-LXX, which shall be here
referred to as Anmerkungen; he provides a similar set of observations for the
Pneumática at pp. XXVI-L). These illustrations, however, which were drawn by
H. Querfurth (dates unknown), are not always based on the manuscript
diagrams, and not infrequently include more details than are warranted by the
text. Schmidt’s edition has three major drawbacks: (1) he did not include
photographic reproductions of the manuscript diagrams (half-tone photo-
reproduction processes had only recently become a regular feature of mass-
market periodicals, were rather expensive, and would probably not have yielded
satisfactory results) but instead included only a small number of graphic
reconstructions; (2) he provided only a partial and at times erroneous account of
the history of the text, without undertaking a thorough stemmatic analysis of the
manuscripts known to him either directly or indirectly; (3) he was excessively
inclined to invoke interpolation in a way that ignores the multi-layered and
incompletely revised nature of the text.

2.2 Translations

The first translation of the Automata into a Western language appeared in the
sixteenth century when B. Baldi (1553–1617), mathematician and polymath
from Urbino, made a translation into Italian, accompanied by explanatory and
textual endnotes, illustrations ultimately based on the manuscript diagrams, and
a prolegomenon tracing the history of automata-making (“Discorso di chi
traduce sopra le machine se moveint”). Originally a project of his master F.

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48 All these errors are collected in Appendix 2.
49 For the history of half-tone technology, see e.g. Twyman (1970: 31-2).
50 Recent years have seen a surge of interest in Baldi’s life and works: see Nenci (2005),
51 Baldi’s translation has been recently studied by Micheli (2005). This article contains
much valuable information on Baldi’s situation within the Renaissance and the scholarship of the
time, but is not unproblematic, especially in relation to its treatment of Baldi’s endnotes.
Commandino (1509–1575), the translation was completed in 1576 and published in 1589 under the aegis of the dedicatee of the work, G. Contarini (1536–1595). This publication most probably encouraged Baldi’s contemporary, the Neapolitan mathematician J. D’Auria (fl. c.1590), to undertake a Latin translation of the whole treatise (date unknown), now preserved in the seventeenth-century manuscript Parisinus gr. 2380, ff. 211v–241v. During the last decade of the century, after the publication of his first translation, Baldi retranslated the treatise into Italian. This second translation, preserved in the autograph manuscript Laurentianus Ashburnham 1525 (Due libri di Herone Alessandrino delle machine da se operanti), has remained unpublished. Shortly afterwards, in 1601, Baldi published in Venice a minimally revised version of his first translation, under the title Di Herone Alessandrino de gli automati, ovvero machine se moventi, libri due, nuovamente ristampato e con ogni diligenza ricorretto. Baldi’s unpublished translation has

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52 Baldi mentions this in his Vita di Herone Alessandrino (Ambrosianus D 332 inf., f. 107).
53 For the date of the translation’s completion, see the colophon at p. 41v. Prou 121 erroneously cites the year 1569.
54 D’Auria was particularly famous for his Latin translations of Autolycus of Pitane, Euclid and Theodosius of Bithynia, all published in Rome in the years 1587–1591 (Prou 121-2). For further biographical information, see Toppi (1678: 145).
55 Unfortunately, this translation became available to me too late (February 7, 2019) to be fully incorporated into the present edition. The colophon at the end of the manuscript (f. 241v) indicates that D’Auria’s exemplar was a Vaticanus.
56 A caveat is in order here. This translation was first catalogued under the erroneous title Due libri d’Herone Alessandrino, delle machine da se operante (cf. no. 1525 in Catalogue 1853, unpagged), which was later corrected to Due libri di Herone Alessandrino, della macina da se operante (Relazione 1884, available online at http://www.blonline.it/la-biblioteca/cataloghi/fondo-ashburnham-catalogo). Micheli (2005: 248), who seems to have consulted the manuscript, has Due libri di Herone Alessandrino delle machine da se operanti. I myself do not know the correct form of the title because, unfortunately, I have been unable to examine the manuscript. The form cited by Micheli is certainly the most plausible, for it is consistent with the title of Baldi’s original translation.
57 The approximate date of the translation suggests itself from Baldi’s statement that he had retranslated the Automata and (once again) dedicated his translation to Contarini (Laur. Ashb. 1525, f. 217v, cited in Micheli 2005: 248).
58 Scholars have been divided into several camps: those who regard Baldi’s 1589 and 1601 translations as identical (G. Mazzucchelli, cited in Affò 1783: 168–9; Martin 1854: 40; Micheli 2005: 249), and hence claim that the only difference between the two is in the frontispiece; those who find no significant differences between them (Schmidt, Supplementum 140 n. 2); and those who consider them to be completely or significantly different from each other (P. Paitoni, cited in Villa 1767: 481 n. 10; Affò 1783: 169). I have selectively collated the two translations against each other, and have only very rarely found minor stylistic differences. For this reason, and
been erroneously considered as the autograph copy of either the first or the third translation: \(^{59}\) in his manuscript preface Baldi is explicit that he had based his first translation on a manuscript belonging to Commandino and that, in order to retranslate the treatise, he compared this manuscript with a manuscript that belonged to G. V. Pinelli (1535–1601). \(^{60}\) Two further translations are reported to have appeared, respectively, in 1647 (Bologna) and 1661 (place of publication unknown). \(^{61}\)

Baldi’s 1589 translation is of primary interest because it represents the first serious attempt to make sense of the Heronian text. As Baldi 3’ himself states, his rendering was based on a very corrupt manuscript. As a result, his translation leaves much to be desired in terms of internal coherence and soundness, but it is nonetheless generally accurate, showing peculiar sensitivity to technical language. \(^{62}\) Although not free from mistranslations and misunderstandings, particularly with reference to architectural or mechanical descriptions, it contains a number of corrections which are unlikely to be based upon readings of his exemplar and which have been either found in other manuscripts or confirmed by later conjectures (see, for example, my Comm. on II.7 [10.11-14]). Baldi’s endnotes are typically informative and succinct, explicating his translation practice and elucidating (albeit not always successfully) problematic passages or less familiar words (his failure to make acceptable sense of the text is exemplified by his imaginative comments on the corrupt words τὸς τῶν δαιμόνων χρόνους: VI.3 [24.19]; see Comm. on VI.3

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\(^{59}\) For the former misapprehension, see Rose (1975: 246); for the latter, see Libri (1841: 72 n. 1)), followed by Schmidt, Supplementum 140 n. 2.

\(^{60}\) Laur. Ashb. 1525, ff. 4rv. The access to Pinelli’s manuscript, which Baldi consulted in Padua, allowed him to clean up a number of mistakes in his first translation (Ambr. D 332 inf., f. 107). The only example known to me is Baldi’s rendering (34) of XXII.4 [72.6], ‘si vedevano le navi condotte al mare sui carretti’ (reading ἰσχίον in place of Ἀγαθίων), which he later (Laur. Ashb. 1525, f. 44) was able to correct to ‘vedendosi le navi da Grechi al mare condotte’ (cited from Micheli 2005: 251 n. 18). D’Auria (f. 232), too, has the erroneous version: ‘Naves enim videbantur a curtibus deductae’. See further below, n. 63.

\(^{61}\) See, respectively, Affò (1783: 169) and Martin (1854: 40), who refers to the 1661 translation as an unaltered re-edition of the first translation. Despite my best efforts, I have been unable to locate these posthumous translations.

\(^{62}\) I agree with Micheli (2005: 251-2) on this point.
Some of his translations suggest that his exemplar was a manuscript belonging to what Schmidt considered to be the inferior branch of the tradition (below, §3.2), and, in particular, a manuscript somewhat allied to \( M \).

The second half of the sixteenth century saw the appearance of at least another translation into vernacular Italian (Delle cose che si muovono. In volgare, Ambrosianus N 237 sup., ff. 56-78), but the next milestone in the attempts to make the text more accessible to a larger audience is the Latin translation by Couture, Professor at the Collège de la Marche and member of the Académie des inscriptions since 1701. Couture's translation is not particularly noteworthy except for the fact that it is highly dependent on Baldi's. While it is true that Couture shows a certain (admittedly low) degree of independence, as already noted by Schmidt, Supplementum 138, he does not improve the places where he deviates from Baldi (there are several mistranslations/misconstructions

\[ 24.16-20 \].

\[ 63 \] See already Schmidt, Supplementum 141, who supported his view by citing Baldi's translation (40) of XXVIII.1 [100.9-10]: 'si vederanno le navi, secondo che s'è detto' (his exemplar probably had φαίνονται in place of οὐ φαίνονται, as in \( M \)). The Teubner editor (Supplementum 140-1) was inclined to accept Prou's suggestion (214 n. d) that Baldi's exemplar was the same as that used by D'Avrili (on which, see above, n. 55; more precisely, Schmidt suggested that the only plausible candidate is \( Vb \), a manuscript which I have not been able to consult). Prou explained the shared error of Baldi's and D'Avrili's translations of XXII.4 [72.6] (above, n. 60) as owing to the corruption of οὕτω τῶν Ἀρχιμόν into οὐτῳ (or ἐτί) τῶν ἀμαξῶν. This corruption, however, is utterly implausible on palaeographical grounds. Both translators seem to have corrupted ἀρχιμόν (not ἄρχιμον, as with Micheli 2005: 251 n. 18), which appears in \( M \) and other manuscripts, to ἀρχιμόν ἄρχιμον <ἀρχιμόν <ἀρχιμόν). The reading presupposed by these translations does not seem enough to posit a common exemplar. More recently, Micheli (2005: 251 n. 18) has argued that Baldi based his translation on \( Ab \), a manuscript which he unwarrantedly believes to have belonged to Pinelli. But, as Micheli (2005: 248-9) himself acknowledges, Baldi's first exemplar rather belonged to Commandino, see above.

\[ 64 \] In addition to the passages cited above (n. 63), see the following readings (the readings given in brackets occur in \( M \)): 'accomodata di maniera' (188; ἀριστή ὃς, II.8 [12.6]); 'nturneasi' (20; ἄναγχορησία, IV.3 [18.20-21]); 't' (21; ἄναγχορησία [26.4]); 'che si vede' (30; οὐ λέγήθηκοι, IX.5 [32.11]); 'una' (24; οὐ, X.3 [34.14-15]); 'al tutto' (24; πάσας, X.4 [34.20]); 'simile' (25; ὁμοιός, XI.10 [40.19]); 'che basti' (30; μὴν ἀπήρχον, XVII.2 [58.1]); 'di com' α' (34; ἔλαφον κράτωσι, XXIV.1 [80.7-8]); 'Resti hona' (41; Λοιπὸν δὲ ἐστὶν ἠμοί, XXX.1 [106.4]). Cf. also the following readings cited by Baldi: θερίζωντα (42 n. 8: 1.5 [4.12]); διαφελητεν/διαφελητέων (43 n. 10; II.2 [6.16]); κοκλίων (45 n. 28; XVIII.3 [60.3]). None of the manuscripts that I have consulted appears to have been Baldi's exemplar because they do not contain the following readings which the scholar claims to have found in the Greek text: διαπε-λέξιον (44 n. 21; X.1 [34.1]); περάννη (46[45] n. 6; XXV.5 [88.6]; κρόταφον (46[45] n. 12; XXV.1.7 [96.2]); σάκκομα (47 n. 20; XXIX.2 [104.22]).

\[ 65 \] Unfortunately, I have not been able to consult this translation, which, according to Micheli (2005: 249 n. 15), covers only Book One. The manuscript (whose date is 1551-1600) also contains an Italian translation (presumably by the same hand) of Heron's Pneumática (Degli effetti dei venti. In volgare, ff. 1-50).
and a few independent omissions scattered throughout, which seem to stem from a hasty reading of the text). For the most part, he pays very little or no attention to the Greek, as is apparent from the number of calques and omissions that he shares with Baldi.\textsuperscript{66}

It was not until 1881 that the treatise was (partly) retranslated into a Western language. Prou's translation into French is fluent and easily readable but is based on an inadequately constituted text. Although Prou pays some attention to technical terminology, his translation often lacks accuracy and precision. His tendency to translate freely becomes most obvious in cases where he relegates the correct translation to a footnote. Contrast, for example, his translation of XXVI.2 [90.16-17] καταδεδεμέναι [sc. αἱ γονίαι] as ‘munis de cordons’ (230) with the following explanation (230 n. b): ‘reliés par le bas, au moyen d’un cordon sans fin, entourant extérieurement le pied carré de chaque barreau vertical’. Or, to take a more extreme case, in a footnote he translates the term γομφοτήρια (XXVII.1 [98.5]) as ‘tenons de menuiserie’ (236 n. c), but in the body of the text, apparently in order to avoid supplying the term of comparison, he opts for its opposite (‘mortaises des menuiserie’, 236). Some of his renderings are more paraphrases than translations (see, for example, his rendering of XXIV.2 [80.12-13]: ‘Les outils seront également de couleur naturelle’, 216-17), while others are blatantly wrong (see, for example, his rendering of XXX.7 [110.12-13]: ‘La translation des personnages, aussi bien que leurs gestes secondaires’). For a more serious misunderstanding, cf. his Greek text and translation of XXIII.5 [76.16-18]: ὅταν δὲ τάναντα ἐπιστρέφω τὸν ἄξονα, καὶ μέντοι ἀνοικθήσονται (ἀνεπθήσονται plerique codd.), δόθεν κλεισθήσονται ἀθώα (‘si je fais tourner l’arbre en sense inverse, pendant que la porte est ouverte, celle-ci sera refermée’, 223).\textsuperscript{67}

\textsuperscript{66} Calques and shared omissions occurring in Couturé’s translation of Book One, too many to list here, are cited where appropriate in the Commentary. The following list gives examples of (a) calques and (b) shared omissions in Couturé’s translation of Book Two (as far as (a) is concerned, Baldi’s translations appear first, followed by Couturé’s): (a) XXVI.7 [94.20] ‘sia un naspo’(38)’ ‘sit modiolus’ (270), XXV.2 [106.12] ‘ornamenti da capo delle donne’(41)’/ad capitis ornamentum mulieres’ (273) and [106.14] ‘giovanetto’(41)’/adolescentem (273), XXX.6 [110.1] ‘se altra cosa gli si vede vicina’(41)’/si quid aliud in proximo videbatur’ (274); (b) XXIII.5 [76.17] and μέντοι... δόθεν, XXX.6 [110.2-3] τὸ δύον.

\textsuperscript{67} See also the criticisms in Schmidt, Supplementum 139.
The first complete modern translation appeared as part of Schmidt's edition. His is a rather sophisticated translation and one which privileges stylistic concerns and accessibility (so to speak) over strict faithfulness to the text. His translated text often does not reflect his Greek text, introducing conjectures and/or supplements (whether his own or someone else's) which are otherwise relegated to the apparatus criticus. Sometimes he alerts the reader to the phenomenon, but other times he does not (in his translation he generally uses square brackets to indicate deletions but refrains from using angle brackets to enclose additions). The most conspicuous example of such discrepancies is his rendering of XXVI.4 [92.15-17], where he (435) does not fail to include his tentative emendation <<ει δε το πνακος ξαφνος μονον έως των οθονιων των συνιλλεμένων τοι χάρτου, οταν τω κανονι εγγίσης,>πεπληροκέναι σε (in place of τε): 'Es ist aber notwendig, wenn man die Wanddekoration der Achse wirklich nahe gebracht hat, dass man die Fläche der Bühnenhinterwand nur bis zu den Prospektrollen gefüllt hat' (in his note ad loc. he signals his intervention but stresses that the whole of XXVI.4 [92.14-17], which he deletes as spurious, is suspicious).68 There are also terminological inaccuracies and misinterpretations (or not so stringent interpretations). For examples of the former, see Comm. on III.1 [14.18-19] and XIII.3 [46.4-6]; for examples of the latter, see Comm. on III.2 [16.7-10], XI.10 [40.19-42.1] and XVII.2 [56.22-58.1].

It was only after more than ninety years that the treatise received a translation into English. Murphy's 1995 translation, which comes accompanied by a brief introduction, bidimensional illustrations and textual and explanatory endnotes, is generally of very poor quality. In her introduction, Murphy discusses (albeit sketchily) several aspects of the text, provides a rapid and

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68 Examples of this phenomenon in Schmidt's translation of BOOK ONE will be found in the Commentary. For further examples pertaining to BOOK TWO, cf. Schmidt 411 (suggested transposition of πάλιν, XXI [68.11-12]; unclaimed), 415 (Diels' addition of <το δε Αθον αντι>, XXII.6 [72.20]; claimed), 435 (Schmidt's suggested addition of <την μονη> or Prou's addition of <πληρωμα την>, XXVI.1 [94.6]; unclaimed), 439 (no fewer than seven emendations, of which six are claimed and one unclaimed, XXVI.7-9 [94.19-96.13]), 443 (Schmidt's suggested addition of <εμπεπαγινον>, XXVII.2 [98.10]; claimed), 445 (Schmidt's suggested emendation ἐπιφόρτατα or R. Schäfer's conjecture ἐπιφέρατα, XXVIII.3 [102.1]; unclaimed) and 453 (Schmidt's suggested addition of <το τις μάθος> Xxxx.7 [110.15]; unclaimed but enclosed in parentheses).
incomplete survey of previous scholarship on the treatise and its author, and partly explains her principles of translation. These principles can be summarised as follows (Murphy 8): (1) the translation is mostly based on Schmidt’s text, although some reference is made to Prou’s edition of Book Two; (2) some of Schmidt’s emendations are adopted for the purpose of improving the legibility of difficult or corrupt passages, whereas some of his lacunae are ignored when the text is deemed translatable without recourse to emendation; (3) occasional departures from Schmidt’s textual choices and assessments are duly indicated in the endnotes.

There are several problems with the application of principles (2) and (3) and with Murphy’s translation more generally. First, Murphy has a poor grasp of Greek grammar and syntax, which results in frequent mistranslations, misinterpretations and/or unwarranted interpretations. Murphy seems to have a peculiar notion of how to deal with corrupt or lacunose passages, and while she usually uses angle brackets to enclose additions, she also uses square brackets for the same purpose (Murphy otherwise uses square brackets to indicate deletions). This is perhaps best exemplified by her translation of VI.2 [24.12-15] ἀλλὰ μηρομάτων ποιήσαντες καὶ προσκολλήσαντες ἐπὶ τὴν ἐξελικτραν καὶ πάλιν τὰ ἑναντία ἐπειλήσαντες ἀποδόσομεν εἰς τὴν λείαν: ‘take stretches of it [sc. the cord], glue them on to the cylinder and then wind the [remaining] cord in the opposite direction and attach it to the counterweight’ (15-17). Terminological choices aside, it is unclear what the reader should make of ‘[remaining]’ and whether it is intended to correspond to {ἐπειλήσομεν}, which is enclosed in square brackets in Schmidt’s text. Take also, for instance, her rendering of XIII.4 [46.11-13], which contains a lacuna (ἐκ δὲ τοῦ ἐξ οὐ-γείου <***>ἐτερος σωλὴν ὁ χρυσός καὶ φέρων ὀμοίως εἰς τὸν ὑφ σωλήνα): ‘and from the container ΞΟ, another pipe ΧΨΩς, likewise bearing towards cylinder ΥΦ’ (23) Here the subject σωλὴν seems to be treated as the direct object of the main verb of the immediately preceding sentence, κεῖσθαι, which is freely translated as ‘put’. Second, Murphy only very rarely takes note of the (admittedly many) instances in which she departs from Schmidt’s text, and, even when she does, misreadings may be involved (see Comm. on III.2 [16.7-10]). In

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69 The most notable omissions are Olivieri (1901) and Schmidt (1903); Weil (1882) is cited once, but has been taken into account only marginally and superficially.
all other cases, it is not always clear whether she emends the text in a different way (but see the caveat in Murphy 8), whether she in fact follows Schmidt’s (or Prou’s) translation, whether she translates creatively or whether she understands the Greek text correctly. One example will suffice. Her translation of \textit{XX.2} [64.19-66.2] runs as follows (28): ‘as though drawn up [sc. the figure of Athena] by means of a cord, it can appear, upright, and then be hidden again as though drawn down by another cord’ (δοκεῖ σπάρτου τινὸς ἐπισπασμένης ὁρθὸν φανεῖν καὶ πάλιν ὡς ἐτέρας κατακλυθήναι). There is no such parallel structure (‘as though… as though’) in the Greek, and it is difficult to see how ‘drawn up’ could correspond to ἐπισπασμένης, which cannot but refer to the cord (σπάρτος τινὸς). If the verb were meant to refer to Athena’s figure (ζώδιον), it would have been ἐπισπασμένου (gender switch should here be ruled out because ‘upright’, ὁρθόν, still agrees with ζώδιον). Third, Murphy has a contradictory approach to interpolations, and while she generally follows Schmidt in deleting passages as interpolated, she treats (or appears to treat) some of these passages as authentic (XI.7 and XI.10, on which see synopsis on XI; for equally unfortunate results, see Comm. on XVI.2 [54.17-18]). Her translation is also not free from omissions (in \textit{Book Two} alone, for example, she omits translating the whole of \textit{XXVIII.7} [104.9-13] ἐπιστρέψει…εῖ), (terminological) inconsistencies and errors (note especially that she has section XVIII.4 start with XVIII.3 [60.3] καὶ τὰς ἀλλας, etc.). On the whole, Murphy has produced a translation that is certainly more accessible than Schmidt’s (at least to readers who may not know German) but which lacks coherence and is misleading or confusing. Murphy’s illustrations are rudimentary, not always faithful to the text and occasionally without letter labels; despite her claim to the contrary (Murphy 8), additional elements not mentioned in the text are inconsistently indicated in the endotes or in the illustrations themselves. For reasons that she leaves unspecified, she did not see the manuscript diagrams.

A number of partial translations also exist, scattered throughout various books, theses, and articles. Let me single out only McCourt (2012), who offers not always accurate English translations of \textit{III.1} [14.17-16.4], \textit{V.3-5} [20.18-22.20], \textit{VI.1-2} [22.21-24.9], \textit{VII.1-VIII.2} [26.6-28.19], \textit{IX.1-3} [28.4-30.2], \textit{X.3} [34.12-13], \textit{XI.1-4} [36.1-28]. My debt to previous translations is clearly seen in the Commentary.
2.3 The present edition

The overview offered so far shows that previous attempts to edit and translate the treatise have been unsatisfactory to a greater or lesser degree. Until now, one major drawback was the absence of a comprehensive edition and commentary, an absence more acutely felt in recent years in response to the growing scholarly interest in ancient science and technology more generally and in Hero and his works more specifically. The present edition aims at partially filling this gap by offering the first-ever full-scale commentary on Book One, alongside a re-examination of the manuscript tradition and a systematic, consistent and accurate translation of the entire treatise based on a completely new text. The following aspects of this doctoral study should be particularly noted: (1) the edition depends on a larger manuscript-base than the edition of Schmidt, and alphabetical sigla have been consistently assigned to all manuscripts; (2) the constitutio textus and concomitant interpretation have taken into account, in addition to those emendations and editorial interventions already found in Schmidt’s edition, the contributions by Weil (1882), Olivieri (1901) and Schmidt (1903); (3) a more balanced approach has been adopted with regard to interpolations, and careful attention has been devoted to the nature and status of the text; (4) the oldest manuscript diagrams have been consulted and included in the study, and a whole new set of reconstructions accompanies the thesis (Appendix 4); (5) in order to facilitate comparison between pre- and post-Schmidt editions (where chh. XXII-XXV are arranged in different orders), a concordance of editions has been appended (Appendix 1). For an explanation of the principles and criteria followed in the present edition, see below, §6.
3. THE HISTORY OF THE TEXT OF THE AUTOMATA

On the basis of current evidence, the text of the Automata has been transmitted by 43 manuscripts either in its entirety or in part. Schmidt knew only of 38.\(^{71}\) The earliest manuscript dates to the thirteenth century: A (Marcianus gr. Z. 516, ff. 196v-209),\(^ {72}\) which Schmidt selected as codex optimus. All the other manuscripts are recentiores, dating from the fifteenth to the eighteenth centuries. The three other manuscripts upon which Schmidt mainly based his text all date from the sixteenth century. These are G (Gudianus gr. 19, ff. 1r-20v),\(^ {73}\) M (Magliabechianus II.III.36, ff. 125v-141r) and T (Taurinensis B.V.20, ff. 82v-101r), the last of which, having been heavily damaged by fire in 1904, now contains only portions of lines 2.1-66.6 (ff. 102v-114 are completely lost).\(^ {74}\)

In what follows, I shall first discuss Schmidt’s method of listing manuscripts and then provide an updated list, which includes those witnesses to the text that were unknown to him (Ba, Bd, Mb).\(^ {75}\) This will also allow me to provide information on my use of the manuscripts. I shall proceed to give a summary of Schmidt’s account of the tradition. This will lead to an examination of the relationships between the manuscripts. Finally, I shall offer conclusions and future lines of enquiry into the transmission of this text.

\(^{70}\) For reasons of space, and for the sake of legibility, the vast majority of references in this section to individual readings and portions of text cite page and line numbers only.

\(^{71}\) Schmidt, Supplemmentum 56 n. 1 cites Montfaucon’s (1739: 677) reference to three more manuscripts of the work, once in the possession of I. Voss in York (numbered 2256, 2312 and 2323). He suggested that since he knew of four Vossian manuscripts in Leiden, two of which contained the Automata (i.e. Lc and Ld), Montfaucon might have simply made a mistake. Another possibility is that the manuscripts were already lost in Schmidt’s time. I have been unable to trace these three manuscripts.

\(^{72}\) I follow Schmidt’s dating of the manuscript, which was confirmed through personal communication with D. Riccoboni. Scholars before him had argued for a twelfth-century date (Zanetti-Bongiovanni 1740: 278) or even a fourteenth- or fifteenth-century date (Haase); see Schmidt, Supplemmentum 3 with n. 4.

\(^{73}\) The last folio of the manuscript (f. 21) is erroneously indicated as 18 in Schmidt, Supplemmentum 7.

\(^{74}\) F. Porticelli, special collections librarian, Biblioteca Nazionale Universitaria di Torino, personal communication, June 30, 2015.

\(^{75}\) To these should be added Ha and Hb. Although Schmidt, Supplemmentum 10 knew of the existence of these manuscripts, he was not aware of the fact that, in addition to the Pneumatica, they both transmit the Automata.
3.1 List of manuscripts

Before listing the manuscripts, it is important to note that the treatise has come down to us under three different titles: Περὶ αὐτοματοποιητικῆς (the oldest attested form), Περὶ αὐτοματοποιητικῶν and Περὶ τῶν αὐτοματοποιητικῶν. (In my view, none of these is the original title, which I have reconstructed as Περὶ αὐτομάτων; see my detailed discussion below, §4.) Schmidt, Supplementum 54-6 classified the manuscripts in three main categories according to the presence, absence and form of the title, citing separately those whose title was unknown to him (in his list manuscripts are numbered continuously 1-38, followed by number 39, which corresponds to D'Auria's Latin translation). Schmidt's list is no longer satisfactory for at least three reasons. First, as will become clear below, the form of the title is not necessarily suggestive of a distinct branch of the tradition. Second, Schmidt lumped together manuscripts bearing the title Περὶ αὐτοματοποιητικῶν and manuscripts bearing the title Περὶ τῶν αὐτοματοποιητικῶν when in fact the latter form is a corruption of the former. Third, his fourth and last group of manuscripts (nos. 33-8) includes manuscripts whose title either was already known in his time (nos. 36-7) or is no longer unknown (nos. 33-4). The list below gives (in alphanumerical order) the name and date of each manuscript, and, when known, the folios containing the text or portion thereof (square-bracketed numbers refer to errors made by Schmidt in the respective descriptions of the manuscripts whereas angle-bracketed numbers and/or letters to information he did not provide). The following superscript signs when appearing over manuscript sigla are used to indicate, if known and applicable, the presence or absence of the (different forms of) the title: * = Περὶ αὐτοματοποιητικῆς, ** = Περὶ αὐτοματοποιητικῶν, *** = Περὶ τῶν αὐτοματοποιητικῶν, φ = no title. A superscript indicates that the title is unknown.

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76 Although I do not follow this system, in my list I have included Schmidt's numbers within square brackets to enable the reader to compare my discussion of the tradition with his earlier discussion. Note, however, that although Schmidt also adopted his numbering system for A, G, M and T, these are consistently referred to by sigla throughout his discussion.

77 Because most manuscripts of the Automata also contain the Pneumatica, the vast majority of such descriptions are scattered throughout the first chapter of Schmidt's Supplementum ("Der Handschriftliche Bestand der Pneumatik", esp. pp. 1-39), where he adopts a different numbering system. This can easily create confusion for the modern reader.
- Ambrosianus C 266 inf., saec. XVI, ff. 331v-349r = Aα [1]
- Ambrosianus D 131 inf., saec. XVI, <ff. 1r-28r> = AbH [16]
- Amstelodamensis III.F.26 (olim 104), saec. XVII, <ff. 1r-28r> = AcH [33]
- Angelicanus gr. 109 (olim S.I.17), saec. XVI (1548–1553), ff. 49r-67r = AdH [17]
- Barberianus gr. 69, saec. XVI-XVII, f. 6 (only 64.2-14 up to ἀβιλαν) = Ba
- Barberianus gr. 261 (olim II.82), saec. XVI, ff. 44r-66r = BbH [18]
- Baroccianus gr. 169, saec. XV (1476–1500), ff. 194r-212v = BcH [3]
- Bureianus gr. 108, saec. XVI1/4, ff. 81v-100r = BdH
- Escurialensis T.I.3, saec. XVI, <ff. 51r-69r> = EhH [19]
- Escurialensis Φ.I.10, saec. XVI, ff. 50v-<70r> = EbH [20]
- Fabritius 93 kvart (olim Hauniensis universalis 93), saec. XVIII, <ff. 1r-15v> = F'H [5]
- Gudianus gr. 19, saec. XVI, ff. 1r-20r = G'H [4]
- Harleianus 5589, saec. XVI3/4, ff. 19-27r = HaH
- Harleianus 5605, saec. XVI2-3/4, ff. 50v-69r = HbH
- Leidensis Bonaventurae Vulcanii 4, saec. XVI/XVII (1500–1600?), ff. 35<υ>–44<υ> (up to 32.18 ἐρωμέν) = LaH [21]
- Leidensis Scaligeri 45, saec. XV ex./XVI1, ff. 64v–96v = LbH [32]
- Leidensis Vossianus Miscellaneus 6, saec. XVII, ff. 35<υ>–39<υ> (up to 32.18 ἐρωμέν) = LcH [22]
- Leidensis Vossianus Miscellaneus 17, saec. XVII, ff. 11r[10]-36<υ> = LdH [23]
- Magliabechianus II.III.36, saec. XVI, ff. 125v-141r = M'H [24]
- Marcialus XXX.4 (Clars. 11), saec. XVI/XVII = MaH [35]
- Marcialus gr. Z. 516, saec. XIII1, ff. 196r-208r = A'H [6]
- Matriensis 4788 saec. XVI, ff. 52r-71r = MbH
- Monacensis gr. 431, saec. XVI, ff. 17r-36r = McH [7]
- Monacensis gr. 577, saec. XVII, ff. 1r-11r = MdH [8]

78 According to Schöne (1891: 73 n. 2), this manuscript, which was still available to Haase (see above, §2.1), was lost before the time of his writing. Unfortunately, I have been unable to trace the manuscript. I have used round brackets to indicate that the manuscript is lost.
Apart from A, G, M and T, Schmidt fully collated manuscripts La, Lb, Mc, Pi and R. Others he partially collated (Aa, Bb, Ma, Md, Ta), although the extent of his collations is not always clear. Additionally, he also relied on the (selective) collations made by Haase ((Ae), Pa, Pc, Pe, Pd, Pf, Ph), Hildebrandt (Vb) and Prou (Pa, Pb, Pe, Pd, Pf, Ph). On the other hand, he had no access, either direct
or indirect, to Ab, Ac, Ad, Bc, Ea, Eb, F, Lc, Ld, O, Tb, Va, Vc and Vd. In producing the present edition, I have prioritised the main manuscripts used by Schmidt and those that he did not collate or were unknown to him. Given the scope of this work, I have decided to leave out of consideration Pi, which Schmidt convincingly eliminated as apograph of A (Supplementum 114). I have thus seen manuscripts La, Lb, Lc, Ld, Pa, Ph, Pg and Pf, and photographic or microfilm reproductions of manuscripts A, Aa, Ab, Ac, Ad, Ba, Bb, Bc, Ea, Eb, F, G, M, Mb, O, Pb, Pc, Pd, Pe, T, Ta, Tb and Vd. I have also been able to consult images of Bd, Ha and Hb, but these manuscripts came to my attention too late to be examined and collated for the purposes of the constitutio textus and the stemmatic analysis. In addition to the lost manuscript (Ae), I have been unable to locate Ma, Mc, Md and Va. For this reason, and because of pressing time and financial constraints, I could not secure access to all manuscripts. I have therefore taken the readings of manuscripts (Ae), Mc and R either from the apparatus criticus or from the Supplementum of Schmidt. The same applies to those readings of T which are (a) partially preserved or (b) no longer extant. The following list gives all the occurrences of (a) and (b) within 2.1-66.6 (in the former case square brackets enclose portions of text now lost):

(a) [περὶ αὐτοματοποιητὴν], 2.2; βάρως, 8.20; πλειονότατοι, 8.20; [ἐξ]αρχής, 10.1-2; κατάποστας, 16.5-6; [ἐξαρτήσεις], 18.3; προ[λά]σεσθαι, 20.5; [πρ.,] 22.6; περ[ι]τείχεσθαι Τομη, 24.1; ἀπο[δείκνυσθαι] Τ1: [ἀποδεικνύσθη] ὁμόφως εἰς τὴν λέσχην κρίσεως μεխνος αὐτῆς. πάλιν ὅπως κατα[φερομένην] Τομη, 24.4; [περικρεμένην], 26.4; βάρος, 28.8; λειτουργίας, 32.11; κέρκος, 32.12; διάμετρου, 34.16; ἐπεισόδιος, 34.21; [καὶ] συμβιβασται, 36.16; ἀποδεικνύσθαι, 60.7; πόλις, 64.17;

(b) βάρος, 12.1; κατὰ Τ2: μετὰ Τ1, 22.2; εἰς, 22.21; προσωπικόν, 30.1; ἐκδόθην, 32.9; κλεισθεὶς…πληθυνθὸν Τομη, 32.14-15; ἦ, 34.7; περιειληφθεῖσα,

82 Strangely, his account of the tradition does not include discussion of Pg, although the manuscript had in fact been collated by Haase and Prou. Also, he did not mention Ma, Mcl, Pf, Ta among the manuscripts that were more or less known to him (see Supplementum 112 and 115). These discrepancies must probably have depended on the amount of information available to him.

83 These three manuscripts first came to my attention after my primary supervisor learned about them (see Ruffell 2016). Because of the tight timescale for the completion of the thesis, and because other in situ collations had yet to be carried out, it was decided to postpone collating Bd, Ha and Hb until I should be able to revise the thesis for publication (Prof. Costas Panayotakis, personal communication, June 14, 2017).
3.2 Schmidt’s account of the tradition

Schmidt divides his account of the tradition into three parts. Misleadingly titled “Der Archetypus der Automaten”, the first part combines discussion of the disruption of the order of chh. XXII-XXV with observations on the archetypal manuscript of the text (Supplementum 107-111). He convincingly argues that, because the manuscripts (known to him) have the disrupted chapter order, they

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84 All of the complete manuscripts that I have consulted (including Bd, Ha and Hb) have the following textual sequence: XXII.1-6 [70.4-74.3] Οι μήν οὖν... μέδος +XXIV.1-XXV.1 [80.1-84.11] σύνος γίνεται... τούς τεκτονεύοντας σύνος +XXII.6 [74.1-3] τῷ πίνακι... μέδος (with slight variants) +XXII.6-XXIII.8 [74.3-78.19] ή μήν οὖν διάθεσις... διόδος +XXV.1-7 [84.12-90.5] κλεισθέντως... ὑπόν (the correct sequence is henceforth resumed). The disruption is signalled in most manuscripts either with οὖν ἄμεταλφης ὁ λόγος οὖς (as in A and G) or with λέπτα (as in M), which appear (usually in the margin) where the repetition of XXII.6 [74.1-3] τῷ πίνακι... μέδος occurs. The editors’ principles (and before them Baldi 46 n. 5) took the marginal λέπτα to indicate a lacuna in the text (printed by Thévenot 266.25-6). Prou 133-7, who recognised the editors’ mistake (or, rather, the scribe’s mistake), argued that the repeated lines were the result of scribal interpolation (he considered the words τῷ πίνακι as belonging to the beginning of ch. XXV) and filled what he apparently thought was a different lacuna as follows. Τά μήν <οὖν> περὶ τούς τεκτονεύοντας σύνος <δ> τῷ πίνακι ζύγεται, γενομένης τῆς πρώτης ανάλυσος τῶν ὁμών. Ταύτας δ’ ἄμεταλφης ἀναγράφεσις δεί άμα συγκλεισθήσατο> XXV.1 [84.11-12] (Prou 133 n. 45 erroneously states that οὖν is found in PbdPdpPgPh the word is nowhere found in the manuscripts). Prou’s supplement does not restore the coherence of the text because it leaves the chapter order unaltered (ch. XXIV describes the first scene of the Nauplius play and must follow ch. XXIII, which describes how the doors of the πίνακας are opened and closed automatically). Schmidt’s text is based on Schöne’s (1891: 74 n. 2) restoration of the original chapter order. Instead, I follow Weil’s (1882) reconstruction, which, as we have seen in §2.1 above, was altogether overlooked by Schmidt. The difference between Weil’s and Schöne’s reconstructions lies in whether or not the words τῷ πίνακι are considered as repeated from the end of ch. XXII. My endorsement of Weil’s reconstruction is based on stylistic grounds. The πίνακας is not mentioned in the openings of chh. XXVI (Ταύτα μήν οὖν οὖς γίνεται, 90.6) and XXVII (Ο μήν οὖν παράπαρος οὖς γίνεται, 98.1), which follow the same pattern as XXV.1 [84.11-12]; cf. also XXIV.1 [80.1], where, however, the opening words have been supplied. The omission of τῷ πίνακι after ἀναγράφεσις (XXV.1 [84.12]) is easily explained by the very repetition of τῷ πίνακι. Neither Schmidt nor I consulted all available manuscripts, but I find it
all ultimately derive from a single common exemplar (‘Exemplar’, not ‘Archetypus’). Schmidt ascribes such disruption to a transposition of two folios rather than to the combination of said transposition with the replacement of a lost folio with a folio coming from a different manuscript (Schöne’s thesis), and advocates (wrongly in my view) for the archetype as a strongly interpolated manuscript. The second part, titled “Der kritische Wert von AGT für die Automaten”, examines the (comparative) value of A, G and T, mainly showing that (1) A is the best manuscript, and (2) AG belong to a superior class of manuscripts as against T (Supplementum 111-12). Building upon the analysis of the preceding section, the third part, titled “Beurteilung der übrigen Handschriften der Automaten”, assesses the rest of the tradition, and includes preliminary consideration of D’ Aurora’s Latin translation (Supplementum 112-18). Here Schmidt divides the tradition into two classes of manuscripts. One class consists primarily of manuscripts bearing the title Περί αὐτοματοποιητικῆς (as in A and G). To it also belongs Lb (where the treatise is untitled). This he regards as the better class (‘bessere Klasse’). The other, inferior class (‘schlechtere

unlikely that Ma, Va, Vb and Vc contain the correct textual sequence. On how the disruption occurred, see below, n. 86.

85 See already Schöne (1891: 74 n. 2).
86 Schöne’s (1891: 74 n. 2) thesis rests on two facts: (1) the repetition of XXII.6 [74.1-3] κεραυνὸς…μύθος; (2) the lacunose state of XXIV.1 [80.1]. In his view, the lost folio contained XXII.6-XXIV.1 [74.3-80.1] ἢ μὲν οὖν διάθεσις…<Καὶ ταῦτα μὲν> and was replaced by another folio which contained more words at the beginning (κεραυνὸς…μύθος) and less words at the end (hence the lacuna at the beginning of ch. XXIV). I espouse Schmidt’s thesis (Supplementum 108-9) that the scribe, after skipping one folio and realising his mistake, signalised the disruption by repeating the lines immediately preceding the end of ch. XXII (which, however, would include τῶ πίνακε, following Weil’s reconstruction) and by writing in the margin the words ἤτα συνέχεις ὁ λόγος οὗτος (which are indeed attested in the oldest manuscript). The textual divergences between the two iterations of XXII.6 [74.1-3] τῶ πίνακε…μύθος can be explained by assuming that the scribe was citing from memory. Equally, the omission of the initial words of ch. XXIV need not necessarily have occurred at the same time as the disruption, and might represent a later stage of the transmission. Schmidt’s thesis makes sense only if we assume that, out of the four folios containing chh. XXII-XXV, the first and the third were rectos: (a) […]XXII.6 [74.3] καταστροφὴν εἶχεν ὁ μύθος, (b) XXII.6-XXIII.8 [74.3-78.19] ἢ μὲν οὖν διάθεσις…διδόσια, (c) XXIV.1-XXV.1 [80.1-84.12] <Ταύτα μὲν οὖν>…τοῦ τεκτονεώτατος οὗτος, (d) XXV.1 [84.12] κλεισθέντος δὲ καὶ[…] (where b) and (c) have been transposed).
87 Schmidt, Supplementum 110 bases his argument mainly on the assumption that XI.7 [38.15-40.2], XI.10 [40.17–42.3] and XXVI.4 [92.14-17] are the result of interpolation. I believe that these passages are authentic, and consider the treatise to have been compiled from various sources. See further below, §5.6 (esp. §5.6.1 on snake-like motion). Regardless of the passages in question, Schmidt’s appeal to interpolation is logically flawed because extraneous material is much more likely to have been interpolated at a later stage.
Klasse') consists of manuscripts bearing the title 'Περὶ αὐτοματοποιητικῶν (as in M and T) or 'Περὶ τῶν αὐτοματοποιητικῶν.' In addition to these two classes, he identifies three broad groups of manuscripts:

(a) Aa (Ae), Mc and Md, a group closely allied to G. Aa, Ae and Mc are shown to be independent of each other, whereas Md is considered a copy of Mc. Ph, which Vincent (1858: 171) was inclined to consider a copy of (Ae), closely follows this group (Supplementum 112-13);

(b) Pa, R and presumably Ta, a group closely allied to T. Pa and R are dismissed as unimportant in view of this affinity (Supplementum 115-16);

(c) Bb, La, M, Ph and presumably Pd (Supplementum 116-17).

Two points are especially striking about Schmidt's evaluation and use of the manuscripts. The first is that he seems to include M among the codices potiores, although in fact he discusses it together with the other manuscripts (his consensus codicum a indeed comprises only AGT). The second point is that he is inclined to regard even those manuscripts of which he has no knowledge as either good or bad, depending on which title they bear (see Schmidt, Supplementum 114, 117). I have investigated the manuscript tradition in more detail and have constructed three provisional stemmata based on a partial collation of the manuscripts (Appendix 3). (Note that, in order to avoid incorrect, incomplete or misleading results, my stemma includes neither those manuscripts which Schmidt collated and which I did not collate nor the lost manuscript (Ae) nor the extremely fragmentary manuscript Ba for the purposes of the constitutio textus, I have undertaken a complete collation of A, G, M and T, the last three of which have been consistently cited in the apparatus criticus as representatives of different sub-branches of the tradition.) As I shall demonstrate, my investigation offers some significant corrections to Schmidt's analysis.

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88 See Schmidt 336 (Conspectus Notarum).
89 In the stemmata, I use dashed lines to indicate contamination.
3.3 Stemmatic analysis

The manuscript tradition divides into two branches: branch $\beta$, represented by manuscripts $A$, $Aa$, $Bc$, $Ea$, $F$, $G$, $Lb$, $O$, $Pb$, $Pc$, $Pe$, $Pg$, $Vd$ (Stemma 1); and branch $\gamma$, represented by manuscripts $Ab$, $Ac$, $Ad$, $Bb$, $Eb$, $Ld$, $M$, $Mb$, $Pa$, $Pd$, $Pf$, $Ph$, $T$, $Ta$, $Th$, and the fragmentary $La$, $Lc$ and $Ba$ (Stemma 2). The disruption of the order of chh. XXII-XXV suggests that both these branches derive from a common hyparchetype ($\alpha$) rather than directly from the archetype ($\Omega$), which will have presumably contained the correct sequence of chapters. Manuscripts of the $\beta$ branch are superior to manuscripts of the $\gamma$ branch, as is clear, for instance, from the following textual divergences:

12.11 τῆς $\beta$ : καὶ $\gamma$ (praeter Ba)
20.16 οὗ $\beta$ : καὶ $\gamma$ (praeter Ba)
20.19 κνώδακι $\beta$ : κνώδαξι $\gamma$ (praeter Ba)
28.15 ὅταν $\beta$ : οὖτος $\gamma$ (praeter Ba)
36.3 ἔτι $\beta$ : ἔστι vel ἔστι vel ἔστι vel ἔστι $\gamma$ (praeter BaLaLc)
42.5 ὡς $\beta$ : ὡς καὶ ὡς $\gamma$ (praeter BaLaLc)
64.11 τῶν $\beta$ : καὶ $\gamma$ (praeter LaLc)
82.8 τρυπῶ $\beta$ : τρύπημα $\gamma$ (praeter BaLaLc)
100.12 ἐπιστύλου $\beta$ : στύλου $\gamma$ (praeter BaLaLc)
102.23 γὰρ $\beta$ : τὸ $\gamma$ (praeter BaLaLc)

This bifurcation is further evidenced by a number of omissions that are found in $\gamma$ but not in $\beta$. Take the following examples:

4.10 δὲ $\beta$ : om $\gamma$ (praeter Ba)
28.13 γὰρ $\beta$ : om $\gamma$ (praeter Ba)
28.20 τῶν $\beta$ : om $\gamma$ (praeter Ba)
54.13 οὖτος $\beta$ : om $\gamma$ (praeter BaLaLc)
58.9 καὶ $\beta$ : om $\gamma$ (praeter BaLaLc)
These two branches are each further subdivided into two main sub-branches, with the β branch leading to A and δ, and the γ branch leading to ε and ζ. Let us first consider the β branch and then turn to γ.

3.3.1 The β branch

The manuscripts belonging to this branch share only one error in common, namely the omission of 90.6 οὖν. The δ sub-branch contains manuscripts Aa, Bc, F, G, O, Pb Pc, Pe, Pg Vd and cannot stem from A, because A (and its indirect descendants Ea and Lb) has a separate error at 22.19 ἀμον (ἀν δ). Schmidt, Supplementum 111 rightly regarded A as the codex optimus because it has comparatively few significant errors and offers good readings not found in the other main manuscripts: 2.9 ἡστι δὲ (ὁστιν A₆), 14.14 δ’ ἐν (δὲ οὐ A₆), 96.12 μέρος (shared by 1). (Of these readings, he cites only 14.14 δ’ ἐν and 96.12 μέρος, to which he further adds 20.13 εὐθείας; but here A reads ἐπευθείας rather than ἐπι εὐθείας.)

On the other hand, the vast majority of the δ manuscripts offer a superior text than A at 20.20 ἐν τοῖς (ἐντοι A Pc) and 24.8 ἀποπείρα (ἀποπείρα P₆), although they share the former reading with ε and the latter with χ. (Schmidt, Supplementum 112 cites the former reading among the good readings of G; for the disadvantages of his approach, see below.)

δ splits into two further sub-branches (σ and 1), containing, respectively, manuscripts Aa, Bc, G, F, O, Pb Vd and Pc, Pe, Pg.

The σ manuscripts share several conjunctive errors, which prove that they form a close-knit group:


They share an error found in A:

8.8 συνεσμηρισμένας] ἔχον ἐσμηρισμένας (ἔχον εσμηρισμένας A₆)
They share two errors found in ζ:

6.16 δὲ ἐφηλωτῶν] δὲ ἐφηλατῶν
36.13 εἰργασμέναι] εἰργασμένας

Pe and Pg cannot derive from Pc because Pc has the following separate errors against both manuscripts:


Pc cannot derive from Pe and Pg because the latter two manuscripts share at least two significant errors not found in Pc: 2.17 καὶ] καὶ, 20.19 ἐν ὧ] ἐν ὧ ἐν ὧ φ. Cf. also the correct reading of PePg at 20.14 ἀποπορεία not found in any other manuscript, including Pc (ἀποπορεῖα). Pe cannot have been copied from Pg because Pg has a separate error at 18.17 ἀναπτυσσόμενος (a reading taken from ζ). Similarly, Pg cannot have been copied from Pe because at 14.12 Pe has an error (καὶ νέοτέρον) which Pg could hardly have corrected by conjecture (καὶ νότερον Pg). Pe and Pg thus seem to share a common exemplar (ξ), in its turn derived from ι.

Manuscripts Αα, Βc, F, O, Pб and Vδ ultimately derive from a common exemplar with G, namely θ, as shown by the following conjunctive errors:


The existence of intermediate exemplars (v and τ) between θ and Αα, Βc, F and O (from which are indirectly derived Pb and Vδ) is supported by two facts. The first is that all these manuscripts (henceforth indicated by v) share at least two significant errors not found in G:

4.13 ἀφύρες v (σφύρας AeC Om) : ἀφύραις G (sicut 1)
64.17 γιγκύμω ν (γιγκύμω F) : γιγλύμω G (sicut M*ed)

The second is that Aa, Bc and O (together with its indirect descendants Pb and Vd) share a number of conjunctive errors not found in F:

2.3 αὐτόματοποιητικῆς] αὐτόματης (αὐτόματοποιητικῆς Oπ), 2.10 προσάγονται] προσαγορεύονται, 42.3 μεσολαβοῦσα] μεσοσυλλαβοῦσα, 54.13 οὖν] δὲ, 92.12-14 περιείλειν... πίνακος om, 96.1 δὲ] δὲ καί.

Aa, Bc and O must therefore derive not from ν (as F seems to do) but from its descendant τ. Before looking more closely at the τ manuscripts, let us consider F. Fs scribe seems to have had access to G because the manuscript contains errors of G not found in the other witnesses: 6.1 δημιουργοῦντας] δημιουργοῦντας, 32.14 ὁμίῳν] ὁ μῆν, 48.10, βάρη] βάρα, 52.20 αὐτόματα] αὐτόματος. Cf. also the following two passages, where F reproduces (almost exactly) the readings of G:

100.18 ἐπιμήκει κειμένη Fπ (the main text reads ἐπιμήκει μένη, which shows that the scribe does not realise that G’s underlining is meant to correct κειμένη to μένη)
108.10 με-τὸ Gζ: με- vac. c.3 τὸ F (Fs underlining draws the reader’s attention to the tentative marginal correction μέσον, presumably taken from the γ branch)

F also shows signs of cross-contamination from ν (cf. 90.14 ὑπογεγραμμένα) and o (cf. 90.14 ἐν, 106.1 ἀποσπασθείσης, the former also occurring in Pe*ed).

Aa, Bc and O form a recognisable subgroup, as shown by the following agreements:


Aa and Bc probably derive from a common sub-hyparchetype (u) because they both have at least one significant error not found in O: 50.17 γίνεται] καὶ γίνεται (καὶ γίνεται Aa). Bc cannot derive from Aa for chronological reasons, and
because it has the correct text at 28.8 κορυφή (κοινωφή ΑαΟ) and 100.15 ἔπαρσιν (ἐπάρπασιν ΑαΟ). Similarly, Αα is independent of Βc because of the following two separate errors of Βc against Αα: 80.9 μὴδὲν μὴ δὲ, 110.8 καὶ καλυφθήναι] κεκαλυφθήναι. Manuscripts of this subgroup show signs of contamination from the γ branch, and perhaps more specifically from ζ: cf. readings at 4.12 σκεπανίζοντα, 6.15 ἀπωθόσαντες (a further corruption of ἀπωθόσαντες) and 20.12 πεπερασμένοις (a reading found in ζ and also shared by BBbEaLbTB). Cross-contamination is also likely to have occurred between Αα and, respectively, ο and Ψθ for the former relationship, cf. 42.2 τούτον (Ααοδ : τούτον ο) and 48.17 ἔπαρτος (a reading tentatively added by Ααον and which in all probability was already found in ρ); for the latter, cf. 106.12 ἀμπικας (Αα Ψθι(δεβηαν)).

Ο, Ψθ and Vd share the following errors against Αα and Βc:

20.9 ἀποπορεία] ἐμπορείας (ἐκπορείας Ψθ), 46.2-3 τὰ δὲ... ζητικομ, 94.8-9 τὸν ἐν... κανόνα μομ, 98.9-11 ἐν φ... δελφιναρίου μομ

Ψθ and Vd share numerous conjunctive errors not found in Ο, for instance:

4.6 θυραγον] ρυτον, 22.2 ἡ μιν] ἡμιν, 50.21 κλειδριον] κλειτριον, 52.20 αὐτόματα τὰ] τὰ αὐτόματα, 58.5-6 πάχος... ἄξονος μομ, 66.4 βροντης] βροντης, 80.8 μαλα κατεργασιμαν] μαλακα τετεργασιμας, 108.18 τὰ κύματα] τὰ κύματα καὶ κύματα.

Ψθ cannot derive from Vd because Vd has omissions not found in Ψθ: 22.1 ἵσου, 30.19-22 πορευθήναι... τευράν (πορευθήναι om Ψθ), 66.21-22 ἀναγεγραμμένον... αὐτοῦ (omitted also by BBbTa probably through contamination), 106.4 ἡμίν. Likewise, Vd is unlikely to have been copied from Ψθ because Vd does not reproduce the text of 42.5-7 as it appears in Ψθ: ὡς ἐὰν προαρισμέθα διαμεμηριμένα, ὡς εἰρηται, καὶ ἢ τοῦ πλυνθίου] ὡς εἰρηταὶ, καὶ ἢ τοῦ πλυνθίου ἐὰν προαιρησθεῖσθη διαμεμηριμένα ὡς εἰρηται καὶ ἢ τοῦ πλυνθίου. Ψθ and Vd, therefore, seem to be close copies of an exemplar (ω) derived from Ο.

The θ manuscripts present a superior text than Α at 6.19 ὑτάρχημ, 40.19 ἐτέρους, 106.7 ἑδαφος, 106.13 θωράκιον, 108.13 περόνιον, although some of
these readings are shared either by ε (106.7, 106.13), by η (6.19) or by both (108.13). (Schmidt, Supplementum 112 cites 40.19, 106.7 and 106.13 among the good readings of G but he clearly overlooks the connections between G and manuscripts of the ε branch, in particular M.) G is superior to the other manuscripts of this family (including the earlier manuscript Bc) because, as the lists above have shown, they contain a number of additional errors not found in G. G has a better reading not found in A, M and T at 108.17 τούτω (shared also by AaAcLdT).

Finally, before moving on to consider the γ branch, let us look at Ea and Lb. These two manuscripts (the former of which transmits the text under the title Περὶ αὐτοματοποιητικῶν, whereas the latter has no title) share some errors of A not found in the other manuscripts. In addition to 22.19 ἄμον (see above), cf. the following (minor) errors: 20.2 γὰρ γενηθέντων] γὰρ γενηθέντων (in A two letters have been erased after γε, perhaps νν, as suggested by comparison with γεν- in γενηθέντων), 36.15-16 περιειλθεῖσα] περιειλθήσα, 62.6 ύπερ τρόχων] ύπερτρόχων (here T now reads [***]όχων, although the agreement of EbPaTa gives us what is in all probability the original reading, ύπερ τρόχων; PF’s corrupt reading ύπερ τρόπων, too, supports both the word-division and the accentuation). Ea and Lb also share numerous conjunctive errors that prove that they are gemelli. Some examples:


Both manuscripts share an error found in ε:

94.10 ἐξηρτημέναι] ἐξητημέναι

They also share some errors found in ζ, for instance:

4.12 πρίζονται] περίζοντα (περὶ ζόντα Ea)
80.14 ἔτρωπησα] ἡμρώπησα

Lb cannot derive from Ea because Ea has omissions not found in Lb. 14.18 τεσσάρων (τεττάρων Lb), 16.15 τοῦ. Ea also has a separate error at 88.2 τρώπημα (a reading taken from ζ; here Lb has τρώπνα, an error probably due to a misreading of the exemplar, which in all likelihood will have reproduced the hardly legible reading found in A: τρυπᾶν Ἀτ: τρυπω Ἀτ(τ. αὐτου). On the other hand, I have been unable to find errors peculiar to Lb which could exclude the possibility that Ea has been copied from Lb. The close correspondences between the two manuscripts would suggest that Ea is the apograph of Lb, but in the absence of a full collation it is difficult to reach definitive conclusions. Regardless, it seems clear that the two manuscripts derive from a descendant of A which is now lost and in which the treatise was untitled (η); Ea must have taken its title from γ.

3.3.2 The γ branch

The γ branch is more complex than the β branch. Its two sub-branches (ε and ζ) contain, respectively, manuscripts Ab, Ac, Ad, Bb, La, Lc, Ld, M, Mb, Pd, Ph, Tb (and apparently also the exiguous fragment of Ba) and Eb, Pa, Pf, T and Ta. The ε manuscripts share errors not found in ζ, and vice versa, although there are evident traces of contamination between the two sub-branches:

4.1 κεκλεισμέναι ε (praeter BaThcol) : κεκλεισμένων ζ Tbcol
6.19 ύπάρχον τι ε (praeter BaLaK) : ύπάρχουν τι (vel τι vel τι) ζ (praeter TaK) : ύπάρχον τι TaK : ύπάρχουν LaK
10.18 κατὰ ε (praeter Ba) : ἐπὶ om. ζ
12.10 στατοίς ε (praeter Ba) : στρατοίς ζ
64.3 ἀναγεγράφθαι ε (praeter LaLc) : ἀνεστράφθαι ζ (ἀνεστράφ[***] Τ)
106.4 ἐμοί ε (praeter BaLaLc) : ἢ μὲν ζ

ε splits into two further sub-branches (κ and λ), containing, respectively, manuscripts Ab, Ac, Bb, La, Lc, Ld and Ad, M, Mb, Pd, Ph and Tb. The
following readings shared by some manuscripts of κ and λ, indicate that there has been contamination between the two sub-families:

42.1 τριῶν] ποιῶν vel poioν AdAb\textsuperscript{mg}BbPd
42.11 κινήσεων] κινήσεως BbM\textsuperscript{Tb}
54.6-7 ἐκδεδεμένα] ἐκδεδομένα AbAcAdBbLd (ἐκδεδεμένα Ac\textsuperscript{c})
80.15 ἐποίησα] ἐποίησας BbM\textsuperscript{c}
96.11 ἔλκυσθείσης] ἐκλυθείσης AbAcAdLdM\textsuperscript{Tb}

The λ manuscripts share a few conjunctive errors and probably derive, through intermediaries, from a common exemplar. I list the common errors that I have found: 2.11 ὁρισμένους] ὁρισμένα, 10.7 κατατεγμένος] κατατημένος, 92.1 εὐστροφα] εὐστροφαί. The following partial agreements should also be noted:

62.1 ἡλειθρὸν M\textsuperscript{Tb}: ἡλειθρὸν AdPdPh: ἡλειθρὸν Mb
72.1-2 τελεύεσιν M: τελέκεσιν AdMb: τελέβεσιν PdPh\textsuperscript{Tb}\textsuperscript{2}(τελέκεσιν Tb\textsuperscript{mg})
104.21 ἐπισπασμένην AdM MbPdPh: ἐπισπασμένην Tb\textsuperscript{c} (ἐπιπασμένην Tb\textsuperscript{cd})

The exact relationship between manuscripts belonging to this group is difficult to establish.\textsuperscript{90} However, it seems possible to make the following suggestions:

(1) Ad, M, Ph, Tb seem to ultimately depend on a different sub-hyparchetype (ω) from Mb and Pd because they have at least one significant error not found in Mb and Pd. 64.10 ἀναγεγραμμένοι] καὶ ἀναγεγραμμένοι. Conversely, Mb and Pd have a separate error at 96.11 ἔγκυσθείς (cf. above; ἔκδεισις Ph\textsuperscript{c}: ἔχρυσθείς Ph\textsuperscript{cd});

(2) Ad and Ph seem close to each other and perhaps presuppose a common exemplar (χ), as suggested by the following conjunctive errors not found in the other manuscripts: 8.2 ὁσκίνητα] ὁσκίνειτα, 52.14 εὐαρμόστως] εὐαρμόστος, 54.3 μέρους] μέρου, 64.19 ὠστε] ὠσται. Ph cannot derive from Ad because of the following separate errors of Ad against Ph: 58.17 τὴν λ’ om,

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\textsuperscript{90} According to Prou 132, Pd and Ph seem to be apographs of Pa. This cannot be because Pd and Ph share no substantial errors with Pa.
Similarly, \textit{Ad} cannot derive from \textit{Ph} because of the following separative errors of \textit{Ph} against \textit{Ad}: 66.9 πολλῶν] πολλῶν, 96.7 ἐξελίσσειν] ἐξελισσεῖν. Cf. also above under (1);

(3) \textit{Tb} appears to have a closer relationship to \textit{M} than the other manuscripts of this group, although it generally presents a more corrupt text than \textit{M} and shows signs of contamination (I have called their hypothetical hyparchetype \textit{ψ}). Consider especially the following common omissions of \textit{M} and \textit{Tb} not found in the other manuscripts and which \textit{Tb} has often filled either above the line or in the margin: 2.17 ἵ (add. \textit{Tb}24), 16.2 ἐπίκειται (add. \textit{Tb}27η), 26.21 ἵ (add. \textit{Tb}24), 98.13 ἵ. Cf. also the following common errors in both manuscripts and not found elsewhere: 18.2 τόπον] τρόπον (τόπον \textit{Tb}26), 26.18 οὕτως] ἔτι (οὕτως \textit{Tb}27η) 90.6 κλεισθέντος] κλεισθέντος (κλεισθέντος \textit{M}20), 90.14 ὑποπεφραγμένα] ὑπογεφραγμένα. \textit{Tb} appears to have derived some readings from \textit{θ} (for instance 94.4 ἐν αὐτῷ) and from \textit{ζ} (for instance 80.12 ὅμο-χόρους, also shared by \textit{Mb}). See also above.

In comparison with other manuscripts belonging to the \textit{ε} branch, \textit{M} more consistently offers good readings not found in \textit{A}, \textit{G} and \textit{T}. Schmidt, Supplementum 117 belittlingly calls these ‘leichteren Verbesserung’ and claims (rightly, I believe) that they are due to conjectural emendation. He gives a list of 19 passages but singles out as particularly remarkable only three: 8.3 ἐγκυκλίους (so also \textit{Tb}, the other \textit{ε} manuscripts are variously corrupted), 10.8 ἐσται δῆλον, 94.17 πλείων (so also \textit{OTa} and the other \textit{ε} manuscripts except \textit{Bb}, which derives its reading, πλείων, from a different branch). Cf. also especially 6.6 μηδὲν ἐπὶθ-τοῦντα (μηδὲν ἐπὶθητοῦντα \textit{AcLc}), 16.11 ἐκπεπτακοῦν (ἐκπεπτακοῦν \textit{Ph}) and 100.18 ἐπικειμένη.\footnote{Schmidt, Supplementum 117 strangely cites the first two readings among the conjectural improvements of \textit{La}. His app. crit. to 6.6 [=342.8 Schmidt], on the other hand, records only \textit{Bb} and \textit{La}} It is likely that most of these conjectural corrections were already in \textit{ε}.

Manuscripts \textit{Ab}, \textit{Ac}, \textit{La}, \textit{Lc} and \textit{Ld} ultimately derive from a common exemplar with \textit{Bb}, namely \textit{κ}, as shown by the following conjunctive errors:

There is also little doubt that some errors common to Ab, Ac, Bb and Ld and occurring beyond the point in which La and Lc break off were already found in κ: 36.7 ἀξὶνες] οἱ ἀξὶνες, 58.14 ἀποδεδέσθω] ἀποδεδέσθω, 64.18 κατακεκλιμέ- νον] κατακεκλιμένον (κατακεκλιμένον Ac²mg : κατακεκλιμένον Ld²mg).

Contamination is likely to have occurred at the level of κ because all these manuscripts have the same reading (or insignificant variations thereof) as that found in Ac (2.9 ἔστι δὲ BbLa: ἔστι δὲ Ab: ἔστι δὲ AcLd: ἔστι δὲ Lc).

Manuscripts Ac, La, Lc and Ld seem to descend (through various intermediaries) from a common exemplar with Ab which was copied from κ, namely o. This is suggested not only by the fact that all these manuscripts have the title Περὶ τῶν αὐτοματοποιητικῶν but also by the presence of conjunctive errors of Ab, Ac and Ld. The ones that I have found all occur beyond the point in which La and Lc break off (for the relationships between La, Lc and Ld, see below). Some instances:


Cross-contamination is likely to have occurred at the level of o, too, because Ab, Ac and Ld all share with β the omission of 90.6 οὖν (on which, see above). Ab, furthermore, seems to have consulted A (or, perhaps more likely, its apograph Ρ) because it shares with A the omission of 12.9-10 διὰ... ἐμβάλλεται (add. Am² Ab¹mg).

The existence of intermediaries between o and Ac, La, Lc and Ld can be inferred from the following considerations.

(1) Ac, La, Lc and Ld cannot derive from Ab because Ab has numerous errors and omissions not found in Ac, La, Lc and Ld (or in Ac and Ld alone when these occur beyond the point in which La and Lc break off). Some examples: 6.10-11 οἱ τρόχοι... μήτε om. (add. Ab¹mg), 34.13 καὶ ταπεινωθῆσεται
om. (add. *Ab¹*), 58.15 εἰς ἡς. Given the mutual independence of *Ac*, *La*, *Lc* and *Ld* (on which, see points below), the following error common to these manuscripts and not found in *Ab* was already in their common (ultimate) exemplar (φ): μήγατι φ : πήγατι *Ab*

οίρος (a reading probably taken from *Bb*). The same applies to some errors common to *Ac* and *Ld* and occurring beyond the point in which *La* and *Lc* break off. One example: 100.6 ἐκποίσει] ἐκπόσει.

(2) *La*, *Lc* and *Ld* cannot (partly) derive from *Ac* because *Ac* has the following omissions not found in *La*, *Lc* and *Ld*: 6.12-13 εἰς τὸ ὀπίσω, 30.3-32.3 ἥ δὲ ἀλλ'.

(3) *Ac*, *La* and *Lc* cannot (partly) derive from *Ld* because *Ld* has a separate error at 16.5-6 διακαταλύπτοντα (καλύπτοντα *Ld³*), a reading taken from β and appearing also in *La φ Ta*, *Ac³* corrects the reading of other ε manuscripts, διακαταλύπτοντα, τὸ διακαταλύπτοντας). Given the independence of *Ld* from *La* and *Lc* (on which, see point (4) below), it is likely that the following errors common to *La*, *Lc* and *Ld* and not found in *Ac* were already in *Lds* direct ancestor (*aa*): 18.17 ἀναπτισμός] ἀναπτισμος, 20.18 τὸ, 30.21 αὐτόν τὴν ομ.

(4) *Ld* cannot derive from *La* and *Lc* both because the latter two manuscripts are incomplete and because they share the following conjunctive, separate errors against *Ld*:

16.9 κοινοειδὲς ομ., 20.14 γίνεσθαι] γίνεται (γίνεσθαι *Laⁱ⁰* *Ld*), 26.8 διήχου] διήχω, 28.7-8 τροχοί...πρὸ ομ.

*Lc* cannot derive from *La* because *La* has the following separate errors against *Lc*: 2.4 ἡξιωμένης] ἡξιωμένας (ἡξιωμένος *Lc*), 2.17 ὑπόδειγμα] ὑπόδειγμας, 8.8 συνεπεμβαμένας] συνεπιμεμρισμένας (συνεπιμεμρισμένας *Lc*, a reading shared by *AbAcBbLd*). Similarly, *La* does not seem to have been copied from *Lc* because *Lc* has at least one separate error against *La* 20.10 ἀπάνω] ὀπάνω (ἀπάνων *Lc³*). It is therefore likely that *La* and *Lc* descended from a common, incomplete exemplar (ββ), in its turn derived from *aa*.

Although *Ac* and *Ld* are somewhat removed from one another, they often share the same variant readings and marginal annotations. Some of these are
nothing more than erroneous conjectures, while others are the result of contamination from β - or, in some cases, more specifically from 1. As an illustration, consider the following agreements:

1.22.13 ἀρμόζοντα Ac1Ld1 (in textu) : ἀρμόζοντι Ac2mg Ld1 (sicut 1, de quo vide supra)
1.54.12 θερίζοντα Ac1Ld1 (in textu) (sicut ceteri codices familiae ε) : πρίζοντα Ac2mg Ld1
XX.264.7-8 ἐπιγράφειν καινότερον Ac1(ἀνιγράφον αντι ἐπιγράφον δεδομένo) Ld1 (in textu) (sicut ceteri codices familiae ε) : al. cod. γράφειν καιν[+]τερον Ac2mg : al. cod. γράφειν καινούτερον Ld1 (γράφειν καινότερον β)
XX.164.8 πρὸ ἡμῶν Ac1Ld1 (in textu) (sicut ceteri codices præter EaPcξ) : πρὸς ἡμῶν Ac2mg Ld1 (sicut Pc : πρὸ ἡμῶν Eaξ)

Let us conclude our analysis by turning to ζ. Within this family, we can distinguish, on the one hand, between Pf and Ta and, on the other, Eb, T and Pa. Pf and Ta appear to derive directly from ζ and to have little independent value when compared with other manuscripts of the same family, especially T. This is so for two reasons. First, Ta presents a composite text, with readings taken from β and ε. Examples of the former:

16.5-6 καλύπτοντα Ta : διακαλύπτοντι T (sicut EbPaPf)
66.7 κατατρέχοντας Ta (sicut Bbadv) : κατατρέχοντες T (sicut ceteri codices familiae γ præter Bbadv)

Examples of the latter:

16.11 ἐκπεπτακώοις Ta : ἐκπεπτακώοις T (sicut EbPaPf)
20.21 συμφωνεῖς Ta (sicut Pe) : συμφωνής T (sicut ceteri codices familiarum β et ζ)
22.1 οἱ Ta (sicut Fmg) : οἱ T (sicut ceteri codices familiarum β et ζ præter Fmg)

See also above. Second, Pf seems more corrupted than T (I will provide some examples below). Pf cannot derive from Ta for chronological reasons, and because Ta has the following errors peculiar to itself: 36.4 καὶ ὁ θ, 96.7 ἐξελίσ-
σειν] ἐξελίξειν (ἐξελίσσειν Τα[4]), 108.11 περονίφι] περόνιν. Similarly, Τα cannot derive from Πφ because Πφ has the following two unique omissions:
24.3-4 ὁμοίως... πάλιν, 100.14-15 τὸν... πραγ-.

Manuscripts Εβ, Τ and Πα share a number of conjunctive errors not found in Πφ and Τα.

8.6 εἰς om. (add. Ταιν), 10.11 καὶ] τῆς (καὶ Ταιν), 20.11-12 ἔστι φανερὸν] ἐπιφανερόν (ἐπιφανερὸν Τ1 : ἔστι Ταιν), 22.2 κατὰ) μετὰ (κατὰ Ταιν Εβταιν Ταιν), 36.16 συμβησται] καὶ συμβησται (καὶ Τ).

Εβ and Πα, moreover, share conjunctive errors (presumably) not found in Τ:


Εβ is closer to Τ than Πα is, because it reproduces, either exactly or nearly so, some omissions and marginal additions of Τ that Πα does not: 24.3-4 -δόσθω... καταφερο- (ἀποδεικνύει ἔστι Εβ1 : ἀποδεδόθω... καταφερομένη add. Ταιν Εβταιν), 28.11 καὶ (add. Ταιν Εβταιν), 32.14-15 κλειδρίον... πλινθὸν (add. Ταιν Εβταιν), 54.4 περιπλήκται... σπάρτου (add. Ταιν : σπάρτου... τῆς add. Εβταιν). These dissimilarities between Εβ and Πα, along with the existence of errors of Εβ not found in Πα (for instance 80.14 αὐτήν] αὐτοῦς), suggest that Πα does not derive from Εβ. Similarly, Εβ cannot derive from Πα because Πα has the following separative errors against Εβ: 6.10 μετὰ om., 16.7 ναῑκος] ανίκος, 36.21-22 χάλασμα] χάσμα. There is, therefore, enough evidence to suggest that Εβ and Πα are descended from the hyparchetype of Τ (μ) through a common intermediary (σ).

Finally, note the following agreements between, respectively, (1) Εβ and Πφ and (2) Πα and Πφ:

(1)
2.6 συνελόντι] συναλόντι (corr. Εβ24)
(2)
20.13 εὐθεῖας] ἐπαλὸν θείας (Πα[4])
22.3 αὐτή] αὐγή
3.4 Conclusions and future research

In this section, I have shed new light on the history of the text of the Automata. As has been seen, Schmidt divided the manuscript tradition into two branches, within which he identified three rather vague groups of manuscripts. While he was able to eliminate Md and Pi as apographs, his analysis did not go far enough in examining the relationships between the manuscripts and, in particular, between the main branches of the tradition. My starting point has been Schmidt's classification of the manuscripts. I have focused my attention on updating his classification, on the one hand, and on attempting to establish the relationship between the manuscripts, on the other. My stemmatic analysis has demonstrated three things:

1. While Schmidt's division into two branches still broadly holds, the manuscript tradition is much more fluid than his account leads us to believe (for cross-contamination, see *Stemma 3*, where, for the sake of simplicity and clarity, I have indicated only the first layers of the main families of manuscripts). Manuscripts belonging to the β branch almost always, but not exclusively, share the title *Περὶ αὐτοματοποιητικῆς*. Although in fact belonging to the β branch, manuscript Ea has been shown to have derived its title (*Περὶ αὐτοματοποιητικῶν*) from the γ branch. Schmidt's criterion for predicting the value of individual witnesses, therefore, is no longer entirely adequate;

2. Although G and T occupy a lower position in the stemma when compared to other manuscripts of their families, they are of superior stemmatic value and should therefore be retained as representatives of their branches;

3. Because M offers good readings not found in A, G and T and presents a purer text than Tb, it deserves to be included among the main manuscripts. As a result, my consensus codicum a differs from that of Schmidt in its inclusion of M.

My analysis of the manuscript tradition of the Automata shows that there is still much work to be done, and I conclude by suggesting briefly some

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92 A cursory look at Schmidt's account of the tradition tends to confirm that, among the manuscripts that I have not collated, those bearing the oldest form of the title belong in the β branch ((Ae, Mc, Md) and those bearing the title *Περὶ αὐτοματοποιητικῶν* belong in the γ branch (R, Vb and possibly also Vc). Casual inspection suggests that the same holds true, respectively, of Bd (β branch) and Ha and Hb (γ branch).
directions for future research. First, future work should focus on undertaking a full collation of all extant manuscripts. Only when that is done and all manuscripts incorporated into the stemma will it be possible to identify apographs, revise the apparatus criticus and use sigla indicating consensus between groups of manuscripts. Second, considering the nature of the tradition, it would be fruitful to investigate contamination at a more granular level. Such investigation, which will necessarily include closer inspection of marginalia, is expected to shed more light on the links between manuscripts. Third, greater attention will need to be devoted to palaeographical and codicological aspects. The primary purpose of such a study will be to provide an updated description of the manuscripts, which will in turn benefit the stemmatic analysis. Fourth, the issue of scribal emendation will have to be examined more closely in order to better assess and compare the value of individual witnesses.

4. TITLES

The discussion in the previous section leads us to the inevitable question: ‘What was the original title of the work?’ The form Περὶ τῶν ἀυτοματοποιητικῶν should be left out of consideration because, as we have seen, it is a corruption of Περὶ αὐτοματοποιητικῶν which appears in an inferior branch of manuscripts. Our choice, then, seems to be between Περὶ αὐτοματοποιητικῆς [sc. τέχνης] and Περὶ αὐτοματοποιητικῶν. The former has been adopted by Schmidt and Murphy,93 while the latter was the only title known to Thévenot (who adopted it) and to Prou94 (who emended it; see below, §4.1) and was apparently endorsed by LSJ s.v. αὐτοματοποιητική.95 Before starting our discussion, we should bear two

93 Schmidt 339 translates the title freely as ‘Die Automatentheater’, although he also offers two more literal translations: ‘Der Automatenbau’ (339 n. 1) and, keeping closer to the original, ‘die KunstAutomaten zu bauen’ (Supplementum 54). Murphy 11 has ‘On Automaton-Making’, and refers to the Greek title either as Peri automatopeitikes or (quite illogically) as Automatopeitikes.

94 But see above, n. 79.

95 Its transliterated nominative form (‘Automatopoeitsa’, LSJ s.v. Hero) has gained favour among classical scholars; see e.g. Mango (1950: 23 n. 42), Sambursky (1962: 177 n. 44), Tarrant (1976: 275), Facal-González (1982: 179), Cuomo (2002: 166 n. 4), Benveniste (2007: 44 n. 19), Mitchell (2007: 226) and De Groot (2016: 56). Although LSJ cite the title as τὰ αὐτοματοποιητικά, they are unlikely to refer to the form Περὶ τῶν αὐτοματοποιητικῶν (see my remarks in §3.1 above about Schmidt’s listing of the manuscripts).
things in mind. The first is that the various versions of the title attested in the manuscripts include the author’s name (usually, "Ἡρωνος Ἀλεξανδρέως") as their first element. The second is that uncertainty often surrounds the genuineness and reliability of titles of ancient works.

While Schmidt, Supplementum 54 found both Περὶ αὐτοματοποιητικῆς and Περὶ αὐτοματοποιητικῶν plausible, he preferred the former title on grounds of manuscript support. To corroborate his preference, he made two additional points. First, Περὶ αὐτοματοποιητικῆς finds better support in other names of technai: βελοποιή (Ph. Bel. 51.8; Hero, Bel. 74.10), θαυματοποιή (Procl. in Euc. 41.8), ὄργανοποιή (Procl. in Euc. 41.5), διεπτερή (Procl. in Euc. 42.4) and ὀπτική (Procl. in Euc. 38.12, 40.9, 59.23, 63.8). Second, Hero uses the term αὐτοματοποιητική at I.1 [2.7]; but cf. also I.1 [2.3]. The parallel forms cited by Schmidt are not parallel stricto sensu. They are suffixed either with -ικός or with -ποικός, not with -ποιτικός. Furthermore, in none of the passages quoted do they serve as titles. The fact that Hero (twice) uses the term αὐτοματοποιητική does not necessarily imply that the treatise originally bore the title Περὶ αὐτοματοποιητικῆς.

Schmidt’s discussion is hardly satisfactory, not only for the reasons just given but also for three other main reasons: (1) he overlooked earlier emendations; (2) he misinterpreted an important piece of literary evidence which so far has not been placed in its proper perspective (see below); (3) he left out of

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96 Manuscripts Ea and Pc have, respectively, Τοῦ αὐτοῦ and "Ἡρωνος τοῦ αὐτοῦ. These readings can be explained by the fact that in both manuscripts the text of the Automata is immediately preceded by Hero’s Pneumática.

97 See especially the discussions in Horsfall (1981) and Fredouille (1997).

98 Titel (1912: 1049), contra, argues that both titles deviate from standard titulature of mathematical and technical works, which usually requires the nominative plural neuter. Murphy 8 n. 1 follows suit, stating that ‘neither title is consistent with the forms of other titles of technical works, such as Heron’s Belopoiika’. This needs correction. The oldest attested title is partly consistent with other Heronian titles (see below). On the characteristic openness of Περὶ-writings, see Dubischar (2015: 565).

99 Similarly, Schmidt, Supplementum 53 compares Περὶ αὐτοματοποιητικῶν with nominative plural neuter forms ending either in -ικά (Πνευματικά) or in -ποικά (Βελοποικά, Λεμναποικά, Ὅργανοποικά). He quotes Λεμναποικά and Ὅργανοποικά, respectively, from Ph. Bel. 49.2 and 49.3. Philo, however, uses the term Ὅργανοποιή not as a title but only as an alternative designation for artillery-construction: νῦν δὲ καθήκα θείων, καθότι ἐξ ἄρχῃς διάταξιν ἐπισθήμεθα πρὸς σὲ, περὶ τῶν βελοποικῶν, ὡς δὲ τῶν Ὅργανοποικῶν καὶ ὄρκους, Ph. Bel. 49-2-4.

100 The term αὐτοματοποιητική is unattested outside the Automata.
account the presence of a separate heading introducing the second part of the treatise (Περὶ στατῶν αὐτομάτων).101 Discussion of such heading will be relegated to the end of the section because it can be used as corroborating evidence for what I think is the original main title.

4.1 Earlier emendations

The following emendations of Περὶ αὐτοματοποιητικῶν have been proposed: Περὶ αὐτοματοποιητῶν (Dindorf ap. TGL s.v. αὐτοματοποιητικός), Περὶ αὐτοματοποιητῶν (Wesch 1867: 71 unnumbered n.), and Αὐτοματοποιή (Prou 117 with n. 1; Tittel 1912: 1049).102 These conjectures are improbable, not least because neither αὐτοματοποιήτως nor αὐτοματοποιή is attested in extant Greek literature.103 Dindorf’s αὐτοματοποιήτων is curious for two reasons. First, Dindorf suggests emending αὐτοματοποιητικῆς (1.1 [2.3]) to αὐτοματοποιή, and therefore we would rather expect αὐτοματοποιητῶν. Second, αὐτοματοποιήτως is a deliberate calque on the Latin automatopoetēs: automatopoetēs [Turtebus: -pitaque vel -pitaque codd.] machinas (Vitr. 9.8.4). Unlike its Latin counterpart, the Greek term looks like a passive verbal adjective, and so would not yield a reasonable sense (‘On things made automatically’). The nominative plural neuter Αὐτοματοποιή is preferable to Περὶ αὐτοματοποιητῶν (cf. above, n. 98), but neither Wesch’s comparison between similar forms (βιοματικά, δραματικά, λματικά)104 nor Prou’s reference to Plato’s use of ὕποσταικός (Smp. 187e4, Græ. 463b3, 464d4, 465b1, 465d6; cf. 101 This heading is omitted in Ab, Ad, Bb, Ha, M, Mb and Pd. Prou 132 erroneously maintains that only four of the Paris manuscripts (Ph, Pe, Pf, Pγ) divide the treatise into two books. The remaining three Paris manuscripts each have a different heading: Περὶ στατῶν αὐτομάτων (Ph), Περὶ τῶν στατῶν αὐτομάτων (Pe) and Περὶ τῶν στατῶν βιβλίων [sic] ρ (Ph). The editio princeps has no heading, whereas Prou and Schmidt have, respectively, Περὶ τῶν στατῶν αὐτομάτων (despite Murphy & n. 1) and Περὶ στατῶν αὐτομάτων. 102 Tybjerg (2005: 206) and Wikander (2008: 788) curiously adopt transliterations of Αὐτοματοποιή. 103 The oxytone form αὐτοματοποιητής, cited by TLL s.v. automatopoetēs and OLD s.v. automatopoetēs, is likewise unattested, and its accented last syllable violates the rules for the accentuation of verbal adjectives in -τος (on which, see KB 1.538-9). 104 Wesch (1867: 71 unnumbered n.) refers to the term αὐτοματοποιή, along with βιοματικά, δραματικά, λματικά, μηχανωτικά and ἑργοτικά. I was, however, unable to find an attestation of the term.
also 465d2 and 500e5) provides sufficient grounds for preferring a compound in -ποικός. For the same reason, αὐτοματοποιητικῆς (I.1 [2.3]) should not be emended to αὐτοματοποιήκης.

4.2 The original main title

None of the emendations proposed so far answers our question, and we are still left with the two alternative forms of the title. The title Περὶ αὐτοματοποιητικῆς is clearly preferable to Περὶ αὐτοματοποιητικῶν, and it is reasonable to think that the latter form arose as a corruption of the former. However, as will become clear below, other Heronian titles which follow the same pattern consist of περὶ followed by the name of an object rather than that of a technē.

The answer to our question comes from the following passage in book 8 of the Mathematical Collection of Pappus (fourth century CE):

καλοῦσι δὲ μηχανικοὺς οἱ παλαιοὶ καὶ τοὺς θαυμαστουργοὺς, ὅν αἱ μὲν διὰ πνευμάτων φιλοτεχνοῦσιν, ὡς Ἡρων πνευματικὸς; οἱ δὲ διὰ νευρίων καὶ σπάρτων ἐμψύχων κινήσεις δοκοῦσι μιμεῖσθαι, ὡς Ἡρων αὐτοματος καὶ ζυγίως, ἅλλοι δὲ διὰ τῶν ἑρ' ὑδατος ὁχομένων, ὡς Ἀρχιμήδης ὁχομένως, ἦ τῶν δὲ ὑδατος ὄρολογίων, ὡς Ἡρων ὑδρίος, ἂ ἄ ὁ καὶ τῇ γνωμονικῇ θεωρίᾳ κοινωνοῦσα φαίνεται.

5 ὑδρίος scripsi seclusus Martin (infra, n. 108); vide etiam locos ibi citatos: ὑδρίος codd., rec. Commandino et Hultsch

The ancients also call mechanicians the wonder-workers, of whom some pursue their art by means of air, as Hero in Pneumatica, some seem to imitate the movements of animate things by means of little strings and cords, as Hero in Automata and Balances, others by means of bodies floating in water, as Archimedes in Floating Bodies, or by means of water-driven clocks, as Hero in Hydria, which in fact appears cognate with the study of sun-dials.

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105 On ὑγιοποιήκος as preferable to ὑγιοποιητικός, see TGL s.v. ὑγιοποιήκος. Other examples of the alternation between -ποικός and -ποιητικός are ἄνδραποιοποιητή/ἀνδραποιοποιητική, ἀρτοποιοποιήκος/ἀρτοποιητικός, πιλοποιήκος/πιλοποιητικός, στυποποιήκος/στυποποιητικός.

106 Papp. 1024.24-1026.2.
Scholars almost unanimously agree that the term αὐτόματος is here used as the title of the treatise. This interpretation is supported by the mention not only of other works of Hero but also of Archimedes' Floating Bodies. If one were to follow Tittel (1912: 1049) in interpreting these words as referring to classes of objects, one would have to understand the dative as instrumental, which does not accord well with the repeated use of διὰ + genitive. Moreover, a reference to Archimedean floating bodies would be redundant, because the corresponding generic class is designated as τὰ ἐκ ἅδατος όρχομενα. The crucial issue here is not, I believe, whether the plural datives refer to ancient works, but rather what sources lie behind the passage. Berryman's (2009: 59–60) comparison between the classifications of mechanics by Pappus (Syn. 1024.12–1026.4) and Proclus (in Euc. 41.3–18, drawing on the first-century BCE writer Geminus) led her to conclude that Pappus, too, drew on a doxographical tradition. This is correct as far as it goes, but it does not go far enough. The question of sources proves much more complex. Hultsch (1877: 115, 119–22) identifies two main sources for Pappus' book 8. He feels that one major source was Hero's Mechanica, which he believes to have been excerpted by Pappus himself in the introduction. However, he contends that an informed but less polished interpolator, in addition to excerpting Hero's Mechanica, supplemented the introduction, and particularly

107 Schmidt, Supplementum 54 n. 1 takes the words αὐτόματος καὶ ζωγής as an inaccurate quotation of the title. But see below, n. 108.
108 Hero's now lost Ζώγια (or Περὶ Ζωγίου?), which was presumably concerned with entertainment devices such as statuettes balanced on pins (Martin 1854: 42 with n. 3), is mentioned nowhere else. By contrast, Hero's treatise on water-clocks ("Ὑδρα" or, following Martin 1854: 42, Περὶ ὑδράτων) is also known as Περὶ οὐδέριων ὁροσκοπείων (Procl. Hyp. 4.73; cf. Papp. in Ptol. 89.5). Martin (1854: 42 with n. 5) cites a third form of the title (Περὶ ὑδράτων), which replaces Περὶ οὐδέριων ὁροσκοπείων not in Halma's (1820: 107) edition of Proclus' Hypothesis but in the edition of the same work by Grynæus (1540: 42). The title of the work cited by Pappus may be an abbreviated form of Περὶ οὐδέριων ὁροσκοπείων.

109 Archimedes' treatise is so titled (Ἀρχιμήδου Ἐρωτήματα) in the so-called Archimedes Palimpsest (on which, see Netz et al. 2011); cf. also Hero, Spir. 24.11-12 (ἀπειδήσθη γὰρ Ἀρχιμήδης ἐν τοῖς Ὀρωτήμασις, etc.). Str. 1.3.11 refers to it as Περὶ τῶν ὁρωτήματος.
110 Berryman (2009: 60 n. 21), for instance, draws attention to the parallel between Pappus' words οἱ δὲ δὴ διὰ... μεταφθασεν and Procl. in Euc. 41.8-9 τὰ δὲ διὰ νεῖρων καὶ σπαρτῶν ἐμπνεύσεως ὀλίκας καὶ κειμένας ἀπομακρύνεται: cf. also οἱ μὲν δὲ... φιλοτεχνοῦσιν with τὰ μὲν διὰ πνῶν φιλοτεχνοῦσα (Procl. in Euc. 41.8-9).
111 Hultsch (1877: 119) had already recognised that the two classifications were drawn from a similar or identical source.
112 Hultsch (1877: 123 n. 12) considers Pappus' definition of mechanics (Syn. 1022.8-13) to have been repeated verbatim from Hero's Mechanica. See Cuomo (2000: 105) for the tentative suggestion that this definition derives from some work by Ptolemy.
the section devoted to the classification of the discipline, on the basis of a commentarial tradition originating from the so-called Heronian school (οἱ περὶ τὸν Ῥονᾶ ἡμερολογίου, Papp. 1022.14-15). The main implication which concerns us here is that, even if Hero did not mention his work on automata in his Mechanica, the interpolator’s source contained a reference to the title of the treatise. This title, which likely reflects an earlier stage of the tradition, can be reconstructed as Περὶ αὐτομάτων on analogy with other Heronian titles, such as Περὶ διόπτρας, Περὶ ὑδρίων ὑροσκοπείων and possibly also *Περὶ ζυγίων.

How are we to explain, then, the oldest attested title? The most plausible explanation involves the assumption that the treatise came to lack all or part of its title. The fact that in the manuscripts the title is not repeated at the end may be taken as a tentative indication that it was originally placed at the beginning, rather than at the end, of the roll. If so, it would have been more easily exposed to damage, and hence more likely to be replaced by a different title. The presence of an internal title, of course, does not preclude that the roll also bore an external title, but ancient testimony suggests that such titles (usually written on fragile parchment labels) were optionally added at the request of the owner of the roll. The title Περὶ αὐτοματοκοιτικῆς, therefore, may have been supplied on the basis of the opening of the treatise, all the more likely because ancient works were often identified by their incipits. So, while we cannot be

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113 That the references to ancient works in Pappus’ passage have been added by a later interpolator is suggested by the use of the simple dative. In other, similar cases, Pappus employs ἐν + dative. Syn. 54.31-56.1, 270.20-1, 270.31-272.1, 272.2, 298.3, 312.7, 312.20-1, 360.19-20, 410.22-3, 1026.9, 1060.5-6, 1064.8, 1068.3, 1068.19-21, 1106.13-14, 1114.5-6, 1130.7.


115 See above, n. 108. Another mechanical treatise has a comparable title, Athenaeus Mechanicus Περὶ μηχανημάτων.

116 Turner (1987: 13): “[t]he habit of putting a title at the end is carried over into the codex form”; see also Holtz (1997: 479). For a recent discussion of initial and end-titles in papyri, see Caroli (2007: 52-60).

117 The inclusion of Hero’s name could be taken as an argument against my proposal. However, we can envisage at least three scenarios: (1) only the title of the work was lost, either entirely or in part; (2) the whole title was lost, but the scribe supplying the information was already acquainted with the work; (3) the whole title or part of it was lost after the treatise had been transcribed into codex form, but the authorship was deduced from the fact that the manuscript contained other Heronian works.

118 See Cic. Att. 4.4a, 4.5 and 4.8, with Oliver (1951: 243) and Holtz (1997: 472 n. with 12). For a comprehensive discussion of external titles, see Caroli (2007: 23-52).

119 See Nachmanson (1941: 37, 49-50); Kenney (1970); Holtz (1997: 470, 474-77).
entirely sure that Περὶ αὐτομάτων is Hero’s original title, it has two clear advantages. First, albeit based on thin evidence, it rests on more solid and authoritative ground than Περὶ αὐτοματοποιητικῆς, which is attested only relatively late. Second, it conforms more closely to the author’s mode of titling. If Hero had used αὐτοματοποιητικὸς in the main title, he would probably have chosen a plural neuter (Αὐτοματοποιητικά).120

4.3 Περὶ στατῶν αὐτομάτων

There are three possible interpretations of Περὶ στατῶν αὐτομάτων: (1) it is a genuine title; (2) it is an interpolation;121 (3) it is a subtitle.122 The first two interpretations support the idea that neither of the manuscript titles is the original one, although (1) is more unlikely than (2). Let us briefly consider these three options:

(1) This interpretation does not tally well with the main titles, which do not include indication of the book number. If either of them were the original title, one would have expected Hero to use the same title for both books and to specify the book number, just as he does with his Pneumatica. Furthermore, accepting this interpretation would seemingly require that the original title be Περὶ ὑπαρχόντων αὐτομάτων, which is not only unsupported but also unsuited to the more general character of the first book (cf. I-II);

(2) This interpretation begs the question of how the heading was supplied. It might have been based on ΧΧ.1 [64.7] περὶ δὲ τῶν στατῶν αὐτομάτων (cf. also I.8 [49–50]), but the absence of the article would seem to suggest that the scribe had Περὶ αὐτομάτων before his eyes. This interpretation, therefore, may serve as indirect confirmation of our reconstructed title;

(3) This interpretation, at least as I understand it, presupposes that the heading is genuine. Two possibilities arise here: either Hero felt the need to add

120 See above, nn. 98-9.
121 Prou 132 (albeit without substantiation). It is unclear to me why he prefers the (corrupted) form Περὶ τῶν στατῶν αὐτομάτων (above, n. 101).
122 Murphy 8 n. 1. See also Schmidt 404, who prints this heading in a smaller type than that employed for the main title.
a subtitle to the second part of the work, or (more likely) he found it in book 6 of Philo’s Mechanical Collection.\textsuperscript{123}

While I cannot exclude entirely (2), I am inclined to interpret this heading as a genuine, originally Philonian subtitle.

5. THE WORK

Hero’s Περί αὐτομάτων is our only extant treatise entirely devoted to the design and construction of ancient automata. It belongs to what might be called the ‘supergenre’ of technical ekphrasis, namely the verbal description of a technical artefact.\textsuperscript{124} ‘Supergenre’ is a more appropriate term than ‘genre’ not only because distinctions between different genres of technical literature are not easy to grasp, but also because such descriptions appear across a variety of text types and genres, ranging inter alia from epigram and didactic poetry to commentary, instruction manual and epistolary prose.\textsuperscript{125} The treatise situates itself firmly in the context of Graeco-Roman culture, while also being highly reminiscent of Hellenistic mechanical works. It combines an interest in a single specialised subject, such as is found in Philo’s Belopoeica (and such as would presumably have been found in his lost treatise on automata),\textsuperscript{126} with a systematic, unified approach typical of other works of its time (the most important example certainly being Vitruvius’ De Architectura); Hero achieves this mainly in two

\textsuperscript{123} The title of Philo’s now-lost book 6 has been reconstructed by Orinsky-Neugebauer-Drachmann (1941: 53) as Αὐτοματονομικός (cf. also ‘Automatopeetica’, Haase 1847a: 432). Some modern scholars prefer Αὐτοματονομικός (in its transliterated form), although without providing any explanation (Lewis 1997: 86; Tyberg 2008: 654; Beacham 2013: 21; Koesler-Kerle 2016: 354; Rance 2016: 444; Whitehead 2016: 21).

\textsuperscript{124} For groundbreaking work in this area, see Roby (2016).

\textsuperscript{125} For discussion of the different genres included under the umbrella of technical ekphrasis, see Roby (2016: 26-42). On ‘supergenre’, see Hutchinson (2013).

\textsuperscript{126} The content of book 6 of Philo’s Mechanical Collection was first inferred from Hero’s comments about Philo being his source (XX.1 [64.8-10]; Haase 1847a: 432), and it has been commonly accepted that it represents the work mentioned by Philo himself in ch. 3 of his Pneumática, called De arbitris mirabilibus (On Marvelous Opinions) in the Latin version (Spir. 462.26-7). Carra de Vaux (1902: 37) disputed the content of the book and suggested emending the corresponding Arabic text to read On Marvelous Instruments (Des instruments marveilleux). A comparison with the classification of sciences in Avicenna’s Treatise on Wisdom (resā’ l fī ‘l-hikmeh) led him to argue that the book dealt with water-organs. This argument has not gained favour among classicists, and although Carra de Vaux may be right to think that ‘opinions’ does not make much sense, I cannot see why the reconstructed title cannot refer to automata.
ways: by intertwining several disciplines, both scientific and non-scientific, and, as we shall see, through presenting variations upon a range of mechanical arrangements.127

As has been already noted, Hero presents us with two types of automaton, one mobile (ἵππαγον) and the other stationary (στατόν). Both these, as Hero himself describes them (in Book One and Book Two, respectively),128 are devices that use stored energy to perform a series of actions. One shared characteristic of both the mobile and the stationary automaton is their power source. Both devices are powered by a falling counterweight, although Hero (II.6 [10.8-9]) mentions another possible power source for mobile automata – the so-called ὑπάλληγς, a mechanism analogous to the torsion engine for catapults and which is not used anywhere in the treatise. (In Book Two, we find a different device, mostly referred to as ὑπαλλήγας, which is used to produce a vertically swinging motion; see further below, §5.2 and Comm. on II.6 [10.4-8].)

It is interesting to note that, when Hero uses the term ἀυτόματος (or its corresponding adverb ἀυτομάτως) elsewhere, he refers to motion that is brought about by means of a falling weight.129 But, mechanics (and indeed language) aside, Hero does not tell us exactly where or how his automata were used, nor does he tell who his treatise (or similar treatises) was intended for. He is, on the other hand, slightly more explicit about his sources, for, apart from Philo, he acknowledges the existence of a tradition that he has inherited and improved upon.

In what follows, I shall first provide a convenient overview of the structure of the text, paying particular attention to the editorial practices of previous editors. This will be followed by a brief critical description of the contents of the treatise and then by a discussion of its historical, literary and cultural background. This, in turn, will allow me to consider possible settings in which Hero’s automata might have been used. After that, I shall discuss the

127 See Roby (2016: 266-8 and, more generally, 86-9).
128 The division into books goes back to Hero himself (I.8 [6.3] and [6.7]). It is partly retained in one of the manuscripts, Ph, where the second book is numbered in the margin (above, n. 101).
intended audience of the treatise. Finally, after discussing Heron’s use of sources, I shall address the status of the text.

5.1 Internal arrangement

The treatise, as it stands in the Teubner edition, is divided into 30 chapters, further subdivided into 161 numbered sections. Chapter divisions mostly follow manuscript practice, with a few being supplied by Schmidt (XXIII, XXIV, XXVI, XXX). Further subsectioning, as well as chapter and section numbering, is a modern innovation, although two points should be noted: (1) XI.9 and XIII.3 are marked off, respectively, in G (with an L-shaped sign) and T (by rubric); (2) Schmidt’s claim (app. crit. to 342.11) that in the manuscripts the chapters are not numbered is misleading, because even though no corresponding numbers are found, in M chn. V-XXVII are (discontinuously) numbered 1-16. The division into chapters is also adopted in Thévenot (31 indented paragraphs) and, as far as Book Two alone is concerned, Prou (11 θεωρήματα, subdivided into 45 sections), but in neither case does it reflect faithfully obvious divisions in the manuscripts.

Heron’s material is usually organised into (semi-)coherent, largely self-contained units, with cross-references both within and between books. However, order is far from being the governing principle of the text. Although Heron uses signposting throughout (most of) the work, the narrative is interspersed with digressions, and some topics are addressed in more than one place.

For readers wishing to obtain an overall impression of the contents of the treatise, Schmidt’s edition provides a useful starting point. His translation is accompanied by 44 descriptive headings, which are placed both at the beginning of each chapter and at the beginning of (or within) sections. Most of these are

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130 The only exceptions are chh. X and XXI, which are made to begin, respectively, with IX.6 [32.17] ὄγχος δεδει μεν and XX.5 [68.3] περὶ τῆς τῶν.

131 Schmidt is silent about the first three editorial interventions. Ch. XXIX was first marked off by Haase (noted by Schmidt in his app. crit. ad loc.).

132 This series omits number 15, while also including number 7 twice (i.e. chh. XII and XIII, although in the latter case the number seems to have been added by a later hand). The marginal number 13 is placed next to XXIV.2 [80.14] rather than at the beginning of the chapter. The following chapters are not numbered: VIII, XV, XX, XXI, XXII, XXIII, XXIV, XXVI.

133 In this regard, see Biddell 46 [erroneously numbered 45] n. 5, cited by Prou 135 with n. 49.
incorporated, sometimes in a slightly altered form, in his list of contents (Schmidt 510-11), which, however, does not give a complete idea of the internal arrangement of the work. Prou, too, provides descriptors, though not always satisfactory. Here I attempt to remedy these shortcomings by offering a fairly detailed outline of the structure of the text:

**Book One**

I [2.3-6.8] Preface
   I.1 [2.3-8] Automata-making
   I.2-7 [2.9-4.22] Mobile and stationary automata
   I.7 [4.22-6.2] Automata-makers as wonder-workers
   I.8 [6.3-8] Affirming one’s authority

II [6.9-14.16] Constructional preamble
   II.1 [6.9-17] Ideal ground surface, trackway
   II.2 [6.17-8.2] Lightweight materials
   II.3 [8.3-8] Smoothness of components, different types of bearings (κνώδακες and χοινικίδες)
   II.4 [8.9-12] Importance of lubrication
   II.4-5 [8.12-10.3] Cords
   II.6 [10.4-10] Two different power systems (ὑπεληνευτικός and counterweight)
   II.7 [10.11-19] Basic components (axle, wheels and case)
   II.8 [12.1-3] Calibrating the forces
   II.8 [12.3-6] Movements other than locomotion
   II.8-9 [12.6-13] Descent of the counterweight in the tube, trickling grains
   II.10 [12.16-19] Unequal movements
   II.12 [14.11-16] Novelty and pleasantness of the arrangement

   III.2-4 [16.5-22] Arrangement of the mobile automaton
   IV.1-4 [18.1-20.1] Performance of the mobile automaton
   IV.4 [20.1-6] General advice on dimensions

V-VI [20.8-26.5] Forms of motion. Straight-line motion
   V.1-2 [20.8-17] Forms of motion (straight-line, circular and rectangular)
   V.3-5 [20.18-22.20] Straight-line forward motion, drive mechanism
   VI.1-2 [22.21-24.15] Straight-line backward motion
VI.3 [24.16-20] Repeated forward and backward motion
V.4 [26.1-5] Side elevation of the case
VII-VIII [26.6-30.2] Circular motion
VII [26.6-28.3] Configuration for circular motion
VIII [28.4-30.2] Mathematical principles underlying circular motion
IX-X [30.3-34.24] Rectangular motion
IX.1-3 [30.3-24] Configuration for rectangular motion
IX.4-6 [32.1-17] Pauses, initiation of movement (digression)
IX.6-X [32.17-34.24] Raising and lowering the wheels (re-configuration)
XI [36.1-42.8] Other forms of motion
XI.1 [36.1-5] Polygonal and snake-like motion
XI.2-5 [36.6-38.6] First configuration for snake-like motion
XI.6 [38.7-14] Measurement of cords (digression)
XI.7 [38.15-40.2] Second configuration for snake-like motion
XI.8 [40.3-7] Technical superiority of pivots (κνόδακες) over hubs (χοινικίδες)
XI.9-10 [40.8-42.3] Third configuration for snake-like motion
XI.11 [42.4-8] Smooth and easy movement of the case
XII [42.9-44.14] Other movements. Lighting of the altar(s)
XIII.1-7 [44.15-48.13] Pouring of liquids
XIII.7-9 [48.13-50.15] Rotation of Dionysus and Nike
XIV [50.16-52.6] Sound of kettledrums and cymbals
XV [52.7-54.7] Descending garlands
XVI [54.8-56.10] Dancing Bacchantes
XVII.1-2 [56.11-58.2] Concealing the cords
XVII.3-XVIII [58.3-60.9] Increasing the range (I). Potentially unsuccessful modifications
XVII.3 [58.3-8] Bigger wheels, smaller axle
XVIII.1-3 [58.9-60.3] Mechanical transmission
XVIII.3-4 [60.3-9] Increasing the range of other movements, repeated rotation of Dionysus
XIX [60.10-62.20] Increasing the range (II). Two-counterweight system

Book Two

XX [64.2-68.4] Preface
XX.1 [64.2-7] Looking back
XX.2-3 [64.7-66.2] Praise and criticism of Philo, Athena’s machine
XX.3-4 [66.3-10] Philo’s forgetfulness (sound of thunder, bolt of lightning)
XX.4 [66.10-18] Sound of thunder (digression)
XX.5 [66.19-68.4] Praise of Philo, improved presentation
XXI.1-2 [68.5-18] Generic account of stationary automata
XXI.2 [68.18-70.3] Setting the scene
XXII.1-2 [70.4-16] Ancient versus modern stationary automata
XXII.3-6 [70.17-74.4] The Nauplius arrangement (five scenes)
XXIII.1-2 [74.5-13] Construction of the πίναξ
XXIII.2-8 [74.14-78.19] Automatic opening and closing of the doors
XXIV [80.1-84.10] First scene. Greeks repairing their ships
  XXIV.1-3 [80.1-82.7] Preliminaries
  XXIV.3-6 [82.7-84.10] Automatic movement of the arms
XXV [84.11-90.5] Second scene. Launching of the ships
  XXV.1-3 [84.11-86.12] Preliminaries
  XXV.4-6 [86.13-88.12] Automatic unrolling of the cloth
  XXV.6-7 [88.12-90.5] Concluding remarks
XXVI [90.6-96.15] Third scene (I). Sailing of the ships
  XXVI.1-6 [90.6-94.14] Preliminaries
  XXVI.6-7 [94.14-96.15] Automatic (un)rolling of the papyrus scroll
XXVII [98.1-100.4] Third scene (II). Plunging dolphins
  XXVII.1-3 [98.1-19] Preliminaries
  XXVII.4 [98.20-100.4] Automatic movement of the dolphins
XXVIII [100.5-104.13] Fourth scene. Nauplius the torch-bearer and Athena
  XXVIII.1 [100.5-10] Appearance of Nauplius and Athena
  XXVIII.1-3 [100.11-102.2] Concealing the torch and other devices
  XXVIII.3-6 [102.2-104.4] Construction of the torch
  XXVIII.6-7 [104.4-13] Automatic lighting of the torch
XXX.1-6 [106.4-110.10] Fifth scene (II). Shipwreck. Drowning Ajax
  XXX.1-5 [106.4-108.14] Bolt of lightning
  XXX.5-6 [108.14-110.10] Disappearance of Ajax
XXX.7 [110.11-15] Epilogue

5.2 Contents

As is clear enough from the schematic outline I have just provided, BOOK ONE (which takes up two-thirds of the treatise) opens with a preface which introduces the whole work. There Hero describes the types of automata that can be built, articulates his position as author and editor, and, more importantly, makes a number of claims to justify his enterprise. He gives two main reasons for dealing
with the topic of automata-making, both grounded in the tradition that he has
received. First, there is a striking element of wonder involved in the viewing and
contemplating of automata (τὸ ἐκπληκτὸν τῆς θεωρίας, I.1 [2.5]).¹³⁴ He is
explicit that the construction of automata belongs to a broader tradition of
spectacular marvels (θαυματουργία or θαυματοποιία; I.7 [4.22-6.2]), and we
have seen in §4.2 above that in later times Hero’s treatise was still felt to belong
to such tradition (the later interpolator in Pappus). Second, the making of
automata incorporates all types of mechanical knowledge (I.1 [2.6-8]), and thus
requires a complex variety of craftsmanship (τὸ πουκίλον τῆς...δημιουργίας, I.1
[2.4-5]). This claim certainly serves to magnify Hero’s own work, but it is not
without grounds: when we read Hero’s descriptions of the automata (particularly
of the mobile type), we find that he makes use of hydraulic elements, with
comparisons drawn between some of his devices and artillery technology (II.6
[10.6-8], XIII.9 [50.10-11]).¹³⁵

The rest of the book deals almost in its entirety with the mobile
automaton (which I will describe shortly). Hero’s account is preceded by an
explanation of the (pre)conditions leading to mechanical success (or failure),
including information on procedures and principles for achieving motion (I have
called this section ‘Construcational preamble’). Two points of particular interest
emerge from this portion of the treatise. One is Hero’s concern with the
characteristics of the surface on which mobile automata (such as wheeled shrines
or temples) move (II.1.2 [6.9-17]). The ground should be as flat and as even as
possible to ensure smooth operation of the device. As an alternative, Hero
suggests the use of a prepared trackway consisting of grooved wooden boards so
that the wheels of the automaton may be made to fit into the grooves. This
arrangement recalls the railways used in theatrical performances to move either
total stage buildings (theatres at Sparta and Megalopolis) or έκκοκλήματα
(theatre at Eretria).¹³⁶ What is particularly suggestive here is the fact that, as
noted by Lewis (2001a: 9), in the Hellenistic theatre at Megalopolis the rails

¹³⁴ In a recent article, Tybjerg (2003) has argued that Hero deploys wonder to strengthen
the epistemological claims of mechanics, but this misses the point of the text. For discussion, see
Comm. ad loc.
¹³⁶ See Lewis (2010a: 9-10), with references. On the έκκοκλήμα, cf. Poll. 4.128; Taplin
(1977: 442-3); Newiger (1990: 34-9); Csapo-Slater (1994: 270-3); and, most recently, Britos
were probably made of wood rather than stone (as in the other examples) because no trace of them has been found. The second point is that all the movements in both the mobile and the stationary automaton are ultimately brought about by the vertical action of a single counterweight (although in fact Hero later suggests the addition of a second counterweight in the mobile automaton; see below, §5.6.2). The counterweight is located in a (rectangular) tube (στύπιες) full of millet or mustard seeds (dry sand is instead preferred in the stationary automaton to extend the length of the performance: cf. Comm. on II.9 [12.10-13]). When these grains trickle through an aperture situated at the bottom of the tube (which is opened manually: IX.5 [32.12-13]), the counterweight falls down, drawing cords which are connected to various instruments – mainly axles, but also drums, pulleys and other cylindrical components. To regulate the timing of movements, there are slack hanks of cord glued onto the appropriate place with wax (II.10 [12.19-14.6]). These are Hero’s tools. He makes no use of toothed wheels or gears, and yet he achieves a variety of results.\footnote{Drachmann (1963a: 197). The absence of gearing can probably be explained on technical grounds, such as problems related to wear and excessive heaviness (Murphy 40 n. 6). The first attested example of gearing is found in Ctesibius’ water-clock (rack and pinion), on which see below, §5.3. Later examples include the famous Antikythera mechanism (second century BCE), a device used to calculate astronomical positions, Vitruvius’ mention of wheels engaging each other at right angles in water-mills (DeArch. 10.5.2) and Hero’s use of different types of gearing in the dioptra (cf. esp. Dio. 1.3), in the hodometer (Dio. 1.34), and in the baroulcos, which latter would allow (albeit probably only theoretically) a weight of 1000 talents to be lifted with a power of five talents (above, n. 8). For discussion and further references, see Drachmann (1963a: 200-3).}

Hero’s mobile automaton is essentially a roofed shrine of Dionysus set on top of four columns (Fig. 1), with Bacchantes dancing around the figure of the god, self-kindling altars (one in front and the other behind him), a miniature panther effigy lying at his feet and a winged Nike holding a wreath and resting upon the apex. The automaton is about 1.5 metres high – Hero gives only approximate dimensions of some of the automaton’s components such as the base, the column shafts and the (Ionic) architrave (III.1 [14.17-16.4]) – and moves upon wheels which are housed in a small casing (οὖνότιον). In its basic form, it moves forward in a straight line, stops, performs a ritual scene (‘apotheosis of Dionysus’),\footnote{I borrow the descriptive phrase of Prou 138 (‘Apothése de Bacchus’).} and then moves back to its starting point. Other patterns of movements are possible, either theoretically (rectangular) or
practically (circular, snake-like, and perhaps also the more elusive polygonal),
and the automaton can also move back and forth many times;\(^\text{139}\) Hero likewise
suggests several possibilities for extending the range of motion, although only
the last one might have proved feasible at all (further details on all these
configurations are given below and/or in the Commentary ad loc.). When the
automaton comes to a halt, the upper display animates itself. The altar in front of
Dionysus flares up. Milk or water sprouts from the thyrsus the god holds in his
left hand, and wine flows out of his cup onto the panther lying beneath.\(^\text{140}\)
Garlands sink down from the upper part of the peristyle, immediately followed
by the Bacchantes dancing in a circle to the accompaniment of kettledrums and
cymbals. When the sound ceases, the figures of Dionysus and Nike rotate
simultaneously 180 degrees. All these movements (except for the sinking of the
garlands) repeat themselves once more, with Dionysus and Nike returning to
their original position.

Book Two opens with a preface that provides a transition between the
two main themes of the treatise. The stationary automaton consists of a box
called πίναξ, which is set on top of a wooden pillar. Hero does not provide any
information about its size,\(^\text{141}\) although we are informed that in neither type of
automaton should the dimensions raise suspicion of human agency (IV.4
[20.1-6]). The πίναξ type mimics the function of a theatre, with, among other
things, doors that open and close and figures painted on a series of backdrops
which possess movable parts. (On the theatrical relevance of the term πίναξ, see
below, §5.4.2.) In this case, too, there is scope for repeating the movements
(XXI.1 [68.8-14]; cf. I.3-4 [2.17-4.9]). The particular specimen chosen by Hero
seems to go back to Philo, although it is not impossible that it predates him by

\(^{139}\) Some movements are presented as occurring ‘(as many times) as we may choose’ (X.3
[30.23], XI.11 [42.7]). Similar expressions are very frequent in the treatise and seem to
emphasise the mechanical (or scenic) adaptability of the devices.

\(^{140}\) Much the same arrangement can be seen in two Pompeian frescoes, known
respectively as ‘Bacchus and Silenus’ (Temple of Apollo, VII, vii, A; MANN, inv. no. 9269) and
‘Bacchus and Vesuvius’ (House of the Centennial, IX, viii, 6; MANN, inv. no. 112286). This
iconography probably serves to characterise Dionysus as an allmighty god who can unlock
the secrets of the universe. I shall explore this in a forthcoming article, provisionally entitled
“Unlocking the Secrets of the Universe: Hero, Aut. 3-4 and AP. 14.24”.

\(^{141}\) See, however, XXIII.1 [74.7-9], where he advises that the boards forming the frame
(πλυθίου) of the πίναξ should be one-sixth as wide as their length. Marshall (2003: 261)
suggests that perhaps the box is ‘over a metre wide’.
some years.\textsuperscript{142} Before describing his preferred model, which presents the myth of Nauplius through a succession of five scenes,\textsuperscript{143} Hero (XXII.1 [70.4-14]) recalls the earliest type of stationary automaton. This presumably pre-Philonian model featured a succession of three scenes, allowing only limited movements (opening and closing of doors, a painted face with moving eyes, and dropping backdrops).\textsuperscript{144} On the other hand, in Philo's model, which was improved upon by Hero (see further below, §5.6), we find a wider range of movements (cf. the remark at XXII.2 [70.14-16], which suggests that the passage was already to be found in Philo). The animated scenes of the automaton can be briefly summarised as follows:

(1) Twelve figures are painted on the backdrop of the box. They represent the Greeks (Δαναοι or Ἀχαιοί) repairing their ships after the capture of Troy.\textsuperscript{145} Their right arms, which are made of horn, are attached flush to the backdrop and move up and down. Their movement is brought about by means of a star-shaped wheel (ωστερίσκος) which repeatedly hits a counterweighted bar (ὑπελήγγειον) behind the backdrop;

(2) The ships are launched. They are painted on a piece of cloth the same size as the backdrop of the box and which is held up by means of a cord fixed to a pin. When the cord is released, the cloth drops under the weight of a rod which is attached to its underside (the same principle is at work at XV.4 [54.6-7] and XXX.3 [108.1-2]). Similar dropping backgrounds are used in scenes (4) and (5);

\textsuperscript{142} This view has been forcefully held by Marshall (2003: 263), although he did not elaborate further. But see below, n. 144.

\textsuperscript{143} On the main sources for this myth, and on the connections between the automaton's narrative and Sophocles' fragmentary Nauplius Pyrkæus, see Marshall (2003). Although I cannot here examine the relationship of the automaton to tragic drama, I must nevertheless mention the position taken by Weil (1882: 417-8). He contended that only the fourth scene may have been inspired by Sophocles' play, while also attributing the first and the second to Hero. I find his position pessimistic and his attribution unconvincing because it ignores the Philonian origin of the material. The question certainly deserves to be studied in greater detail, particularly in light of the existence of Roman tragic evidence (Pac.Trag. inc. 45 Ribbeck = Cic. Div. 1.14.24).

\textsuperscript{144} Marshall (2003: 275 n. 40) has suggested that the Nauplius automaton represents an expansion of a three-scene pre-Philonian model on the basis that the third scene follows closely on the second in the same way the fifth follows closely on the fourth. For a brief description of the individual scenes, see below.

\textsuperscript{145} Brumbaugh (1966: 124) misreads Δαναοι (XXII.3 [70.22]) as Δαναΐδες (‘Danaës’), and hence takes these figures to represent ‘nymphs’ (pp. 54, 114, 124; cf. ‘busy shipbuilding girls’, p. 126). The manuscripts have no such variant reading here.
(3) The ships sail by, with dolphins swimming alongside. The sailing of the ships is achieved by means of a horizontally scrolling backdrop made of papyrus and with sky and sea painted on it. The scroll slides back and forth rapidly so as to produce the illusion that the ships painted on the cloth background actually move. The dolphins are each fixed by means of an axle to a pulley hidden inside the floor of the stage. As the pulley rotates, the dolphins appear to swim, plunging down into the hidden cavity which shields the door axle.

(4) Nauplius and Athena appear, both painted on a backdrop. Nauplius holds up a blazing torch. The lighting of the torch is effected by means of a lamp hidden inside the top part of the box. The lamp is set inside a chest which has a triangular bronze plate. When the plate slides, turning around its own pin, the flame reaches up and sets the shavings on fire. A similar arrangement is used to kindle the altars of Dionysus;

(5) The ships are wrecked, Athena appears on stage and (Locrian) Ajax drowns being struck by lightning. The last dropping backdrop depicts the shipwreck and Ajax swimming. The rotating figure of Athena is placed on a pivoted base, which allows it to flip up and down, with two cords pulling it from below. (This mechanism, as we shall see below, replaces Philo's earlier use of a μηχανή.) The base is either on or connected to an axle. The combination of these two elements forms a mechanical joint (ισχάριον). As for the painted figure of Ajax, it is made to disappear by being covered by a piece of cloth of its size. The cloth is painted so as to resemble the rest of the background, and drops down at exactly the same time as the board depicting the bolt of lightning.

The description of the stationary automaton is followed by two cursory, interrelated observations (XXX.7 [110.11-14]): (a) that all the movements occur in the same way (with explicit reference to the forward motion of the mobile automaton, πορεία); (b) that all the πίνακες are managed by the very means that have been put into practice in Hero's chosen arrangement. These reassert the mechanical and scenic flexibility of contemporary automata as opposed to their distant predecessors, thus picking up a number of remarks made throughout the treatise (1.8 [6.4-7], II.12 [14.12-14], XXI.2 [70.2-3]). The text, as it stands now,-------------------------------------

146 I follow here the reconstruction by Ruffell (forthcoming 1) rather than that by Querfurth (in Schmidt LXIII-VIII), which is overdetailed and not entirely reliable.
ends in a lacuna, which probably contained a statement as to the variability of the stories represented in the stationary automata (XXX.7 [110.14-15]): πλήν δὲν διαλλάσσονται <***>. 147

5.3 Historical, literary and cultural background

In order to contextualise Hero’s models, it is necessary to examine briefly the literary and cultural history of ancient automata. Three main strands can be identified, all of which are somehow connected to the dimension of wonder and amazement. The first strand concerns epic representations of automata. These imaginary automata differ from actual models especially as far as their power source is concerned. The second strand concerns isolated inventions, dating to the Classical period, that use different power sources but which have limited programmability compared to later examples. The third strand concerns the development of a systematised tradition, which begins in the Hellenistic period and extends well into the Imperial era (and beyond). 148 This tradition is associated, in particular, with the name of Ctesibius.

The idea of creating self-working artefacts can be traced back as far as Homer. In the Iliad, we find the first examples of mythical automata, such as the

147 Most manuscripts have the marginal note λείπει at the end of the text. This note has received different interpretations. Prou 248 n.f seems to have taken it as referring to a lacuna occurring before διαλλάσσονται, which he filled with the word μάθης. In his edition, Schmidt (app. crit. to 452.12) apparently took it as referring to the incomplete state of the text ("Unvollständig", Schmidt 452 n. 3), but dismissed it as false (see already Baldi 47 n. 22). Olivier (1901: 431) wrongly regarded it as indicating a big lacuna in BOOK ONE (see further below §5.6.2). In his rebuttal of this view, Schmidt (1903: 277 with n. 1) presented two alternatives: (1) it refers to a lacuna at the very end of the treatise; (2) it refers to a lacuna which contained the complement of διαλλάσσονται (in his edition he printed a lacuna before the verb and suggested adding τοίς μάθησις). I am decidedly inclined to take it as referring to the treatise’s lacunose ending rather than to the (apparently) incomplete state of the text (on which, see below, n. 255). It is hard to decide whether to place the lacuna before or after διαλλάσσονται (XXX.7 [110.14-15]) because the weight of textual evidence does not favour either position (complement before Spir. 10.16-17; complement after: Mech. Frag. 2.1 = Papp. 1116.12). Unlike Schmidt, I have opted for the latter option. If διαλλάσσονται occupied the very end of the folio (possibly a verso), the concluding word(s) of the treatise could have easily been lost. The words added in the margin of Ab by a second hand clearly make no sense: κατά τούς ένομοις καὶ πολλοῖς τόν διαγεγραμμένον τρόπον (‘according to the many dissimilar ways of the things described [?]').

148 I will not consider late antiquity both because the evidence for this period is particularly difficult and because it is not directly relevant to establishing a context for Hero’s automata.
self-opening gates of Olympus (ll. 5.749 = 8.393) and Hephaestus’ self-moving tripods (ll. 18.369-79), the latter being described as ‘a wonder to behold’ (θαύμα ἰδέσθαι, line 377). The workshop of Hephaestus also famously includes golden maidservants ‘with a mind, voice and strength of their own’ (τῆς ἐν μὲν νόσ τετί μετὰ φρεσκίν, ἐν δὲ καὶ αὐθή καὶ σθένος, ll. 18.419-20) and bellows which respond to their master’s will (ll. 18.468-73). It is unclear, indeed unlikely, that any of these devices involves mechanical skill, and other examples such as the Phaeacians’ self-piloting ships (Od. 8.555-62) or the Hesiodic Pandora (Op. 60-82) certainly support the idea that divine power is the source of animation.\(^\text{149}\)

The first securely attested examples of mechanically automated devices date to the fourth century BCE. One such example is found in Aulus Gellius (second century CE), who, drawing on Favorinus, ascribes to the philosopher and statesman Archytas of Tarentum the construction of a wooden flying dove (Gell. 10.12.8-10 = Archyt. T A 10a Huffmann). Although the account lacks necessary details concerning the design of the device, Gellius, who concludes his passage with a direct quotation from his source, informs us that it operated through a combination of air and counterweight (librarentis suspensum et aura spiritus inclusa atque occulta conditum). Schmidt (1904: 349-351) offered a reconstruction of the functioning of the device, arguing that the dove was propelled by compressed air which was released by a valve (nowhere mentioned by Gellius). His reconstruction is not unproblematic, not least because such a use of compressed air is unparalleled in later pneumatic devices, and it is more likely that air was introduced through a tube to provide the initial impulse.\(^\text{150}\)

Nevertheless, he also suggests, rather convincingly, that the dove was used as part of larger display to impress guests at a symposium.\(^\text{151}\) This certainly accords

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\(^{149}\) Berryman (2009: 24-8), who singles out the moving statues of Daedalus (Pl. Men. 97d4-e5; cf. Euthphr. 11b9-d1) as the best candidates for mechanical automata. In my view, she pushes her argument to an extreme. The fact that mechanics did not develop until the fourth century BCE does not mean that later authors could not look upon mythical automata as precursors of existing models, as exemplified, for instance, by Arist. Pol. 1235b34-1254a1. For other mythical automata, see, among others, Cambiano (1994: 624).

\(^{150}\) For full discussion, see Huffman (2005: 572-7), who observes that the dove is unlikely to have been free-flying.

\(^{151}\) This suggestion has been accepted by Schürmann (1991: 175). See also Schürmann (2002: 36).
well with the characterisation of the dove as something wonderful (admirabile).\textsuperscript{152}

Archytas' flying dove is in some respects a unicum in the history of ancient automata. This is so not only and not so much because of its pneumatic power source (we have seen that Hero envisages two different power sources of automata, neither of which involves a fluid) but rather because, as noted by Huffman (2005: 575), there are no other examples of birds actually flying. Nonetheless, it is tempting to associate its origin with the technological advances that took place under Dionysius I, tyrant of Syracuse (405–367 BCE), with whom Archytas was allied and under whose patronage could have been involved in the development of catapults.\textsuperscript{153} A similar association is made by a third-century CE source. In a fictive letter from the philosopher Speusippus to the tyrant Dion ([Socr.] Ep. 35 Hercher),\textsuperscript{154} the Syracusans are congratulated for rejecting a number of innovations of Dionysius I, including the habit of sending ingenious (σοφά) devices to Delphi in the form of dedications. Although the text is rather cryptic, there is mention made of Apollo (perhaps a playful allusion to Dionysius I)\textsuperscript{155} ‘hearing and seeing the small cart running around in the hippodrome automatically’ (ἀκούσας καὶ τὸ ἀμάξιον ἵδον τὸ ἐν τῷ ἱππόδρομῳ περιπλέχον αὐτόματον). Here there is no indication as to what might have powered the automaton. Rehm (1937: 329) ruled out the use of a counterweight (it is not clear where it would go) and suggested, on the basis of his reconstruction of Demetrius' snail (see below), that the cart was operated by two men, one turning a windlass to drive the wheels and the other changing the direction of motion.

\textsuperscript{152} Berryman (2009: 96) speculates that Archytas' device was in fact either a catapult (?) or, more probably, a catapult projectile because, whereas Gellius refers to it as simulacrum columbae (‘representation of a dove’), his source simply calls it περιπτερά (‘dove’), possibly appealing to the rather widespread use of animal names in describing machines and their parts (on which, see esp. von Staden 1998, as well as the use in the Automata of the terms κοτλέας and κόρας, indicating respectively a ‘screw’ and a ‘hook’: chh. X and XV, respectively). This is extremely unlikely for at least two reasons. First, mechanical writers never use the verbs volare or πέτωμαι (which are found in Gellius' account) to refer to the hurling of a projectile. Second, although the precise mechanism of the device remains conjectural, there is no parallel for the combination of air and counterweight in artillery technology. For Ctesibius' air-powered catapult, see below, §5.6.

\textsuperscript{153} See Berryman (2009: 95), citing Keyser (1994: 31). The connection between automata, artillery and Dionysius I is investigated by Ruffell (forthcoming 2), on whose work I base the discussion which follows.

\textsuperscript{154} On the date of the Socratic Epistles, see Sykutris (1933: 106-22).

\textsuperscript{155} Rehm (1937: 330), endorsed by Ruffell (forthcoming 2).
Technical considerations aside, the cart is explicitly described as small (although it is difficult to say how small) and would probably not have contained all that equipment. A perhaps more likely power source would be something like Hero’s ῥυπληγξ, involving sinew spring, which would have been well known to the technical entourage of Dionysius I.

The tradition exemplified by the pseudo-Socratic letter is also reflected in the works of Aristotle, where we find the first references to αὐτόματα (whether or not in direct connection with wonder). The two sources I have in mind are Arist. GA 734b7-15 and MA 701b2-10, where automatons are invoked as analogues for living organisms or biological processes (in the former case for sperm motility, in the latter for animal locomotion). In both cases the point of comparison is the ability to turn an initial impetus into a causative sequence of actions.\(^156\) The second passage distinguishes two types of device, αὐτόματα and ἄμαξια, but the text is particularly difficult and corrupt;\(^157\) and it is not clear exactly how these devices would have functioned. Nussbaum’s (1976: 149-50) interpretation is that the first type refers to marionettes which move thanks to a system of interlinking pegs and cables (στρέβλαι), but this is perhaps overprecise and it is not impossible that their power source may have been the unwinding of cords (possibly of sinew) from a windlass.\(^158\) As for the cart mentioned in line 5, I am not entirely convinced that it was fully automatic (as Ruffell has it),\(^159\) but

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157 For discussion of the text-critical problems, see Nussbaum (1976: 146-52). For consideration of the passage in connection with Michell’s (2005) argument that Aristotle’s automatons were powered by a ῥυπληγξ, see Comm. on II.6 (10.4-8).
158 A suggestion made by Ruffell (forthcoming 2) and already found in nuce in Nussbaum (1976: 150). The ‘interlinking pegs’ in Nussbaum’s reconstruction depend on an emendation of the quite problematic phrase κρουόντων ἀλλὰ τὰς στρέβλας (line 3) to κρουόντων ἄλλα τῶν ἑλκιών. In commenting on this passage, Philoponus (in GA 77.16-17) talks of pieces of wood transmitting motion to one another ‘through some mechanism’ (διὰ τινος μηχανῆς), which, as noted by Ruffell (forthcoming 1), admits of several different reconstructions.
159 Again, the text is rather problematic. Most manuscripts describe the cart as ὅπερ ὑγόμενον αὐτὸ κανείς εἰς εἴδος (others have either ὅπερ ὑγόμενον or ὅπερ ὑγόμενον in place of ὅπερ ὑγόμενον). The most commonly accepted emendation is ὅ γαρ ὑγόμενος, which makes ἁυτὸ the object of κανείς. Ruffell (forthcoming 2) suggests an ingenious emendation of ἁυτὸ to ἁυτὸ on the basis of the reflexive use of κανείο in Aristotles’s discussion of how something can be ἁὐτοκάτιτος (Ph. 258a15), which makes the cart automatic. This slight emendation is very tempting, especially in view of the evidence from the pseudo-Socratic epistle discussed above. But it seems to me that Aristotle implies a contrast between the initial impetus of motion (κανείς) and the subsequent steering of the device (κανείται). See further below.
certainly Aristotle refers to an automatic change in the pattern of movement (κύκλω κινεῖται τῷ ἀνίσους ἐχειν τοὺς τροχούς...καθάπερ ἐν τοῖς κυλινδροῖς, lines 5-6). Both the mention of unequal wheels and the (rather obscure) comparison in relation to solid geometry bring the device closer to Hero’s mobile automaton.\(^{160}\)

It is only in the Hellenistic period that we see a sustained tradition of automata-making emerge. Perhaps the originator and first exponent of such tradition was Ctesibius of Alexandria (c.300–230 BCE),\(^{161}\) who, according to Vitruvius (De Arch. 9.8.2; cf. 9.8.4), was also the founder of pneumatics as a discipline. Unfortunately, none of his works has survived, but we know that he wrote two works, called respectively Pneumatic Theorems (Πνευματικὰ θεώρηματα, Ph. Bel. 77.12) and Commentaries (Ὑπομνήματα, Ath. Mech. 29.10).\(^{162}\) Although best known for inventing the fire-pump, the water-clock and, as we have seen, the water-organ, he also described the application of hydraulic principles to the construction of automata of the kind we find in Philo’s and Hero’s Pneumatica (singing birds and drinking animals).\(^{163}\) Vitruvius selected only Ctesibius’ more practical inventions and instead left out of consideration ‘those things which are not for the sake of necessity, but for the sake of pleasure’ (quaer non sunt ad necessitatem sed ad deliciarum voluntatem), referring the reader for more details to Ctesibius’ own Commentaries (DeArch. 10.7.5).

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160 See Ruffell (forthcoming 2). For the tentative suggestion that κυλινδρος here refers to a children’s toy, see Nussbaum (1978: 348).
161 On the question of Ctesibius’ date, see Drachmann (1948: 1-3). Ctesibius may not have been originally from Alexandria, for Ath. Mech. 29.9 calls him ὁ λασκριτός (Fraser 1972: 2.622-3 n. 445). But the ethnic is conjectural (cf. Wesccher 1867: 29) and unattested outside this passage and Hero Byz. 263.1, as noted by Whitehead-Blyth (2004: 142). The ethnic of Boeotian Ascr is λασκριτός, and Vitr. 9.8.2 refers to Ctesibius as Alexadnirus. Whitehead-Blyth (2004: 142) speculate that the obscure ethnic provides an indication that Ctesibius’ family migrated to Alexandria from rural Boeotia, unless another otherwise unknown Ascr (or Ascra) is meant.
162 Fraser (1972: 1.431) erroneously cites the latter as Ὑπομνηματικοῖ. But cf. Fraser (1972: 2.619 n. 421).
163 Vitr. 9.8.4 and 10.7.4, with Oleson (1984: 125) and Callebat (2003: 168-170). For singing birds and drinking animals, see below. Granger (1934: 313 nn. 1-2) unintelligibly connects the term angubalae in Vitr. 10.7.4 with the automatic owl appearing in Spir. ch. 1.16 (erroneously cited as 1.91), on which see below. The meaning of this hapax is uncertain, but it seems to refer to the kind of figure described in Ph. Spir. ch. 36 (Drachmann 1948: 70; cf. Callebat 2003: 169), today commonly called ‘Cartesian diver’. Hero’s owl, at any rate, is made to turn rather than walk, as presupposed by Granger’s (1934: 313) translation of the term (‘walking automata’).
That Ctesibius was associated with the royal court at Alexandria under the reign of Ptolemy II Philadelphus (283–246 BCE) is made clear from Hedylus’ description (in Athenaeus) of Ctesibius’ invention of a drinking-horn (ὑπότον),\textsuperscript{164} to which I shall return in more detail below. Similar drinking vessels are later encountered in Philo’s and Hero’s Pneumática, and some of them would have provided spectacular entertainment at royal symposia.\textsuperscript{165} Ctesibius’ horn, however, belongs to a different class of devices, namely that of ‘temple automata’: automata that were placed in temples, sanctuaries and similar confined religious settings, either temporarily or permanently, and which mainly served either (politico-)religious or decorative functions (or both).\textsuperscript{166} At the same time, it also belongs to what Bur (2016: 79 n. 31) calls ‘dedicated inventions’, that is to say dedications which were used to promote scientific and technological achievements.\textsuperscript{167} Although much of our evidence for automatic contrivances comes from the Roman Imperial era (Hero’s Automata and Pneumática) or is filtered through the Arabic tradition (Philo’s Pneumática), automata must have featured prominently among such Hellenistic achievements because they were an offshoot of the intellectual activity of the Mouseion, whose scientific work reached its apex in the third century BCE.\textsuperscript{168}

Ctesibius’ horn was shaped in the form of the head of the Egyptian god Bes and featured an automatically operated trumpet which would emit a shrill sound (λαγών ἰχθύς, HE 1845) when the wine flowed out. It was dedicated by Ctesibius himself in the temple of Arsinoe Zephyritis (erected 270 BCE), and was probably placed upon a pedestal or plinth on which was inscribed Hedylus’

\textsuperscript{164} Athen. 11.497d–e = Hedyl. HE 1843–1852. The text is particularly corrupt. For full discussion, see Galli Calderini (1984: 87–91), with ample bibliography.

\textsuperscript{165} See Schürmann (1991: 164–70); Wikander (2008: 790); and, most recently, Bur (2016: 7, 130). For (symptotic) drinking-horns, cf. Ph. Spir. ch. 16; Hero, Spir. chh. 1.18, 2.13, 2.28. Bur (2016: 130) rightly notes, albeit without citing any source, that Hero’s use of the term κρυστίριον provides an indication of the symptotic context of such devices. The term occurs 30 times in Hero’s Pneumática (Spir. chh. 1.14, 1.19–20, 2.12, 2.31, 2.34–5).

\textsuperscript{166} For ‘temple automata’, see Schürmann (1991: 224–34). See also, most recently, Bur (2016: 127–87), who, however, includes in this category not only devices specifically flagged for use in temples – such as, for instance, Hero’s holy water dispenser (Spir. ch. 1.21) or the so-called ἄγνωστος ἤνωτριη (‘ritual purifier’, Spir. ch. 2.32) – but also devices which are reasonably thought to have been used in private houses. See below.

\textsuperscript{167} Fraser (1972: 1.412–3) mentions two other examples: Eratosthenes’ dedicatory epigram on the duplication of the cube (Eutoc. in Arch. Sph. Cyl. III 96.10–27 Heiberg-Stamatis = Powell, Coll. Alex. fr. 35) and Archimedes’ inscribed tombstone (Cic. Tusc. 5.64–6).

\textsuperscript{168} See Fraser (1972: 1.319, 426) and Fragaki (2012: 30), with further bibliography.
dedicatory epigram. The poem leaves no doubt that its true focus is on the
figure of Ctesibius, who is emphatically praised for his clever invention (Ἀλλὰ
Κτησίβιον σοφὸν ἔρημα τίτε τοῦτο, HE 1851). This can be understood as part
of a larger propagandistic strategy in the Ptolemaic programme of political
legitimation and self-aggrandisement, as the following example will make
clear.

At a slightly earlier date than the erection of Arsinoe’s temple,
Alexandria was host to a procession which took place at the Ptolemaic festival in
the city’s stadium, the so-called Grand Procession. The procession, which
occurred under Ptolemy’s auspices (probably in the years 280-275 BCE), was
described by Callixeinus of Rhodes in a work called On Alexandria (Ath. 197c-
203b = Callix. FGrH 627 F 2; Rice 1983) and consisted of a series of smaller
processions. The surviving text deals almost entirely with the procession of
Dionysus, featuring a conspicuous display of wealth. The procession was opened
by Silens, Satyrs, Nikai with golden wings and other lavishly ornamented
figures, followed by the statues of Dionysus (4.60 metres high) and Nysa (3.70
metres high), both seated on a cart (Ath. 197e-198f). Holding a thyrsus in its left
hand, the statue of Nysa – a personification of Dionysus’ birthplace, following
(Rice 1983: 66-8), rather than the god’s nurse – stood up ‘mechanically without
anyone laying their hands on it’ (μηχανικῶς οὐδένας τὰς χεῖρας προσάγοντος)
and then sat back down after pouring a libation of milk (Ath. 198f). Callixeinus’
description, textually and iconographically, recalls Hero’s mobile automaton, all
the more so as the seated statue of Dionysus appears to pour a libation. The
functioning of Nysa is unclear. Rice (1983: 63-65), picking up and amplifying
an earlier suggestion by Fraser (1972: 1.426), suggested that Nysa was the work
of Ctesibius (or of someone directly influenced by him) on two grounds: (a) that
Ctesibius was connected with the royal court (as noted above); and (b) that the
Nysa statue (which was presumably built with hinged joints) was powered by a

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169 Fraser (1972: 1.413). Rice (1982: 63) is more cautious about identifying the dedicating
with Ctesibius, although she does not explain.


171 On the propagandistic intent of the poem, see Galli Calderini (1984: 89).

172 Compare the expression Hero uses at 1.6 [4.18] μηχανικῶς προσάγοντος.

173 Rice (1983: 59) notes that, because the liquid is not specified, the statue was probably
only positioned to suggest the action. Contra (rightly, in my opinion), Ruffell (forthcoming 2),
who observes that the procession involves a large amount of fluids.
cam-and-lever arrangement, a solution which would accord well with Ctesibius’ experiments with the transference of circular motion into linear motion attested by the rack-and-pinion mechanism of his water-clock (Vitr. 9.8.4-7). Leaving aside the attribution (and therefore also leaving aside Ctesibius’ water-clock), it is worth noting that, while the cam seems to be attested already in the third century BCE, Rice’s reconstruction is perhaps over-detailed, and Nysa’s repeated action could just as easily have been achieved using cords and axles in the fashion usually favoured by Hero and apparently also Philo. Be that as it may, what needs to be stressed here is that the prominence assigned to Nysa by being positioned at the beginning of the procession anticipates and confirms the propagandistic intent of the parade, which is most fully accomplished through the celebration of the Indian campaign of Dionysus-Alexander (Ath. 200d-201c) and thereby of Ptolemy’s own legacy. What we have here, it seems to me, is a combination of propaganda, entertainment and the element of wonder.

A similar example of this, but with more emphasis on technical mastery, is described in Polybius’ Histories. Polybius, quoting the Athenian orator Democharis, briefly mentions a mobile type of automaton associated with one of Democharis’ sworn enemies, Demetrius of Phalerum, the governor of Athens in the years 317–307 BCE (Plb. 12.13.11 = Democh. FGrH 75 F 4). The automaton was part of a procession through the theatre of Dionysus, which probably took place at the Dionysia festival of 309/308 BCE (Rehm 1937: 317): ‘a snail moving automatically went before him [sc. Demetrius] in the procession, spitting up slime’ (κοχλίας αὐτομάτου, βαδίζων προηγεῖτο τῆς πομπῆς αὐτῷ, σίλαν ἀναπτύον). On the basis of a highly speculative reconstruction by Schramm (in Rehm-Schramm 1929: 20-1 with Figs. 6-7) of a siege-engine known as the ἐλέφαλος (‘city-taker’) of Posidonius of Macedonia and described by Bito (Constr. 53.4-56.7), Rehm (1937) reconstructed Demetrius’ snail as a

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174 For similar reconstructions, see Lewis (1997: 84-5) and, most recently, Koetsier-Kerle (2016: 354-5).
176 Ruffell (forthcoming 1), citing as a paradigmatic example ch. XXIII of the present treatise.
178 For criticism of Schramm’s reconstruction, see Marsden (1971: 89) and, more fully, Lendle (1983: 49-53) and Campbell (2003: 12-13).
three-wheeled, human-operated automaton, three or four metres in height, with
its two rear wheels powered by an internal treadmill and a controllable wheel at
the front. The implausibility of Rehm’s reconstruction aside,179 comparison with
the ἀμὸς discussed above, on which Demetrius’ snail seems to have been an
advance,180 and with Hero’s mobile automaton suggests to me that this model
should have been considerably smaller than the size suggested by Rehm. What
brings the snail closer after all to its Heronian successor is the combination of
motion (in this case, probably linear) with the projection of liquids. It is certainly
noteworthy that, in describing Dionysus’ libation, Hero uses the terms ἀναπτυ-
σις (IV.3 [18.17]) and ἀναπτυξία (XIII.1 [44.15-16]), themselves ultimately
derived from ἀναπτύω,181 which suggests that the same or a similar hydraulic
mechanism was at work in Demetrius’ snail. At any rate, although frustratingly
silent about the mechanics of the device, Democra’s testimony is particularly
valuable for what it tells us about the snail’s performance context.

The theatrical use of automata is better attested in the Roman Imperial
period, although most of our evidence from that time more directly relates to
private settings (see below). Two examples seem to me particularly relevant.
The first example concerns Nero’s famous attempt to kill his mother Agrippina
in 59 CE. One of our sources for the episode (or, in fact, series of episodes) is
Suetonius,182 who tells us that Nero, after trying to kill her with poison and then
contriving a collapsing ceiling (lacunaria, quae noctu super dormantem laxata
machina deciderent), devised a ‘collapsible boat’ (solutilis navis) to destroy her
either by shipwreck or by the falling down of its cabin (vel naufragio vel
camarae ruina).183 The (ultimately unsuccessful) idea of such boat is attributed
by Tacitus (Ann. 14.3) to Nero’s former preceptor Anicetus, who would be
responsible for Agrippina’s death (Tac. Ann. 14.8; D.C. Epit. 61.13.4-5).

179 For a full discussion, I refer the reader to Ruffell (forthcoming 2). I am not particularly
interested here in the strictly technical side of things. Bito’s passage dealing with the internal
mechanisms of the ἀμὸς is also textually problematic (cf. esp. Bito 55.4-5).
180 So Ruffell (forthcoming 2).
181 Note, however, that the quotation of Democra’s text known to us through the indirect
tradition contains the variant reading ἀποπτύων (‘spitting out’; Suda α 352).
Although the three accounts differ significantly in detail, they are likely to have been derived at
least in part from a common source (see Devillers 1995).
183 Suet. Nero 34.2, Tac. Ann. 14.5 has a collapsing, lead-weighted ceiling, which does
not seem to be automatic; see Ruffell (forthcoming 2).
whereas in Cassius Dio it is associated with the emperor's future wife, Poppaea Sabina, who herself instigated the murder, and with whom Nero watched an automatic collapsing ship in the theatre (D.C. Epit. 61.12.2-3):

ναὸν ἰδόντες ἐν τῷ θεάτρῳ διαλυμένην τε αὐτὴν ἕφ᾽ ἑαυτῆς καὶ τινα θηρία ἄφιεσαν, καὶ συνισταμένην αὐτῶν ὡστε καὶ ἠρρώσθαι, τοιαύτην ἐτέραν ταχέως ἐναυπηγήσαντο.

Having seen in the theatre a ship parting asunder by itself, letting loose some beasts and coming back together so as to be robust again, they quickly had one such ship built for themselves.\(^{184}\)

The second example is found in Apuleius' Metamorphoses, where the protagonist Lucius attends the pantomime performance of the Judgment of Paris in the Roman colony of Corinth (Met. 10.30-4). The scene is Mount Ida, a towering wooden structure 'built with sublime craftsmanship' (sublimis instructus fabrica), with abundant vegetation, goats grazing among the low grasses and a fountain pouring out water from the mountain's peak (Met. 10.30). The performance prominently features dances of Juno, Minerva and Venus (all with attendants) with the aulos accompaniment, followed by a moralising interlude on the corruptness of judges. It concludes with a wine-saffron mixture showering down from the peak of the mountain and a spectacular earthquake (Met. 34):

tunc de summo montis cacumine per quandam latentem fistulam in excelsum prorumpit vino crocus diluta sparsimque defluens pascentis circa capellas odoro perpluit imbre, donec in meliorem maculatae speciem canitiem propriam luteo colore mutarent. Iamque tota suave fraglante cavea montem illum ligneum terrae vorago decepit.

\(^{184}\) Exactly how the ship would have disassembled itself remains unclear, but Tacitus' account is slightly more accurate (Ann. 14.3): ergo navem posse componi docet [sc. Anicetus] *culus parsipso in mari per artem solutae ssehunderet ignaram [sc. Agrippinam].
Then, from the very peak of the mountain, through a concealed pipe, saffron dissolved in wine spurted out high into the air and, flowing down in scattered streams, sprinkled the goats grazing all around with a fragrant shower, until, dyed to a greater beauty, they changed their natural hoariness to a golden-yellow colour. And now that the whole theatre was smelling sweetly, a chasm in the earth swallowed the wooden mountain.

Although Dio’s account may have been rooted in anecdote, and despite the fictional nature of Apuleius’ story, both examples reflect theatrical practices which were common in early Imperial times. The best evidence comes from Seneca’s Epistles. In one such letter, Seneca contrasts the true sapiens with someone who invents (among other ingenious devices) ‘a system for squeezing saffron up to an immense height from concealed pipes’ (quamadmodum in immensam altitudinem crocum latentibus fistulis exprimat, Ep. 90.15), whereas in another letter he describes ‘unexpected devices such as objects fitting together which come apart, or separate objects which join together automatically, or objects which stand erect, then gradually collapse’ (ex inopinato varietates aut dehiscentibus quae cohaerebant, aut his, quae distabant, sua sponte coeuntibus aut his, quae eminebant, paulatim in se residentibus, Ep. 88.22). Significantly, these contrivances are mentioned as a product of the arts of entertainment (artes ludicrae), which, as Seneca says, ‘aim at the pleasure of the eyes and the ears’ (ad voluptatem oculorum atque aurium tendunt; cf. Vitr. 10.7.5 quae delectationibus oculorum et aurium usu sensus e glandantur, in reference to Ctesibius’ devices).

Quite the same taste for entertainment is known to have been catered for at the private banquets of the Roman elite. Our richest source of information is Petronius. In the Cena, we find frequent references to automata (or closely

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185 It is difficult to say whether Dio’s account is more historically reliable than Tacitus’. What seems certain, however, is that Tacitus’ amplification of Anicetus’ role was due not only to his being the prefect of the fleet at Misenum but also, and more especially, to the similarities with the Tacitean account of the death of Octavia (Ann. 14.60-4), in which Anicetus also played a significant role (Ann. 14.62); see Devillers (1995: 327-8, 330-1), with bibliography. On Tacitus’ account of Octavia’s death, see, more recently, Murgatroyd (2008).

186 The comparison between the Apuleius passage and the Senecan Epistles has been noted by Zimmerman (2000: 367, 403, 405); see also Denard (2007: 154). For the widespread use of saffron in theatres, Zimmerman (2000: 403) also refers to Lucr. 2.416, Hor. Ep. 2.1.79-80 (crocus used metonymically for ‘stage’) and Ov. Ars 1.103.
related devices), and the use of actual theatrical apparatus contributes to transforming Trimalchio's house into a stage (see Panayotakis 1995: 91). So, at the beginning of the dinner, Trimalchio is introduced to us as having a 'clock and a uniformed trumpeter in his dining-room' (horologium in triclinio et bucinatorem... subornatum, Sat. 26.9), where horologium seems to refer to a water-clock.¹⁸⁷ Later on we encounter the narrator Enolpius watching out for a not better-specified automaton (Sat. 54.4) and then, a few chapters later, a self-opening ceiling which lets out a hoop adorned with golden crowns and perfumes (Sat. 60.1-3; note especially the description of the automaton as an earthquake: lacunaria sonare coeperunt totumque triclinium intremuit, Sat. 60.1).¹⁸⁸ Immediately following this is a dish with a pastry figure of Priapus holding fruits and grapes which spurt out saffron when touched (Sat. 60.4-6). Yet another textual portion presents us with the famous zodiac dish (Sat. 35.1-6 and 36.1-4). The disclosure of the upper part of the dish allows the guests to see an impressive display (Sat. 36.1): birds, sow's udders, a winged hare made to look like Pegasus, and fish swimming in a spiced sauce which was flowing out of the wine-skins of the four figures of the satyr Marsyas at the corners of the dish (notavimus etiam circa angulos repositorii Marsyas quattuor, ex quorum utriculis garum piperatum currebat super pisces, qui quasi in euripo natabant). This was certainly intended to resemble public fountains, which were often ornamented with statues (see, for instance, Prop. 2.32.15-16), and Hero in the Pneumatica describes similar figures of Satyrs pouring water from their skins (Spir. chh. 1.37 and 2.15).¹⁸⁹ Meerwaldt (1921: 411 with n. 1) argued that the swimming of the

¹⁸⁷ See Raíos (2000: 26), citing Maiuri (1945: 151) and Smith (1975: 53). Baldwin (1978: 87 n. 3), on the other hand, is undecided between a sundial and a clepsydra. Meerwaldt (1921: 407-10), apparently endorsed by Raíos (2000: 26-7), proposed to interpret the participle subornatus as instructus ('equipped') and the phrase horologium... et bucinatorem... subornatum as horologium bucinatore subornatum, which makes Trimalchio's trumpeter an automatic piece of apparatus (contra, Panayotakis 1995: 57 n. 13). The text makes sense as it stands, and Meerwaldt's interpretation strains the syntax. Raíos (2000: 26) wrongly attributes to Meerwaldt the claim that, in its remaining occurrences in the Satyricon (21.2, 36.2, 40.5), subornatus means either 'dressed in' or 'decorated with'. Cf. Meerwaldt (1921: 408): '[u]lt his locis [sc. citatis], ita l. l. mea quiadem sentientia proprio, non translato, sensu est accipierundum subornare' (my emphasis).

¹⁸⁸ Similar movable ceilings were rather common in upper-class Roman dining-rooms; see Sen. Ep. 90.15; Suet. Nero 31.2; Val. Max. 9.1.5; Macr. S. 3:13.5; Panayotakis (1995: 90); Raíos (2000: 21-2, 24).

fish was effected automatically by mechanical means, an argument which seems to have ultimately depended on the difficulties he faced in interpreting the text (he printed the reading quicunque instead of qui quasi). On the basis of a (highly dubious) comparison with Hero's configuration for circular motion in the mobile automaton and with the mechanisms used in Spir. ch. 1.16, he suggested that there was a hollow cavity beneath the 'canal' (euripoi), with a cord wound around an axle and having one end passing through two pulleys and the other end attached to a counterweight; the falling weight would have caused the axle to turn by pulling upon the cord, which would, in turn, rotate the canal. There are many problems with this reconstruction. I shall mention only the most conspicuous. First, there is no hint in the text that the basin containing the fish would rotate; the fish are merely said to 'swim', and the illusion could easily be achieved by the constant flowing of garum. Second, the circular pattern of motion in the mobile automaton in reality depends on the fact that the two main driving wheels are not of the same size, but the outer wheel is bigger than the inner one (cf. synopsis on VII-VIII). Third, the mechanical arrangement found in Spir. ch. 1.16 features a combination of weights and pneumatic elements and, although a counterweight is used to turn an axle (only 180 degrees), the ultimate power source of the whole device is running water. Here mechanical means are used to animate a scene where birds stop singing when an owl turns to look at them and then resume when it looks away again (Spir. 90.10-16):

Several birds are constructed, arranged either in a spring or in a cave or generally wherever there is running water, and beside them an owl which turns automatically towards the birds and turns away again; when it has turned away, the birds twitter, and when it has turned towards them they no longer twitter. And this takes place several times.

\footnote{This reconstruction has been accepted by Raïos (2000: 28).}
It has been recently suggested that this and other Heronian and Philonian displays involving singing birds\textsuperscript{191} or drinking animals\textsuperscript{192} are likely to have been used in temples because, unlike temples and other public spaces, the ἄνδρον of private houses did not have access to running water (ἐπίρρυτον ὕδωρ)\textsuperscript{193}. This suggestion is partly misleading, since it does not take into account the architectural transformations of the Roman house occurred between the third century BCE and the first century CE. Schürmann (2002: 41, 44) has argued (rightly, in my view) that Hero’s hydraulic showpieces, with their emphasis on a continuous source of running water (cf. above, n. 193), seem to reflect the development of the Roman house in the Late Republic and Early Empire, when many triclinia either looked onto or were built in a planted garden with different water sources. It seems very tempting, therefore, to take Hero’s reference to a ‘cave’ as a sign of the popularity of elaborated grottoes in the Roman Imperial period\textsuperscript{194}.

Tracing the history of ancient automata from their first mythical appearances as imaginary artefacts to their more spectacular Imperial instantiations reveals that they were used in different contexts, ranging from public occasions such as religious festivals and theatrical shows (with occasional overlaps, as in the case of Demetrius’ snail) to private elite settings such as the Greek symposium and the Roman comissatio (with or without overtly theatrical connotations). Mainly used for entertainment, automata took the form of performance pieces or dedications (sometimes overlapping), and could also serve religious and political purposes, especially in the affirmation of economic and technological power.

\textsuperscript{191} Philo: Spir. ch. 60 (owl and birds); Hero: Spir chh. 1.15 (blackcap), 2.4-5.
\textsuperscript{192} Philo: Spir. ch. 59 (Pan and the dragon); Hero: Spir. chh. 1.29-31.
\textsuperscript{193} Bur (2016: 152, 162). Schürmann (2002: 41) notes that Pan and the dragon (Spir. ch. 59) is the only Philonian device which makes use of continuously running water; it is also the only one explicitly flagged for use in temples (Schürmann 1991: 223 n. 2). For running water (or lack thereof), cf. also Hero, Spir. 136.10 (ὕδωρ ἐπίρρυτον), 140.7 (ἐπιρρύτον ὅ τι ὅσος), 144.7-8 (μὴ ἐπιρρύτον ὅ τι ὅσος).
\textsuperscript{194} On which, see Robinson (2011: 198-200).
5.4 The performative context of Hero’s automata

The discussion in the previous section leads us to the question of where the automata described by Hero were used. Very few scholars have addressed this issue, and, as far as I know, in only two cases has the question of the context of use of the mobile automaton been the subject of separate investigation. In what follows, I shall discuss the context of use of the mobile and the stationary automaton separately. Before doing so, it is worth summarising briefly the positions taken by previous scholars both because they sometimes argue that the automata were used in the same context and because none of them discusses in detail the context of deployment of both automata. The following positions are mentioned in logical rather chronological order:

(1) Schümann (1991: 190) confidently claims that both automata were used in private parties (‘privaten Festen’), but she does not explain.\(^{195}\) This argument is slightly elaborated in Schümann (2002: 45, 53), where, however, she focuses only on the stationary automaton.\(^{196}\) The envisaged sympotic context concerns Philo’s stationary automaton rather than Hero’s later version.\(^{197}\)

(2) Prou 147 suggests that, while spectacles involving mobile automata were initially performed in the theatre’s orchestra, the \(λογεῖον\) might have provided a more appropriate performance context for Hero’s mobile automaton;

(3) Bur (2016: 101) argues, on the one hand, that the mobile automaton was likely used as a paratheatrical form of entertainment at an ancient festival of Dionysus, and, on the other hand, that the stationary automaton seems more suited to a private context, either the symposium or the temple.

5.4.1 Mobile automaton

Let us start, then, by considering the performative context of the mobile automaton. As noted above, Prou asserted that the theatre’s orchestra was the

\(^{195}\) The rest of her discussion takes the form of a critical description of Hero’s treatise (Schümann 1991: 190-201).

\(^{196}\) In the same article, she also discusses the mobile automaton (Schümann 2002: 45-6), albeit without any direct reference to its context of use.

\(^{197}\) Schümann’s argument is elaborated by Beacham (2013: 33) in relation to Hero’s model.
place where the earliest mobile automata were displayed. There is no need to
discuss the validity of this assertion both because we have seen that other public
venues are attested for the Classical period – Delphi’s hippodrome from the
pseudo-Socratic epistle comes to mind – and because there is no way of knowing
for certain whether this was in fact the case. The premise of Prou’s assertion is
the suggestion that the apotheosis of Dionysus may have been a popular subject
of such representations because it would have served to harmonise the
introduction of brand new (scenic) technology (that is, the mobile automata)
with Dionysus’ role as the patron god of theatre. Again, we do not know whether
the subject was popular, although we do know that the particular presentation of
the mobile automaton was Hero’s (1.8 [6.4]). Certainly, though, Dionysus’
patronage of drama is something we should keep in mind as we proceed.

Prou’s suggestion that the mobile automaton performed its motions on
the λογείον has been harshly criticised by Bur (2016: 101). Bur’s criticism
revolves around two points: (1) Prou misinterprets the symbolic significance of
the automaton in that he compares it to an actor (‘un véritable acteur’); (2)
Hero’s description of the performance, with its emphasis on the repetition of
movements (in particular, the double half-rotation of Dionysus), rather suggests
that the automaton was completely surrounded by the audience. As for the first
point, I cannot find any misinterpretation. Prou’s comparison sounds like a
rhetorical exaggeration, a device not infrequent in his writing. The second point
is not less problematic because, regardless of where the automaton was
employed, Dionysus will not have faced all the spectators at any given time.
Assuming a circular audience, only half of it will have faced the god when not in
motion. Prou’s suggestion, in my view, accords well with the increasing
prominence assumed by the scene building in Graeco-Roman theatres, where the
λογείον could extend out to one-half of the orchestra’s radius (Kuritz 1988: 23),
although some of the spectators would perhaps have been too distant to enjoy the
spectacle. The weakness of Prou’s position rather lies in how he elaborates his
suggestion. He imagines that the automaton travels back and forth along an L-
shaped path: from the outermost thyromata to the middle of the scene, and from
there to the middle of the λογείον.198 This is not an instance of rectangular or

198 Prou evidently had in mind an Eastern type of theatre, such as the theatres at Ephesus
and Miletus (on which, see Dinsmoor 1950: 306).
circular motion, as Prou maintains, but of polygonal motion, a pattern which is only alluded to in passing by Hero. On the whole, the theatre remains a plausible context for the performance of the mobile automaton. Apart from the central role of the figure of Dionysus in the display itself, it is supported by two sets of evidence: (1) the theatrical automata I have discussed in §5.3 above (I am thinking in particular of Demetrius’ snail, whose affinities with Hero’s mobile automaton have been noted);199 (2) Hero’s own observations at II.1-2 [6.9-17] concerning, on the one hand, the properties of the ground,200 and, on the other, the use of a prepared trackway, which, as we have seen in §5.2 above, has recognisable parallels in earlier theatrical practice (the Hellenistic theatre at Megalopolis offers the closest parallel).

Bur’s criticism of Prou’s position leads her to envisage a processional context. She puts forth three possibilities (Bur 2016: 101-2): (1) the automaton was paraded on a cart (as was the statue of Nysa); (2) the automaton was brought out during the final sacrificial feast; (3) the automaton was employed during one of the pauses of the procession when specific ritual acts were performed to the accompaniment of music, singing and dance.201 She prefers options (2) and (3) because, although option (1) has the advantage of being supported by a historical parallel, ‘one cannot help but feel that the overall impact of the “miracle” of the machine would likely have been more impressive in a slightly calmer situation where all the attention was focused on this spectacular piece of technology’ (Bur

199 But see the caveat on the processional use of the automaton below.
200 Hero seems to be referring to a stone slab-paved surface (Comm. on II.1 [6.9-13]). Frederiksen (2000: 148) associates the orchestra’s lack of architectural importance in the Hellenistic period with the few attempts that were made to provide the orchestra with a stone surface (e.g. theatre at Priene), further noting that “[t]here are difficulties in interpreting the “smoothed rock” orchestra found in not a few theatres (e.g. Argos 2, Korinthos 2 and Boiotian Orchomenos); whether they were normally covered by a layer of sand or beaten earth is naturally impossible to know. Traces of such layers have been found at for example Morgantina and Solous’ (for these theatres, see his Appendix at pp. 169-173). For the transition from wood to stone in the Roman amphitheatres of the Republican period, see Welch (2007: 91-4).
201 See Kavoulaki (1999: 295), who cites the famous example of the cult regulation of the Molpoi concerning a procession from Miletus to the sanctuary of Apollo in Didyma (LSAM 50 = Milet. 1.3.133, on which see now Slawisch-Wilkinson 2018); see also Chaniotis (2011: 28). There is no mention of moments of repose in Athenaeus’ text, although, according to Rice (1983: 77-8), the mixing of wine with water and its subsequent distribution to the guests in the stadium described at Ath. 200b probably occurred during one such interval. For a similar station in the procession of the Athenian Dionysia of 309/308 BCE, see X. Eq. Mag. 3.2, erroneously cited by Bur (2016: 102 n. 5) as X. Eq. 3.2.
Although I agree with her on this point, I do not agree that the statue of Nysa offers a historical parallel both because it was considerably larger than the figure of Dionysus - we do not know the latter’s dimensions but the automaton itself was more than half the size of Nysa - and because it was in some respects a different kind of automaton (articulation, absence of rotation). Apart from size, there is another problem with a strictly processional use of the mobile automaton, that is, it would probably have taken a long time to set it up for performance, a feature the automaton shares with the stationary type. It seems therefore possible to rule out both option (1) and option (3), unless we suppose that the automaton had been set up in a fixed location (stadium, theatre or the like) well in advance. As far as option (2) is concerned, it is perhaps worth noting that we do not know where the Grand Procession terminated. Processions usually ended at the deity’s altar, where, after the sacrifice, there was a public banquet generally followed by athletic or artistic contests (Chaniotis 2011: 30-1). This may not have been the type of situation which would have allowed spectators to focus all their attention upon the automaton. Rice (1983: 35) suggested either that each of the smaller processions within the Grand Procession headed toward the altar of its own deity or, more likely, that the whole procession continued to a large assembly point. Alternatively, because no trace of a monumental altar has been found in Alexandria, it has been suggested that the final destination of the procession was the Acre or citadel of the city, which was probably located within the Inner Palaces of the city and where a pavilion had been designed and constructed to serve as a dining hall designated for the entertainment of royal guests (Ath. 196a-197c; Rice 1983: 31-4). This pavilion, as Athenaeus describes it, had important iconographic connections with the procession of Dionysus in terms of its decorative elements, such as columns resembling thyrsoi (196c), symposia scenes featuring figures from tragedy, comedy and satyr drama (197f) and niches containing Delphic tripods (Rice 1983: 32). A context such as this is not processional in the strictest sense but in fact sympotic, and would have certainly offered a more intimate environment in which to enjoy the automatic performance. In this respect, it is certainly not

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202 A point made to me by Prof. Isabel Ruffell.  
203 Viviers (2014: 32), followed by Bur (2016: 78). Rice (1983: 35) suggests that a temporary altar may have been set up for the occasion.
without significance that the iconography of the mobile automaton represents Dionysus as the patron of wine (wine spurtng out of his σκύφος) rather than as the patron of theatre, with explicit emphasis on the god’s orgiastic connotations (thrysus, Bacchantes). Since the automaton would have needed some space to move around in different directions, it might just as easily - in fact, perhaps more easily - have appeared in outdoor spaces such as domestic gardens (compare the examples of hydraulic devices given in §5.3 above).

To sum up, two different performative contexts emerge as the most plausible for the mobile automaton. On the one hand, the evidence pertaining to the device’s mobile ancestors points to public settings, first and foremost among them the theatre. This is further supported by internal evidence concerning the performance preconditions. On the other hand, the automaton would have also provided suitable entertainment at private (outdoor) banquets, where the domestic and theatrical spheres could overlap and intertwine (as with Trimalchio’s dinner party). Represented as the patron of wine, Dionysus could thus reclaim and reassert his role as god of the theatre.

5.4.2 Stationary automaton

The situation is perhaps less complex in the case of the stationary automaton. Schürmann (2002: 45, 53) has convincingly suggested that Philo’s stationary automaton was used as a form of entertainment in Hellenistic private symposia, where it replaced or complemented the more traditional puppet shows.204 The basis of her suggestion is an implicit comparison with some of Philo’s hydraulic showpieces which are not in any way bound to a particular place because all that they need is a table or base on which to be positioned.205 Thus, she argues, Philo describes devices that are appropriate for a sympotic venue both because they do not require access to running water (for an exception, see above, n. 193) and because they do not take up much space; the stationary automaton would have

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204 Among the examples she cites (Schürmann 2002: 37) are X. Symp. 4.55 (νευρόσπαστα), Ath. 19e (Ποθείνος ὁ νευρόσπαστος) and Hdt. 2.48 (ἀγάλματα νευρόσπαστα). But Xenophon uses the term metaphorically to describe a troupe of performance; see Huss (1997: 44; 1999: 302). I take these references from Ruffell (forthcoming 2).

205 See Schürmann (2002: 41 with n. 34), citing Ph. Spir. chh. 40-2 and 46. The stationary automaton is supported by a wooden pillar (καύτιον ξύλινον, XXI.1 [66.8]; cf. 1.3 [2.17-18]).
fitted in the average ἄνδρών even when all the couches (up to seven in number, with a maximum of fourteen people) were occupied. I find no difficulty with this view, and considering that the Roman triclinia generally had only three couches each accommodating three persons, \textsuperscript{206} I cannot see why the automaton could not have been used in Roman banquets as well. A performative context of this type is supported by another set of considerations, which make it a much better fit for the symposium/comissatio than for the temple. Beacham (2013: 33), who, following in the footsteps of Formígé (1921), investigates Book Two as a source of evidence for theatrical practice in the Hellenistic age, observes that such a presentation would find its ideal occasion in private Roman banquets, where, as we have seen, automatons were popular and where a variety of performances took place (cf. below, n. 207). I am not sure that ‘ideal’ is the right word given that we do not know exactly what form tragic presentations took in the Imperial period.\textsuperscript{207} Nevertheless, I believe that the explicit theatricality of the stationary automaton is significant, and it is certainly something that would have appealed to the tastes of learned Roman banqueters. In addition to the narrative itself, which has obvious dramatic origins, I would like to recall briefly other salient connections with the domain of theatre: (1) the automaton forms a proscenium arch, with the audience facing the stage, the performance area ‘framed’ and some of the mechanisms hidden in an upper space which terminates on either side in wings (XXVIII.2-3 [100.11-102.3]);\textsuperscript{208} (2) the automaton displays a series of painted scenes, and takes its name (πίναξ) from the painted panels that were increasingly popular in the Hellenistic and Roman theatres (see further Comm. on I.3 [2.17-18]); (3) the device which Hero uses for producing the sound of thunder is explicitly compared with a theatrical device

\textsuperscript{206} Vitr. 6.5.6; cf. Hor. Sat. 2.8.20-24 (specifying the names and position of the guests at Nasidienus’ party), with Schürmann (2002: 37 n. 13).

\textsuperscript{207} See Jory (1986: 150 n. 2). A wide range of private entertainments (e.g. Attelian farce, mime, comedy, story-telling, acrobatics) is attested in the sources, and is best exemplified by the broad applicability of the term acroama (Petr. Sat. 53.12, 78.5); see Horsfall (1989: 79-80, 87 nn. 53 and 61), with further references.

\textsuperscript{208} See Marshall (2003: 263). A triangular pediment covers the central part of the board hiding the mechanisms, and Hero notes the resemblance with a shrine; although this may have a religious significance, its primary function is to create a rational and coherent whole (ὅποτε δὲ μὴ ἄλογος ἢ σαφῶς ἐπικεφαλέως ἢ, ἀπὸ προστίθεται Ἀυτῇ καθάπερ δὴ ναὸς, XXVIII.3 [100.18-19]).
employed for a similar effect (XX.4 [66.10-18]);\textsuperscript{209} (4) the (possible) use of one or more μηχανάι, first introduced by Philo and later apparently rejected by Hero;\textsuperscript{210} (5) the dropping backdrops which are used for scene changes (scenes two and four) – or, in one case, to bring about the dénouement of the plot (scene five) – are comparable to the Roman siparia;\textsuperscript{211} (6) the continuously moving scroll of papyrus used to create the illusion of movement of the ships (scene three) is similar in effect to the scaena ductilis (as opposed to the scaena versilis), a movable painted screen which could be drawn off to the side to disclose another scene behind.\textsuperscript{212} It goes without saying that the use of such machinery and equipment would create much the same theatricalised environment as we saw in the Cena. My conclusions here do not differ greatly from those reached on the performative context of the mobile automaton.

5.5 Hero’s intended audience

Having established a broader context for Hero’s automata, I would now like to address the question ‘What was Hero’s intended audience?’. In order to answer this question, we need to interrogate ourselves about the nature and purpose of the treatise. It has been said that the work belongs to what I have called the ‘supergenre’ of technical ekphrasis, a category which encompasses many different genres and forms. Hedylus’ dedicatory epigram considered above (§5.3), to take an extreme example, describes Ctesibius’ drinking-horn only from the perspective of the viewer and is far removed in both purpose and form from other works belonging to the same category such as Philo’s and Biton’s construction manuals on artillery engines and Hero’s general introduction to the

\textsuperscript{209} The device used for producing thunder in the theatre was called βροντης and (if we are to trust our sources, which are late and not reporting from their own experience) differed from the one described by Hero. It consisted either of a leather sack filled with pebbles which was made to collide with a bronze plate (Poll. 4.130; Schol. vet. Ar. Nub. 292b alpha) or of an iron container in which stones were shaken (Schol. vet. Ar. Nub. 292b beta); see Horst-Dieter (2003). Hero’s testimony is significant because it attests to a third type of device. In my Commentary (synopsis on XIV), I have therefore used the term βροντης to refer to it.

\textsuperscript{210} See below, §§5.6. On the μηχανή, see Arnett (1962: 72-8) and Newiger (1990: 34-9). A recent reconstruction of the device can be found in Chondros et al. (2013).

\textsuperscript{211} Beacham (2013: 31), with bibliography.

\textsuperscript{212} Beacham (2013: 30). On the scaena versilis and scaena ductilis, cf. Serv. Georg. 3.24, with Beare (1964: 284, 300); see also Bieber (1961: 74-5).
same subject, to name just a few. Roby (2016: 199-242) has investigated the relationship between description and instruction in these and other texts which include instructions for building a technical artefact, showing that the way in which an author modulates his or her authorial voice shapes the relationship between author, reader and technical object. My aim here is not to examine the instructional mode in the treatise because this would require a separate and more detailed discussion, particularly in view of the Philonian origin of the material in Book Two. However, the approach is relevant to the present topic and should be kept in mind when considering internal evidence from the work itself. So, what kind of text is the Automata? Murphy 2-4 emphatically argues that it is neither a complete textbook on mechanical principles (as is, for instance, the Mechanica) nor an instruction manual, basing the latter part of her argument on the fact that Hero frequently leaves out a number of practical details. To illustrate this, she cites examples such as exactly how to connect a cord to the counterweight or how to prevent the cords from getting tangled up. The second example is not entirely appropriate, considering what Hero says at XXIII.8 [78.15-17]. A better example would perhaps have been the complete absence of information on the position of such elements as axles and pulleys. At any rate, while it is true that the treatise does not take the form of a discussion of mechanical principles, the reader is expected to some extent to master such theoretical knowledge, one which can in many cases be acquired only through experience and which is most clearly exemplified by Hero’s appeal to the principle of concentric circles and his subsequent attempt at clarification by implicit reference to the principles of leverage (XVIII.3 [60.1-3], with Comm. ad loc.). On the other hand, I do not understand why the treatise should not be considered a construction manual. Roby (2016: 199-200) shows that the defining characteristic of texts providing instructions for building is the quality of ‘generativity’, namely, the ability to present an object as coming together before the reader’s eyes. And this is

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213 Contra, Prou 139 and Berryman (2009: 140), who argue for a detailed approach.
214 See Schmidt (1903: 276). Murphy 4 also cites the absence of dimensions for the internal moving parts of the mobile automaton, including ‘the volume (not to mention the exact location) of the tube containing the millet seeds’. The tube, however, is not a moving element, and its position is specified at V.5 [22.12-13]: πρὸς ὅρθας κατά μέσον τὸ πλινθίον. On dimensions, see already above, §5.2.
precisely what we see in the treatise, where instructions for constructing the two
types of automaton are provided gradually and sequentially.216

Let us return, then, to the question of audience, a topic which has already
been addressed by scholars. The paucity of practical details has suggested to
Murphy 4 that the treatise may have been intended for craftsmen specialised in
building automata.217 Cambiano (2011: 33) draws a similar conclusion from his
examination of some of the main linguistic features of Book One. He shows that
in the first part of the work, much more than in the second, Hero shows a
preference for an impersonal and geometrical style similar to that of Euclid,
which makes use of letter labels, third-person imperatives like ἔστω/κάτωσαν
and νοεῖτε and infinitive clauses introduced by δεῖ and δεῖσαι.218 In Book
Two, by contrast, linguistic standardisation gives way to a more personal style
that recalls Philo’s instructional mode in his Belopoeica219 and in which first
person singular forms abound along with frequent alternations between present,
future and aorist.220 The higher degree of linguistic standardisation of Book One
(indeed, the more Heronian part of the work) leads Cambiano to think of an
audience consisting of craftsmen or designers (ἀρχιτέκτονες) who, as he points

216 A gradual, sequential approach can be seen most obviously in the description of the
mobile automaton, the different configurations of which are ultimately based on the same basic
model. See further below, §§5.6-7.
217 Contra, Marshall (2003: 267), who maintains that the tone of the treatise ‘is really not
so far removed from suggested hobby projects for boys found in Popular Mechanics over the
past century’. I am not as familiar with this magazine as I probably should be. However, those
familiar with it will certainly know that its mission was (and still is) to make technological topics
readily comprehensible to the general public (one of its mottoes being ‘Written so you can
understand it’); see Seelhorst (1992: 83). This does not seem to be the case for the Automata, as
my discussion below will show.
218 This brings Book One closer to the other Heronian mechanical works, including the
Belopoeica. Roby (2016: 223 with n. 117) claims that Hero’s grammatical constructions and
elements of his vocabulary such as third-person imperatives are characteristic of mathematical
prose, an assertion she bases on a ‘full corpus counts/author’ information available from the TLG
for the verbs of these forms used by Hero. On Hero’s geometrised descriptions of his devices, see
Tybjerg (2004: 46-51); see also Cuomo (2001: 163-4).
219 On which, see Roby (2016: 210-16).
220 See Cambiano (2011: 34-5). I count a total of 50 first-person singulars in Book Two,
including Schmidt’s supplement at XXIV.2 [82.2]. 23 occurrences are in the present tense, 2 in
the future, and 25 in the aorist. Similarly, Book Two contains 15 occurrences of the participle
agreeing with the first-person singular subject, all of which are in the aorist tense and include my
supplement at XXIII.5 [76.13]. In Book One, the first-person singular is replaced by the first-
person plural, be it ‘collaborative’ or ‘editorial’. For the ‘editorial we’, see the prefaces to both
books. On the use of different verb forms in technical texts, see generally Roby (2016: 201-9),
with further bibliography.
out, must have had at least a basic knowledge of geometry. This is especially true if we consider that, according to Vitruvius (De Arch. 1.1.3-10), the architect should ideally be trained in a curriculum which merged theory and practice and which comprised a number of disciplines including draughtsmanship, geometry and philosophy. However, while advanced practitioners would certainly have been able to grasp Hero’s explanation of circular motion in terms of a cone (ch. VIII) or to interpret the diagrams which he intended to accompany the text, it does not follow that non-specialists would not have been interested in the treatise. More recently, Keenan-Jones-Ruffell-McGookin (2016: 182) have tentatively suggested that the treatise envisages a ‘bifurcated audience’. Practitioners, they argue, would probably be familiar with some of the specialised terminology used throughout the treatise and would equally be able to fill the gaps both in Hero’s own account of the automata (practical details included) and in his reasoning for taking certain design decisions. So, for example, not only does Hero not fully explain the differences between the two main axle configurations (by means of two different types of bearing, the κνώδαξ and the χοινικός), but he also leaves it to the reader to figure out why enlarging the wheels is preferable to thinning the axle in order to lengthen the automaton’s journey (XVIII.3 [58.3-8]). Non-specialists, they go on to say, would be fascinated with the exhibition of mechanical skill as Hero expertly reveals the working of ‘wonders’. After all, as is sufficiently clear from what has been said above (§5.2), he is more than interested in offering flexible templates that can be adapted and readapted for multiple arrangements, and this alone is a source of wonder and amusement even to the most inexperienced reader. The idea of a bipartite audience receives further support from Hero’s own descriptive

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221 On this passage, see generally Anderson (1997: 5-8), and note especially Vitr. 1.1.7 item qui Ctesibii aut Archimedis et ceterorum, qui eiusdem generis praecipua consperserunt, leget, sentire non poterit, nisi hisibus a philosophis erit institutus.

222 The passage has been noted as an example of Hero’s flair for geometrical explanation by Cuomo (2001: 164 with n. 39).

223 On diagrams, see further below, §6.5. Explicit references to diagrams are found exclusively in Book Two (γράφωμα: XXIII.1 [74.5], XXIV.2 [80.15]; ἤποιγμα: XXVII.2 [98.12]), although the use of letter labels is a clear pointer to the role of illustrations.

224 Specialised words occurring in Book One are discussed in the appropriate places in the Commentary. For an index of technical terms, see Appendix 6.

225 Keenan-Jones-Ruffell-McGookin (2016: 182). See further below, §5.6.1 and Commentary II.3 [8.5-7].

226 Unless perhaps we place a lacuna after XVIII.3 [58.7] παραφέρω.
strategy. As noted by Roby (2016: 146), Hero pays great attention to what a spectator would see and that requires him to shift imaginatively from the description of the device’s interior to the description of its exterior. On the one hand, then, he repeatedly lays emphasis on the need to hide the mechanisms. On the other hand, he invites the reader to assume the position of the hypothetical viewer, appealing not just to sight but also to the senses of touch and hearing. It is perhaps no coincidence that this two-pronged strategy is implicitly foregrounded in the opening statement of the treatise, where, as we have seen, Hero juxtaposes the perspectives of the craftsman (δημιουργία) and of the spectator (θεωρία).

In summary, the treatise – no doubt an instruction manual on the construction of automata – seems to have been intended both for specialist practitioners and non-specialists. The former would have had to rely on their practical and theoretical knowledge to make full use of Hero’s incomplete instructions. The latter would have focused their attention on the wondrous aspects of the work, in some cases possibly motivated by a desire to further their understanding of the complex art of making automata.

5.6 Hero and his sources

In composing his works, Hero drew freely on a variety of sources, including, but not limited to, his mechanical predecessors. The mechanician Ctesibius was one of his sources, as suggested by the title under which his treatise on artillery has been transmitted ("Ἡρώνος Κτησιβίου Βελοποιικά). As a matter of fact, Hero’s Belopoeicà deals with early third-century BCE models, and Philo, in his homonymous treatise, describes two artillery inventions by Ctesibius that used bronze springs (χαλκέντονον) or compressed air (ἀερότονος καταπάλτης) rather

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227 Hero’s insistence on the concealment of cords is a paradigmatic example (XIII.9 [50.14-15], XVII.1 [56.11-12], XVII.2 [56.21-22], XXX.4 [108.5-6]), but there are many other examples: XIII.7 [48.11-13], XXIII.2 [74.11-12], XXVI.5 [94.2-4], XXVIII.1 [100.12-17], XXX.6 [110.4-6]; cf. XVII.2 [52.14] and XXVIII.5 [102.21-22].

228 A point I elaborate in my discussion of Hero’s notion of ποικίλια (Comm. on I.1 [2.4-5]); cf. also Comm. on I.5 [4.12-14].

229 On the close dependence of Hero’s Belopoeicà on Ctesibius’ lost writings, see Marsden (1969: 3).
than the traditional springs made of twisted sinew or hair. The Pneumatica, as will become clearer later, comes from far more diverse sources. If we limit ourselves to the main written sources, we know that 15 out of the 80 devices described in the work are taken from Philo (albeit usually modified) and that two chapters, Spir. 2.17 (cupping instrument) and 2.18 (pus extractor), appear to derive from some surgical book. In the introductory section of the treatise, moreover, Hero not only quotes almost verbatim the third-century BCE philosopher Strato of Lampascus (Spir. 24.20-26.8) but also appeals to different theories to explain rarefaction effects. Similarly, the Mechanica contains traces of three now-lost works by Archimedes devoted, respectively, to centres of gravity (Mech. 1.24), upright supports (Mech. 1.25-8, 30-1 and 2.35-41) and balances (Mech. 1.33-4).

When considering Hero’s (use of) sources in the Automata, we need to consider separately the whole work and the parts into which it falls. Let us first look at the individual books.

In Book Two, Hero explicitly refers to Philo as his source, stating that the latter’s work far surpassed that of other, unspecified predecessors (XX.1 [64.8-10]). Hero’s aim is to improve the Philonian model, which in turn drew on pre-existing (Ctesibian?) technology. Whether Ctesibius was Philo’s source is doubtful, but, as we have seen in §5.3 above, he certainly had constructed (water-powered) automata. Hero claims (whether explicitly or implicitly) to have improved Philo’s model in two ways: by replacing the μηχανή used for the appearance of Athena with a hinged device (on which, see above, §5.2) and by

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230 These experimental models, the former of which was greatly improved by Philo (cf. Bel. 67.28-68.1), are described at Ph. Bel. 69.31-72.4 and 77.9-78.22, respectively; for discussion, see Marsden (1969: 5-7, 41, 168) and, more recently, Schiefsky (2015: 640-9).

231 See Drachmann (1948: 80-1, 100, 126). Fraser (1972: 1.41 with n. 450), contra, finds it likely that Ctesibius’ lost works on pneumatics served as a source not only for Philo but also for Hero (an opinion misattributed to Diels 1893: 110 n. 3). According to Diels (1893: 106-7), Hero would have reworked Philo’s Pneumatica, which in turn depended on Ctesibius; see Drachmann (1948: 90-1), who is inclined to assign to Ctesibius, rather than to Strato of Lampascus, the experiments supporting the latter’s view of the void in the introduction to Hero’s Pneumatica.

232 This passage appears almost verbatim in Simp. in Ph. 693.11-18, quoting Strato.

233 I cannot discuss here Diels’ (1893) untenable attribution of the introduction of the Pneumatica to Strato, but instead refer the reader to the recent contributions of Bényman (2009: 166-70; 2011). For Hero’s reference to Archimedes’ Floating Bodies, see above, n. 109.

234 Drachmann (1963b).

235 That Philo drew on Ctesibius is presumed by Ruffell (2016).
showing how to produce the sound of thunder and to strike Ajax with lightning (the descriptions of the latter effects were apparently accidentally left out by Philo; XX.2-4 [64.12-66.10]). Despite his intentions, Hero elsewhere makes mention of a μηχανή (XXII.6 [72.20], XXVIII.2 [100.15], XXVIII.3 [102.2-3]σ), which can hardly refer to any other machine than Athena's (but cf. the more generic reference to μηχαναί outside the πίνακες at XXI.2 [68.15-16]). This contradiction has led Schöne (1891: 77) to tentatively suppose that the main part (‘Haupttheil’) of the book was derived verbatim from Philo and that Hero failed to remove all unnecessary references to the μηχανή. This suggestion tends to be confirmed by the linguistic and stylistic differences found between the two books (cf. above, §5.5). At any rate, Hero (XXII.2-3 [70.14-18]) makes it explicit that he relies on technological advances of his time when, after noting the superiority of his contemporaries over the ancients, he goes on to describe the Nauplius arrangement (τοῦ δοκοῦντος μοι κραίττονος, with which cf. XXI.2 [68.18-19]). In Book Two, therefore, Hero’s novelty consists more in providing an updated presentation of earlier material than in the technical improvements themselves, as he himself programatically proclaims at XX.5 [66.22-68.3].

The situation is less clear-cut in Book One, although there is no doubt more scope for innovation. Here, too, Hero refers to his predecessors on a

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236 Apparently, Hero was able to consult several ‘copies’ (συντάγματα, XX.3 [66.5]) of Philo’s work; see Ferrari (1965: 266) and, more dubiously, Cambiano (2011: 26). For another (non-claimed) Heronian improvement, see below, §5.6.3.

237 Along somewhat similar lines, Cambiano (2011: 25) misleadingly argues that the novelty lies primarily in the account Hero gives of contemporary state-of-the-art technology. His argument fails to take into account the extent to which Hero depends on Philo, who receives high praise for his achievements (XX.5 [66.19-22]). Tybjerg (2005: 210-13), by contrast, seems to extend my claim to Hero’s originality tout court, although she draws inconsistent and contradictory conclusions. A detailed treatment of Tybjerg’s argument falls outside the scope of the present discussion, and I must confine myself to a few remarks on the Automata; see below, n. 238.

238 In commenting on this passage, Tybjerg (2005: 211) infers that the novelty of Hero’s presentation relies on his ability to compare and correct pre-existing material, which in turn leads her to interpret the adjective κατάραπτος (XX.1 [64.8]) as referring not only to the technical inventions described in the book but also to the account itself. There are at least two problems here. First, there is no firm evidence that any of the devices presented in Book Two is Hero’s own invention. Second, Tybjerg’s inference is incorrect, based as it is on an erroneous translation of the participle τὰ παραθεωρηθέντα, which should be understood as ‘what has been overlooked’ (‘le cose trascurate’, Baldi 32; cf. Schmidt 407) rather than as ‘comparisons’ (Murphy 28). Indeed, Hero does not compare different devices, but he makes improvements and additions.
number of occasions, and some of his references likewise serve the double purpose of justifying his work as being part of an established tradition and emphasising the novelty of his contribution (see Cambiano 2011: 24). So, while predecessors play a central role in presenting automata-making as a worthy subject of study (I.1 [2.3-4]),239 Hero later criticises them rather harshly. Hero’s criticism revolves around two interconnected issues: the aesthetic appeal of the mobile automaton and the technical effectiveness of the construction techniques. The reason for refusing scenic arrangements of earlier times (II.12 [14.11]) is that the methods used by the ancients were not advanced enough to allow practitioners to achieve aesthetically satisfying results. This becomes evident when we compare Hero’s remarks on the replicability of methods (II.12 [14.12-14]; cf. Comm. ad loc.) with V.1 [20.8-12]. His predecessors, says Hero, have handed down (παρέδωκαν) a system of moving the automaton back and forth along a straight line, but this has often proved unsuccessful owing to methods (αἱ ὑπ’ αὐτῶν ἀναγεγραμμέναι μεθόδοι, cf. XX.1 [64.5]) that not only were unreliable but also could not stand up to systematic empirical testing. Hero does not specify who his predecessors are, but he does refer to a tradition that by his time had already been codified in written form. This seems precisely the kind of tradition to which Vitruvius refers in De Arch. 7 praef. 14, where he gives a list of Greek writers on machinery (de machinationibus) that includes Ctesibius and Philo. The improvement of earlier methods permits Hero not only to provide a fresher-looking device (καίνότερον... κατασκεύασμα, II.12 [14.12]) but also to perfect and extend its mechanisms of movement.240 In addition to providing a safer mechanism for straight-line motion, Hero claims to have introduced more complex patterns of movement such as circular and rectangular (V.2 [20.13-17]).241 He later (XI.1 [36.1-5]) introduces the possibility of moving the automaton in other ways, too, namely, along a non-rectangular polygonal track

239 See above, §5.2.
240 I borrow the concept of ‘mechanisms of movement’ from McCourt (2012: 187), who uses it as a reference to the mechanical configurations adopted for moving the automaton locally from place to place.
241 McCourt (2012: 193) erroneously calls the latter ‘rectilinear movement’, adding that the automaton travels along the sides of a ‘rectilinear form’. Hero unmistakably refers not to any rectilinear figure (εἴδοσμα σχήμα) but to a rectangular polygon (παραλληλόγραμμον ὀρθωγώνιον). On rectilinear figures, see Comm. on XI.1 [36.1-3].
and in a snake-like pattern. A comparison with the Pneumática seems to suggest that at least the first of these patterns of movement represents a Heronian innovation.

Apart from the sources mentioned above, we have no way of knowing exactly what material Hero used in compiling his Pneumática. Drachmann (1948: 81-2) posited a number of different sources, ranging from books to actual instruments. He found confirmation of Hero’s eclectic and varied use of sources in the fact that there are some differences in the wording of the headings of the chapters (Drachmann 1948: 82-4). He identified five different openings, which may occasionally occur within, rather than at the beginning of, chapters. OPENING A, introduced by connecting formulae, characterises completely revised chapters but gives no hint of the underlying sources. OPENING B, corresponding to Ἐπὶ τῶν, etc. or Ἐνὶ τῶν, etc., indicates descriptions of familiar devices, often improved by Hero. OPENING C, namely genitive absolute followed by future indicative or present infinitive, together with OPENING D, which begins with κατασκευή/κατασκευάζεται or the like, introduces either a well-known device or an invention by Hero. Finally, OPENING E, which comprises variations on the foregoing, indicates an improvement made by Hero; it may be introduced by expressions like Δύναται δὲ καὶ ἄλλως, etc. or, exceptionally, by Ἐάν δὲ βουλέμεθα, etc. (Spir. 128.5). Drachmann’s review of the chapter headings of the Pneumática led me to examine the Automata, and I have found that some sections throughout the text begin with OPENING A, OPENING D and OPENING E, or, at least, with variations thereof. Before reviewing these openings, let me make two points. The first point (a methodological one) is that Drachmann’s model does not apply to the Automata in exactly the same way as it does to the Pneumática, because, while in the latter case chapters are devoted to individual instruments, in our case the text has a less rigid structure. This is particularly obvious in the case of OPENING A, but, nonetheless, the nature of the inferences involved is essentially the same. The second point (a more specific one) is that three passages begin with what could be argued to be OPENING C. These are XI.11 [42.4-7], XXVIII.1 [100.5-7] and

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242 Pace Cambiano (2011: 33), who takes the whole section to refer to snake-like motion.

243 Other possible variations are Ἐστι δὲ καὶ ἄλλως, etc. (Spir. 140.7 and 178.27), Καὶ ἄλλως, etc. (Spir. 218.13) and δέον, etc. (Spir. 148.6 and 302.10). I take the last two references from Drachmann (1948: 83).
XXIX.1 [104.14-15]. In none of these cases does the phrasing (genitive absolute + future indicative) introduce the description of a device or configuration. And even though XI.11 [42.4-7] refers generally to an improvement made by Hero, the shared presence of a connective discourages identification with OPENING C. Let me now, then, review the openings:

(A) Connecting formulae occur quite consistently throughout the text, with a preponderance in BOOK ONE. Overall, OPENING A occurs 65 times, of which 39 times in BOOK ONE and 26 times in BOOK TWO. These figures take into account occurrences of ἐκ καί/ἐκ...καί, excluding those appearing in OPENING E, of μὲν οὖν and of οὖν καί, as well as occurrences of ἐκ at (or near) the beginning of the chapter. For the editorial implications of the distribution of connecting formulae, see below, §5.7.

OPENING A, for instance, introduces the descriptions of backward motion (VI.1 [22.21]), circular motion (VII.1 [26.6]) and rectangular motion (IX.1 [30.3]). The descriptions of the piping system (XIII.2 [44.17]), of how the Bacchantes dance (XVI.1 [54.9-10]) and the cords are concealed (XVII.1 [56.12-13]) all begin in the same way (γίνεται οὖν καί τοῦτο οὔτως), with which cf. especially XIV.1 [50.17-18]. The same pattern (ποιήσομεν οὖν καί...οὔτως) is followed by XXVI.1 [90.10] and XXVIII.2 [100.11], although in the latter case the true beginning is XXVIII.2 [102.3-4]; see below.

(D) There is only one occurrence of OPENING D, XXVIII.2 [102.3-4], which introduces the description of Nautilus’ torch: ἡ τοῦ πυρσοῦ γίνεται κατασκευὴ τοιαύτη οὕσα. The basic version of the device is clearly an instrument in common use, as confirmed by XXVIII.6 [104.2-4]. The phrase found at I.2 [2.9-10], κατασκευάζονται ναοὶ ἡ βιομοί, must not be classed here; the verb only refers generally to the process of construction, as it does at II.2 [6.18] and XXIII.1 [74.5].

(E) Overall, there seem to be eight instances of OPENING E, of which four occur in an explicit form. One chapter, dealing with the two-counterweight system, begins with Δύναται ἐκ καί ἄλλως, etc. (XIX.1 [60.10]). XI.1 [36.1] has a slight variation (Δυνατόν ἐκ ἐστι καί ἄλλως, etc.), which concerns the

\[244\] My interest in such implications led me to adopt a looser criterion for classifying occurrences of OPENING A. For this reason, I have included occurrences that do not introduce descriptions of instruments or configurations.
possibility of effecting polygonal motion. The immediately following clause builds directly upon it, and relates to snake-like motion (ἐτὶ δὲ καὶ... δυνατὸν ἐστι, XI.1 [36.3-4]). The explanation of how the mobile automaton makes a pause starts with ἐὰν δὲ βουλόμεθα (VI.2 [24.9]), which is incrementally varied to introduce repeated forward and backward motion (ἐὰν δὲ καὶ... βουλόμεθα, VI.3 [24.16]). To these instances we may add XIV.2 [52.3], XX.2 [64.15] and XXVIII.6 [102.23].

This review sheds some light on the presence of alternative, apparently incompatible versions of mechanisms. These have generally been explained by having recourse to assumptions of interpolation, but unnecessarily so. In what follows, I will discuss three instances of this phenomenon, referring the reader to the Commentary on BOOK ONE when appropriate.

5.6.1 Snake-like motion

In ch. XI, Hero presents three configurations for achieving snake-like motion. McCourt (2012: 194), who discusses in some detail most of Hero’s mechanisms of movement, does not acknowledge the presence of these alternative versions; moreover, he misunderstands the first configuration, claiming that it allows for ‘all patterns of movement’. This seems due to the fact that, as we have seen above, Hero starts off by suggesting the possibility of polygonal motion. But nowhere else in the rest of the chapter does he connect any of his configurations with other patterns of movement. The presence of three distinct configurations is a clear indication of multiple layers in the mobile automaton, although without explicit attribution. The fact that Hero begins his account with what I have classed as a variation of OPENING E seems to suggest that we are dealing with one of his improvements, unless we are to suppose that he is silently appropriating, in part at least, earlier (Philonian?) material. The latter possibility is very tempting indeed, especially since Hero ends up preferring the third configuration, where the hubs (χοινικίδες) are replaced by pivots (κνόδακες) and the front axle is replaced by two independent axles. It may well be, then, that the first and the second configurations do not represent genuine Heronian improvements. And even if Hero had in fact modified the first configuration (with the front wheels mounted on separate rotating hubs and the rear wheel...
turning on pivots), adding a third hub and fixing the rear axle to the base of the automaton would have been the easiest, most natural thing to do. Certainly, Hero recognises that the hubs do not rotate effectively, and expresses his insight into the greater efficiency of the κνώδαξ (X.1.8 [40.3-7]). Hero’s use of the impersonal form ἄρέσκει in this context recalls a similar idiom in Ath. Mech. 33.5 and 35.4, where the phrase ἄρέσκει δὲ μοι, etc. introduces two technological innovations: the forewheel (πρότροχος) for tortoises and other stone-throwing machines and the goblet-jointed crane (where the element of innovation consists in the combination of the goblet-joint, χαρχήσιον, and the crane, γέρανος)\(^{245}\). This somewhat parallel usage lends further support to the idea that the third configuration belongs to Hero. For more on snake-like motion, including discussion of Schmidt’s interpolations, see Comm. ad loc.

5.6.2 Two-counterweight system

In ch. XIX, Hero discusses an alternative system for bringing about motion in the mobile automaton. Instead of having only one counterweight, the automaton now has two counterweights, one bringing about forward and backward motion, the other all those movements that do not have to do with locomotion (αἱ δὲ ἐκτὸς τῆς πορείας κινήσεως, 1.8 [12.3-4]). Each counterweight is located in a separate tube, which is nothing other than a section of the previously undivided σύριγξ. The whole chapter has been deemed an interpolation by Olivieri (1901: 431-2). Olivieri’s main point is that the chapter does not constitute an alternative explanation of how movements are effected, but rather a failed attempt to fill a lacuna in the text. What is missing, he argues, is the explanation of how the movements other than locomotion succeed one another. The chapter, which Olivieri regards as unrelated to the preceding sections (XVII.3-XVIII), would thus provide only limited information on the connection between forward and backward motion and all the other movements. Olivieri’s argument rests on two misconceptions: (1) that ἠλλος (XIX.1 [60.10]) is out of context (he considers

\(^{245}\) See Whitehead-Blyth (2004: 36), I cannot agree with these scholars that Hero and Athenaeus use the ‘same idiom’ (‘I am in favour’, p. 38). As already noted by Whitehead-Blyth (2004: 38 n. 93), Hero uses the impersonal form ἄρέσκει only once elsewhere (Spir. 4.11), where, however, it refers to the ‘generalised agreement’ among ancient physicists on the composition of air; on the impersonal use of the verb, see generally LSJ s.v. ἄρέσκει s.v. IV.
the term ‘strano e sintomatico’, p. 431); (2) that the marginal note found at the
eend of almost all manuscripts (λείπει) indicates a lacuna occurring in BOOK ONE.
As far as these two points are concerned, Schmidt (1903: 277-8) notes that in ch.
XIX the movements are presented as occurring in a different way than before
(namely, by means of two counterweights) and that λείπει can only indicate a
lacuna at the end of the treatise (cf. already above, n. 147). This is certainly
correct, but there is no reason to presume that, because the mobile automaton
features two distinct types of movement, the two-counterweight system
represents the oldest version of the device.246 From what has been said so far, it
is fairly clear that Hero is adapting at least one prior version of the automaton,
and that the version handed down to him by his predecessors is the one featuring
a single counterweight. Furthermore, as we have seen, ch. XIX begins with
OPENING E, which does not merely argue against interpolation but indeed
suggests that the two-counterweight system is Hero’s own improvement. If so,
then, why does Hero seem to prefer the single-counterweight system? There are,
I think, at least two non-mutually exclusive ways of answering this question.
The first way is to assume that the improved model was still in an experimental
phase at the time of Hero’s writing. This would have probably meant that it had
not yet been further adapted to incorporate configurations for more complex
patterns of movement. The second way is to deny downright that Hero prefers
either system. The most logical thing for him to do was to adopt only one system
(the oldest one) and progressively adapt it to various forms of motion.
Describing the two-counterweight system earlier on would have, at least to some
extent, disrupted the narrative, and so Hero relegated his description to the end
of the book. Was Olivieri right, then, in assuming that the chapter has no
connection with what precedes? Schmidt (1903: 277-8) suggests, rather
cryptically, that the connection between XVII.3-XVIII and ch. XIX lies in the
fact that the locomotion of the automaton is still brought about by means of a
single counterweight. While this is true as far as it goes, it overlooks the purpose
of XVII.3-XVIII.2. There Hero proposes three alternative modifications to the
basic configuration of the automaton, which would, at least in theory, lengthen

246 A belief held by Schmidt (1903: 278).
the distance travelled. A tube containing two counterweights would have meant a double length of cord connected to the wheel axle, and that would have increased the range of motion. The two-counterweight system, therefore, does not represent sic et simpliciter an alternative to the single-counterweight system, but rather an improvement on the potentially unsuccessful modifications described in the preceding context. It does, in other words, find its natural place in ch. XIX.

5.6.3 Nauplius’ torch

In ch. XXVIII, Hero deals mainly with the construction and operation of Nauplius’ torch. The device consists essentially of a bronze chest containing a lighted lamp. The chest is initially described as lidless (πῶμα μὴ ἔχον, ἀλλὰ ἀχανές, XXVIII.3 [102.5]), but later as equipped with a triangular bronze plate (ἄλλῳ δὲ λεπτῷ... καταπούσαμεν τὴν ὀψήν, XXVIII.5 [102.15-16]). This second version of the device, where wood shavings are used as a combustible, recalls the mechanism used to light the fire on the altar of Dionysus in the mobile automaton (XII.2-4 [42.16-44.11]). Hero may have this in mind when he speaks of ‘another’ plate. Before explaining how the plate is moved mechanically, Hero proposes equipping it with a wooden peg: καὶ γὰρ ἐξίλινον ἐπιούριον ἔξει, ἑάν βουλόμεθα τελείως πάντωθεν πωμᾶσαντες ἀόρατον ποῦσαι τὴν φλόγα (XXVIII.6 [102.23-24]). Schmidt LXIII found these words suspicious, and tentatively suggested (app. crit. to 444.4) either replacing ἐπιούριον with κλεπτερίον or deleting the whole passage. His main reasons for suspecting interpolation are as follows: (1) the peg is made of wood, unlike the rest of the chest; (2) there is a contradiction with XXVIII.3 [102.5]; (3) capping the lamp means that the flame goes out when oxygen is exhausted. As to the peg, Schmidt no doubt fears that it would catch fire (cf. below, n. 250). If we follow Prou 241 n. q, however, the flame of the lamp is covered by the surface near the base of the plate, which, by absorbing the heat of the flame, would prevent the shavings from catching fire owing to overheating. It is thus unlikely

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247 For details concerning the impracticality of these modifications, see synopsis on XVII.3-XVIII.
248 I cannot infer from Hero’s words that the chest is open on the back side (‘nach hinten’).
that the peg, driven through the extremity opposite the base, would start burning. To this we should probably add that Schmidt’s proposed emendation is pointless – and this not only because a κλιτήριον (‘slide’) would still be made of wood but above all because it could not act as a pivot point for the rotation of the plate. As regards the second point, there is no contradiction here. At first glance, there seems to be a contradiction between XXVIII.3 [102.5] and XXVIII.5 [102.15-16], but, as we shall see, it is only apparent. Moreover, the fact that the passage contains a conditional clause introduced by a slight variation of OPENING E leads us to think that the capping of the lamp is an improvement made by Hero. Finally, with respect to the threat posed by oxygen exhaustion, we note that Hero only intends to conceal the flame. He does not say anywhere that the plate is airtight.When he instructs the reader to cut out an aperture in the upper side of the chest (XXVIII.4 [102.9-10]), he does not say what shape it should be, and nothing compels us to believe that it is shaped to match the plate. All in all, Schmidt’s arguments are at best inconclusive, and it seems unnecessary to resort to interpolation to explain the apparently contradictory elements of the text. The reasons for this claim will become clear in the following section.

5.7 Status of the text

The question of the status of the text is intimately connected with Hero’s relationship to his sources. Once again, a comparison with the Pneumatica is instructive. Drachmann (1948: 79-80) has convincingly hypothesised that the Pneumatica, as we now have it, is Hero’s posthumously published notebook. In his view, the introduction and the first eight chapters, all of which begin with OPENING A, represent either Hero’s own manuscript or a rough draft for the beginning of the work, whereas the remaining chapters would be his material in

\[^{249}\text{At least according to Prou’s reconstruction; but cf. also Schmidt 444 Fig. 107b. The peg is instead missing in Murphy 37 Fig. 13.}\]

\[^{250}\text{Schmidt 445 n. 1 does not betray the slightest awareness of the problematic nature of his conjecture, which he supports by citing XIX.2 [62.1]. That the ignitability of wood represented a concern for the scholar is confirmed by the fact that he suggests, as an alternative to a κλαθρόν, a ‘Klappe aus bronze’. On Hero’s κλαθρόν, mainly designating the lock mechanism of the σφυρίς, see Comm. on IX.5 [32.8-9].}\]

\[^{251}\text{This, too, apparently contradicts the claim that the chest is ‘wide open’.}\]
the form of more or less finished notes. Drachmann’s hypothesis explains not only the disorderly arrangement of the material but also various inconsistencies such as the absence of letter labels in certain descriptions. One of the most interesting examples he cites of the latter is Spir. ch. 2.34, which contains two slightly different descriptions of the same instrument (the so-called miliarium, a water-heating device), one with and the other without letter labels.252

Let us proceed, then, on the assumption that Hero did not complete his revision of the Automata and see whether it fits with, and justifies, the status of the text. This assumption would in effect explain the following:

(a) The references to topics not discussed anywhere in the treatise, such as II.6 [10.8] and III.2 [16.10];
(b) Some digressions or apparently misplaced material, such as XII.3 [44.1-2] and XXVIII.2-3 [100.11-102.3];
(c) The disorderly or discontinuous arrangement of the material such as occurs, for example, in XII.2-4 [42.14-44.11] and XIII.2-7 [44.17-48.13];
(d) The contradiction concerning the appearance of Athena, who is also described as being painted on the cloth background at XXVIII.1 [100.7-8];
(e) The contradiction(s) concerning Nauplius’ torch;
(f) The (partial) repetition or duplication of the information such as occurs at XII.4 [44.7-9], XXVIII.3 [102.3-4] and XXVIII.4 [102.14];
(g) The complete absence of letter labels in some descriptions, such as XIV.1-2 [50.18-52.6], XX.4 [66.10-18], XXV.2-6 [84.15-88.14], XXIX.1-2 [104.19-106.3] and XXX.1-6 [106.7-110.10]. It is interesting to note that three of the four passages from Book Two contain genuine Heronian descriptions;253
(h) The clear-cut bipartite structure of ch. XXVI, where we first find a description without letter labels, mainly dealing with constructional details, and then a short, badly corrupt description with letter labels, explaining the associated configuration. The first description may have been taken directly

252 Drachmann (1948: 80) regards the first description (Spir. 304.10-3) either as something copied from some book or as notes taken directly from the device, although he later (p. 131) opts for the latter option; the second description (Spir. 310.3-316.13), on the other hand, seems to have been intended for publication.
253 Sound of thunder (XX.4 [66.10-18]); appearance of Athena (XXIX.1-2 [104.19-106.3]); disappearance of Ajax (XXX.1-6 [106.7-110.10]). See above, §5.6.
from Philo, whereas the second description may have been either added or, more likely, edited by Hero.\textsuperscript{254}

Drachmann (1948: 80) finds confirmation of his hypothesis, e contrario, in the fact that whenever Hero describes two devices, of which one is a clear improvement on the other, the original version always comes first. The situation is not different in the case of the Automata. We have seen that Hero presents multiple configurations, and that he does so in a progressive fashion. The three configurations for snake-like motion, for instance, follow naturally from each other just as the two-counterweight system follows from the less reliable mechanisms for increasing the range. Similarly, Hero’s own version of Nauplius’ torch comes after the first (presumably Philonian) version of the device, as also happens in the case of the sounding devices described in ch. XIV (see synopsis ad loc.).

The hypothesis that the Automata was published (perhaps posthumously) in an incompletely revised form has clear advantages. It enables us to avoid the vicious circles involved in certain assumptions of interpolation. It enables us to avoid interpreting the lack of details or follow-up information as an indication of the incompleteness of the text.\textsuperscript{255} It enables us to correlate the distribution of connecting formulae with the processes of authorial revision and thereby to confirm that BOOK ONE had been revised to a greater extent than BOOK TWO (which, indeed, shows a higher degree of internal incoherence). Overall, it enables us to see the text in a new light, one which accords best with Hero’s actual use of sources.

\textsuperscript{254} A similar, but less clear-cut, bipartite structure occurs in ch. XXVII. It is not until the end of ch. XXVIII that the components of Nauplius’ torch are mapped onto points in the diagram (XXVIII.7 [104.11-13]; cf. Fig. 25). I have two reasons for deleting these words: (1) the mention of knobs is out of place (see already Schmidt 447 n. 1); (2) the neuter article is repeatedly used with non-neuter nouns.

\textsuperscript{255} A distinction must be made between incompleteness of the text and incomplete authorial editing. The fact that Hero failed to complete his revisions, for reasons unknown to us, does not necessarily imply that he considered the work to be incomplete. I regard the Automata as complete in its internal structure, and take the references to content not found anywhere in the text as due either to incomplete revision or to textual lacunae.
6. PRINCIPLES AND CRITERIA

6.1 Text

The constitutio textus owes much to the work of the previous editor, although divergences are not at all rare. Compared to Schmidt, I take a bolder yet more consistent approach to conjectural emendation, while retaining manuscript readings wherever possible. All text-critical decisions have been driven by the concern to offer a text as close as possible to the original. For this purpose, I took into account Hero’s style and vocabulary, as well as statistical and contextual considerations. Palaeographical aspects played a role as well, and the reader will find evidence of this in the Commentary. Textually, Book Two represents a more difficult challenge for the modern critic than Book One, and it is certainly regrettable that, within the confines of this work, it was not possible to provide a commentary on the whole treatise. Nevertheless, although the precise extent of Hero’s debt to Philo is unknown, the usage of the latter author has been consistently taken into account as part of the text-critical process. Comparison with Philonian material proved particularly instructive wherever Heronian evidence was scarce or absent.

The formatting and layout of the text follows as far as possible manuscript practice. I have adopted the chapter divisions which appear in the main manuscripts, but, for the sake of convenience, I have accepted the additions made by Schmidt and Haase (cf. above, §5.1). Similarly, in order to avoid introducing a new system of internal division, I have employed Schmidt’s subdivisions without altering the consecutive numbering of chapters and sections. Internal paragraphing more faithfully reflects that of the manuscripts, in particular T and – in places where the latter is no longer extant (VII.1 [26.7] and XIX.1 [60.12]) – its closely related manuscript Eb. In two cases, I have followed AGM (XXIV.2 [80.14]) and M alone (XXVI.1 [90.10]). However, in order to achieve consistency with other chapter openings of Book Two, I have
preferred not to indent XXV.1 [84.12] and XXVI.1 [90.6], both of which are marked off (with an L-shaped sign) in M.\footnote{256}

Spelling has been normalised throughout.\footnote{257} Capitalisation has been preserved as found in the manuscripts, except in the case of personal names, which are always capitalised. Unlike in the previous edition, letter labels have been reproduced as they appear in the manuscripts: lower case and overlined. The following spelling and accentuation errors were overlooked by Schmidt: καταπρόσθεν and/or the further corruption κατά πρόσθεν (inexplicably printed by Schmidt) for κατάπροσθεν;\footnote{258} τρόχιλος/-ον for τροχίλος/-ον, where the former is attested much more frequently in later times (from Oribasius onwards), and which I have silently corrected at VI.4 [26.3] and XXIV.5 [84.3]; χερίον/-α for χέριον/-α.

Punctuation presents a different set of issues and problems. Thévenot's (and, to a slightly lesser extent, Prou's) punctuation is, on the whole, confusing and unhelpful, because, apparently, it is based on the manuscript punctuation, which is often haphazard and erratic. The punctuation of Schmidt's edition is much more accurate and systematic, although it is not always clear when he is following the manuscripts and when he is supplying his own punctuation (in his apparatus criticus he does not record deviations from the main manuscripts, nor does he provide a statement of practice elsewhere). I have therefore chiefly adopted his punctuation, deviating from it where a different punctuation either accords better with my understanding of the text (see, for instance, XXIV.2 [80.12]) or improves its readability and consistency (see, for instance, XXII.5 [72.12]).

\footnote{256} In the former case, the sign is most probably intended to indicate the place where the text resumes its normal order. The tilted obelus (\(^\lambda\)) found in the same place in the lower margin of A seems to serve the same purpose, for a similar sign occurs at the beginning of the reiterated passage from XXII.6; see above, n. 84.

\footnote{257} For instance, abbreviations and ligatures have been expanded, and the shape of π, which in some manuscripts is realised in cursive as \(\varepsilon\), has been rendered as π.

\footnote{258} This adverb is attested elsewhere only thrice in the Delian inscriptions: IG 11.2.161A 45, 165.22 and 23; cf. 163A fr. α51 (κατάπροσθεν); LeRoy (1973: 278 n. 54).
6.2 Apparatus criticus

The apparatus criticus has been composed in the positive way, except in the following cases: (1) when a negative entry does not cause inconvenience, confusion or obscurity (for instance II.9 [12.10]); (2) when I record deviations from Schmidt's punctuation (for instances, cf. above, §6.1). As a rule, I have not recorded orthographic errors and variants when they do not alter the meaning of the transmitted text.

6.3 Translation

As has been seen in §2.2 above, the most recent complete translations of the treatise are not unproblematic, particularly with respect to transparency and faithfulness to the text. Moreover, Murphy's English translation is not easily accessible, and readers are still more likely to derive greater benefit from Schmidt's older translation into German. In my English translation I have attempted to adhere as closely as possible to the original text while at the same time aiming at clarity, literary quality and readability. I have tried to convey Hero's stylistic features as much as possible, although on the whole I have prioritised accuracy over style. This proved particularly important in the case of an author like Hero, who intertwines different discourses and domains (to wit, mathematics, technology, theatre, architecture and philosophy) and who deliberately deploys technical language. The reader should therefore not be amazed, for example, that ‘hank’, ‘doorjamb’ and ‘peristyle’ have been preferred over words like ‘coll’, ‘doorpost’ and ‘colonnade’.

6.3.1 Translating ‘diminutives’

A striking characteristic of the Automata and other Heronian works, in particular the Pneumática, is the ubiquitous use of what are commonly, albeit sometimes erroneously, referred to as ‘diminutives’. This broad category, which has been thoroughly studied by Petersen (1910) and others,\(^{259}\) includes, among others, the following kinds of terms: nouns equivalent to their primitives (for instance ἀγάλα, ἀγάλη...
or whose diminutive force is faded (for instance παραστάδιον); instrumental nouns (for instance μοχλίον, κανόνιον); nouns conveying the idea ‘made of’ (for instance πινάκιον, σανιδίον); nouns whose diminutive meaning is closely associated or concomitant with the idea of resemblance (for instance σφαιρίς); nouns more or less exclusively denoting resemblance (for instance ἀστερίς). Unlike in previous translations, where it is not always clear why a diminutive form has been translated in such and such a way, words suffixed with -ιον, -ίς, -ίσκος, -(δ)άριον, -(ε)ίδιον, -ύλλιον have been studied individually.

Their translation has been based upon (1) an investigation of the Heronian usage of such terms and their primitives wherever existing, (2) a careful perusal of previous scholarship (which, however, does not discuss all such terms) and (3) a comparison with terms unambiguously belonging to one of the above-mentioned classes. The results of this study showed, among other things, that, regardless of the class they belong to, a number of ‘diminutives’ tend to be used as stylistic variants in the treatise: ἀγγείον/ἀγγειόν, ἀξών/ἀξόνιον, δελφίδελφινάριον/δελφινίκος, ἐμπελίς/ἐμπελίδιον, κανών/κανόνιον, κεφαλή/κεφάλιον, κίον/κίόνιον/κιονίςκος, κύμβαλος/κυμβάλιον, λεπίς/λεπίδιον, μήρυμα/μηρυμάτιον, παραστάς/παραστάδιον, περόνι/περόνιον, πίναξ/πινάκιον, σανίς/σανιδίον, τρύπημα/τρυπημάτιον, τύμπανον/τυμπάνιον, χάλασμα/χαλασμάτιον/παραχαλασμάτιον, ὀσπληγίς/οσπλήγγιον. A particularly noteworthy case is the term ζώδιον, which, as has been convincingly shown by Kosmetatou (2004), can be used to denote both resemblance and small size (contra, Petersen 1910: 230). This term has been translated here as ‘figurine’, except where it is specified by the possessive pronoun αὐτῆς/αὐτοῦ (XX.2 [64.16-17], XXI.6 [74.2]). In cases where the precise value of a term cannot be easily determined (ἀρμένια, ἐπίουριον, πυργίον), the diminutive value is cautiously preferred.261

260 Translating these two occurrences of the term as a diminutive would suggest that the figures of Athena and Ajax possess a figurine of some sort.

261 While it is not possible here to discuss in detail Hero’s use of (diminutive) suffixation, nor to assign suffixed words to individual categories, it is worth noting that, according to LSJ s.v., the following terms are used as diminutives in the Automata: (1) ἀρμένια, (2) ἀστερίς, (3) δελφίδελφιον, (4) ἐπίουριον, (5) ἐπισκέπτειον, (6) ἑσχήριον, (7) κλεφτήριον, (8) κυμβάλιον, (9) μηρυμάτιον, (10) πανθρήσκος, (11) περόνιον and (12) τρόχιον. The entries for at least nos. (2), (3), (5), (6), (7), (8), (9), (10) and (11) should be corrected. Apart from τρόχιον and ζώδιον, the terms that bear a diminutive sense in the treatise are ἀλυσιδίον, βαρύλλιον, θυρίς, κιβωτάριον, σπερμίον and σφαιρίς. Hellmann (1992: 378) cites the diminutives of these terms as occurring at III.1, but she is clearly mistaken. To the best of my knowledge, the term is nowhere attested.
6.3.2 Translating mathematical language, including the formula with ἔστω

Mathematical language also deserves some comment here. The following points are particularly relevant:

1. Elliptical expressions referring to geometrical (or geometrised) entities have been generally left implicit as in the original Greek except when (a) it is necessary for the sake of clarity to specify what the objects in question are, and/or when (b) such expressions are not otherwise understandable or translatable into English. In the latter two cases, in line with the editorial conventions followed in the translation (on which, see below), angle brackets are used to enclose elided expressions. As an example of (a), take, for instance, VII.1 [26.9], where we find the first mention of ἡ ἐκτ [sc. γραμμή], ‘the <line> ἐκτ’ (later referred to more simply as ἐκτ, VII.2 [26.13]). For (b), see, most relevantly, XXIV.3 [82.12], where the hand and arm are described geometrically as τὸ πρὸς τῷ ὄμορ (‘that <which originates> in the shoulder’). Also note that my use of angle brackets does not extend to expressions involving the term ἡ ἐθνικ, because the reference to a line is unambiguous to modern readers.

2. A related issue has to do with the way in which Hero refers to the diagrams accompanying his mechanical or geometrical descriptions. As shown by Roby (2016: 176-7), Hero - like Biton before him, and unlike Philo - establishes a direct relationship between the mechanical components and the corresponding elements in the diagrams, assigning letter labels to the objects described rather than resorting to the (typically Philonian) periphrastic use of ἐπί + genitive (on which, see point (4) below). As part of his direct approach, Hero describes geometrical/geometrised objects in mathematical style, using constructions such as ἔστω γὰρ τι πλανθέν τὸ ἀβγό (V.3 [20.18-19]). In translating this and similar expressions, I have mostly opted for the more unconventional option and taken the verb εἰμί (or γίνομαι) as existential (‘Let there be a case, ἀβγό’, henceforth referred to as option (a)) rather than as copulative (‘Let ἀβγό be a case’ or ‘Let a case be ἀβγό’, or, even worse, ‘Let the case be ἀβγό’, henceforth referred to, respectively, as options (b1), (b2) and

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262 Cf. the similar practice as regards points and lines in Netz’s translation of Archimedes’ On the Sphere and the Cylinder (Netz 2004b: 7).
(b²)).²⁶³ There are two main reasons for this choice. First, as pointed out by Netz (1999: 43-4) and most recently reiterated by Roby (2016: 175),²⁶⁴ the use of the article in expressions such as Euclid’s ἓτοι ςῦνεια ἢ AB points to the conceptual pre-existence of AB qua straight line, and hence the more conventional understanding (option (b¹)) is much more frequent than (b²) and (b³)) would yield ‘let the straight line AB be a straight line’ (where the straight line AB is assigned an attribute that it already possesses by virtue of its grammatical correlation with the indefinite noun ςῦνεια). On the other hand, the first option (in this case, ‘Let there be a straight line, AB’) establishes (or, in fact, brings into existence) an object, only later assigning a diagrammatic location to it. Second, Federspiel (1995), who, like Netz (1999), advocates the use of existential εἶμι, persuasively demonstrates on linguistic and stylistic grounds that, except under specific circumstances, in a mathematical proposition the first occurrence of a geometrical object (as opposed to its second occurrence) is indefinite (this is what he calls ‘Loi fondamentale’, and is further articulated by his ‘Règle!’).²⁶⁵ Further noting that in such occurrences letter labels are used appositionally.²⁶⁶ This has two important implications. On the one hand, if letter labels are indeed used appositionally, then the more correct interpretation of the ἓτοι formula is the one which takes the verb as existential (option (a)).²⁶⁷ In other words,

²⁶³ For exceptions, see below, n. 267. Baldi and Couture generally seem to take the verb as copulative (= option (b¹)), although such expressions as ‘Sia una cassetta a,b,c,d’ (Baldi 20) and ‘Sia arcula abf’ (Couture 247) are inherently ambiguous. Schmidt opts for option (b¹), whereas Murphy vacillates between options (a) (with or without comma) and (b³).
²⁶⁴ Netz’s discussion is erroneously cited by Roby (2016: 175 n. 83) as Netz (1999: 243).
²⁶⁵ The exceptions to this general rule are found in cases where the geometrical entities are determined either as representative of a class of elements (‘Règle I’a) or in relation to their geometrical construction (‘Règle IIb’). For an example of the former, see XXIV.2 [80.14], where ἢ χεὶρ ἢ ἄρι can be understood as a representative instantiation of the hands and arms of the Greek sailors. For an example of the latter, see VII.1 [26.11], where the expression ἐπεζεύχθοσαν αἱ δε, ὢ δε, δς δυνάει (or, simply, γραμμα) rather than for ἔπεζευχθοσαν εὐθεία αἱ δε, δς (the points δ, ε and ζ have already been mentioned in the preceding context). On similar elliptical expressions, see below.
²⁶⁶ See also his earlier and less detailed discussion in Federspiel (1992: 15-17).
²⁶⁷ The main exceptions here are XV.1 [54.13] and XVIII.1 [58.12]. In the former case, the object has been introduced in the immediately preceding context. In the latter case, stylistic and syntactic constraints prevent the verb from being translated as existential, and I very much doubt that it bears this sense in that specific context (Ἰ τις [το ἤτοι αὐτού] τὸ πόρος ἔστω τὸ δ ζ). Federspiel’s (1995: 267) interpretation of the relative pronoun in the comparable Attolian phrase ἤτοῖς ἐπεζεύχθοσαν κορωφή τῷ Α σημείῳ (Con. 1.1.11 = Hellenberg 16.8) as a genitive of appurtenance depending on an understood (existential) ἕστω rather than as a complement of the noun κορωφή is unnecessarily convoluted.
translating the verb εἰμί as copulative conveys (a certain degree of) definiteness where there is none in the original (Federspiel 1995: 249), and this is particularly obvious in the case of options (b)1 and (b)2. On the other hand, apparently definite expressions such as ἐπεξεύρηκεν ἡ AB (where ἡ AB has not been mentioned in the preceding context) are in fact elliptical indefinite expressions in which letter labels are in apposition to an elided noun (in this particular case, ἐπεξεύρηκεν εὐθεία ἡ AB).268 In all other cases, if the first mention of a geometrical entity is preceded by the article and is not determined either as representative of a class of elements or in relation to its geometrical construction (‘Règles Ila-b’, cf. above, n. 265), the use of the article is dictated by syntactic-stylistic reasons rather than by the actual definiteness of the object at hand (‘Règle Ib’, involving neutralisation of the opposition definite/indefinite. The most relevant cases that have been identified by Federspiel (1995: 255-7, 274-81) are those where (1) the noun agrees with an attributive participle which in turn governs a complement (for instance, Ἡ εἰς τὰς παραλλήλους εὐθείας εὐθεία ἐμπίπτουσα, Euc. 1.29) and (2) the noun is modified attributively by a prepositional phrase (for instance, Ἐὰν αἱ κατὰ κορυφὴν ἐπιφάνεια, etc., Apollon. Perg. Con. 1.14 = 52.21 Heiberg). Generally speaking, therefore, my translation reflects the presence or absence of the definite article, but always omits it when it precedes the first mention of a geometrical/geometrised entity that occurs under the circumstances just mentioned. Consider the following examples:

- VII.1 [26.8] διήχθη τις ἡ ἄδ (‘Let a certain <line>, ἄδ, be drawn’). This is the first mention of line ἄδ. The expression stands for διήχθη τις εὐθεία ἡ ἄδ, and its indefiniteness is emphasised by the use of the pronoun τις (on the usage, see Federspiel 1995: 272). So also VII.2 [26.14]. In this and similar cases, I do not specify that the line is straight to avoid excessive redundancy.

- XIII.3 [46.4-5] ἔστω δὲ καί ὁ ἐπικείμενος πυρήν τῷ ναόσκῳ ὁ κλῆμ (‘Let there be a knob placed on top of the shrine, κλῆμ’). Unlike most of the components mentioned in the immediately preceding context, the knob has not been mentioned before. (Equally, the base of Dionysus has not been mentioned before, but the article preceding βάσις is justified by the genitive τοῦ Διονύσου.)

268 This is Federspiel’s ‘Règle Ic’, and is amply demonstrated by the scholar in Federspiel (1995: 281-5).
The reference is therefore indefinite, and the article particularises the knob as lying on the roof (attributive participle governing a noun in the dative).

- XXVII.2 [98.12-13] ἡ δὲ ἐκκοπή ἢ ἐκ τῆς πλευρᾶς <ὁπω> ἢ αβ (‘<Let there be> a notch on the side, αβ’). The notch has not been mentioned before, and hence the reference is indefinite. The article preceding ἐκκοπή is justified by the prepositional phrase ἢ ἐκ τῆς πλευρᾶς, which specifies the location of the notch. The same principle is at work at VI.4 [26.4-5], where, although the ring has already been mentioned before (VI.1 [24.3]), its mention (ὁ δὲ ὑπ᾽ αὐτῆς ἐν τῇ πλευρᾷ) is part of a reconfiguration in which all other components lack the article. Hero in this case could have dispensed with the article by adopting a different word-order (κρίκος δὲ ἐν αὐτῷ ὑπ᾽ αὐτῆς). Compare X.2 [34.6] ἐκκοπή δὲ ἐν αὐτῷ ἢ κλίμα.

(3) As a corollary to (2), note that, while letter labels usually stand in apposition to the first occurrence of a geometrical/geometrised entity, in subsequent occurrences they are found in attributive position. Contrast, for example, the first mention of the knob ζ at V.4 [22.4] with its second mention in the same paragraph (τὸν ζ τύλων, 22.10). The only way to distinguish between appositionally and attributively used letter labels is the use of punctuation. Therefore, following in the footsteps of Netz (2004b), I place appositionally used letter labels between commas (or between a comma and a semicolon or a period) whenever English syntax allows, even though such punctuation does not reflect that of the Greek text and may appear redundant at times.

(4) The periphrastic use of ἐπι + genitive to denote points of a diagram is found exclusively in the allegedly Philonian portions of Book Two. Perhaps the most illustrative example is XXIII.8 [78.17] ἡ ἀρχή τῆς στάρτου, ἢ πο ἂττι τὸ κ (‘the end of the cord, where the <point> κ is’). In all other instances of this use, the verb ‘to be’ is understood, and has therefore been enclosed in angle brackets.

The editorial signs employed in the translation are the same as those used in the text and apparatus criticus (cf. Conspectus siglorum et notarum), except that square brackets enclose explanations or clarifications of terms.
6.4 Commentary

The Commentary is predominantly, but not at all exclusively, philological. Its purpose is threefold: (1) to explain as far as possible individual translation and textual choices; (2) to offer a fresh interpretation of the text that takes into account not only internal evidence but also how the work relates to the (literary, philosophical, technological) traditions within which it is situated; (3) to assess the technical feasibility of the mechanisms described in the text and, where possible, to provide evidence-based reconstructions. The decision to focus on Hero’s language and style has been made in the belief that the close study of the text is the only way to understand it correctly. Commentary units correspond to the main textual units outlined in §5.1 above and are always prefaced by summarising synopses.

6.5 Illustrations

At the end of the thesis I append a number of illustrations (Appendix 4), namely (a) manuscript diagrams and (b) modern reconstructions.

As far as (a) is concerned, note that the vast majority of surviving manuscripts contain letter-labelled diagrams. These are usually interspersed in the text, but may also appear in the margins and, in one case, are appended at the end (Bb). Other manuscripts leave empty spaces (Ac, Bc, La, M, Pd, Pe, Ph, Vd), while yet others have both diagrams and empty spaces (Ab, Lc). One manuscript alone has neither diagrams nor empty spaces (Ld). As part of a tradition of mechanical diagrams (on which, see Roby 2016: esp. 154-163), our manuscript diagrams did not originate with Hero himself. Because they underwent a number of alterations in the course of their transmission over a long period of time, they cannot be taken in any way as a faithful reflection of the originals (see, for instance, my discussions in Comm. on XI.10 [40.18-19] and XVI.1 [54.13-14]). Therefore, when I refer to manuscript diagrams in my Commentary, I consider them, at best, as offering indicative rather than conclusive evidence. All manuscript diagrams included in this thesis were taken from the oldest manuscript, A, which is stored in the Biblioteca Nazionale Marciana in Venice, Italy. Permission to reproduce these diagrams has been
granted by the holding library. Unfortunately, because of budget limitations, it was not possible to provide coloured photographic reproductions. The reader should also bear in mind that, since the present study is mainly confined to a textual examination of Hero’s treatise, I have not examined the Heronian diagrammatic tradition in any detail. All references to ‘manuscript diagrams’ in my Commentary should, nonetheless, be understood as implying that all the manuscript diagrams that I have seen are unanimous in their representation of specific elements.

As for (b), I provide modern reconstructions of the mobile automaton, which has been the primary focus of the project on Hero’s automata as a whole. All such reconstructions are informed by a minimalist approach to design and are based on a careful study of the text itself. As such, they differ in a number of ways from the surviving manuscript diagrams, and are in no way intended to replace them. Unless otherwise stated, all modern illustrations are my own. The vast majority of my reconstructions were made using Vectr (http://vectr.com). **Figs. 2 and 6b** were made with SketchUp 2018. My own reconstructions, of course, make no pretence to absolute accuracy.

Given the mutually supporting relationship between text and images, the reader may wonder why no attempt has been made to intersperse illustrations throughout the text. The choice to relegate illustrations to an appendix was made to allow strict synchronisation between text and translation. All references to illustrations conveniently appear in the right margin of the English translation next to the pertinent portion of the text.
**CONSPECTVS SIGLORVM ET NOTARVM**

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<td>codex Parisinus suppl. gr. 11, saec. XVI</td>
</tr>
<tr>
<td>R</td>
<td>codex Riccardianus gr. 47, saec. XVI</td>
</tr>
<tr>
<td>Ta</td>
<td>codex Taurinensis B.I.18, saec. XVI</td>
</tr>
<tr>
<td>Tb</td>
<td>codex Thottianus 215, saec. XVI</td>
</tr>
<tr>
<td>Vd</td>
<td>codex Vindobonensis suppl. gr. 21, saec. XVII (c.1600)</td>
</tr>
</tbody>
</table>

Bernardino Baldi
August Brinkmann
Hermann Diels
Maximilien Egger, sed in uno tantum loco incertum est utrum agatur de Maximilien Egger an Émile Egger; vide supra, p. xviii
Friedrich Haase
Paul Hildebrandt
Alessandro Olivieri
Victor Prou
Hermann Schöne
Richard Schöne
Wilhelm Schmidt
Franz Susemihl
Henri Weil
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>X^1</td>
<td>lectio primae manus</td>
<td>adn. crit.</td>
<td>adnotationes criticae</td>
</tr>
<tr>
<td>X^2</td>
<td>correctio vel lectio</td>
<td>app. crit.</td>
<td>apparatus criticus</td>
</tr>
<tr>
<td>X^{ac}</td>
<td>lectio ante</td>
<td>cett.</td>
<td>ceteri (editores)</td>
</tr>
<tr>
<td>X^{pc}</td>
<td>lectio post</td>
<td>corr.</td>
<td>correxit</td>
</tr>
<tr>
<td>X^{ep}</td>
<td>lectio in compendio</td>
<td>distinx.</td>
<td>distinxit</td>
</tr>
<tr>
<td>X^{mg}</td>
<td>lectio in margine</td>
<td>edd.</td>
<td>editores</td>
</tr>
<tr>
<td>X^{sl}</td>
<td>lectio supra lineam</td>
<td>interpunx.</td>
<td>interpunxit (-erunt)</td>
</tr>
<tr>
<td>††</td>
<td>corruptela</td>
<td>n.</td>
<td>nota</td>
</tr>
<tr>
<td>&lt;αβγ&gt;</td>
<td>litterae ab editore</td>
<td>obl.</td>
<td>oblocutus est</td>
</tr>
<tr>
<td>{αβγ}</td>
<td>litterae ab editore</td>
<td>p(p).</td>
<td>pagina (-ae)</td>
</tr>
<tr>
<td>&lt;***&gt;</td>
<td>lacuna suppleta est</td>
<td>rec.</td>
<td>recepit (-erunt)</td>
</tr>
<tr>
<td>[***]</td>
<td>litterae deperditae</td>
<td>suppl.</td>
<td>supplevit</td>
</tr>
<tr>
<td>add.</td>
<td>addidit</td>
<td>transp.</td>
<td>transposuit</td>
</tr>
</tbody>
</table>
TEXT AND TRANSLATION
ἩΡΩΝΟΣ ΑΛΕΞΑΝΔΡΕΩΣ
ΠΕΡΙ ΑΥΤΟΜΑΤΩΝ

1 (1) Τῆς αὐτόματοποιητικῆς πραγματείας ὑπὸ τῶν προτέρων ἀποδοχῆς ἠξιωμένης διὰ τὸ ποικίλον τῆς ἐν αὐτῇ δημιουργίας καὶ διὰ τὸ ἔκτπληκτον τῆς θεωρίας <***>. ἔστι γάρ, ὡς συνελόντι εἶπεν, πᾶν μέρος τῆς μηχανικῆς ἐν αὐτῇ τῇ αὐτόματοποιητικῇ παραλαμβανόμενον διὰ τῶν κατὰ μέρος ἐν αὐτῇ ἐπιτελουμένων.

(2) ἔστι δὲ αὐτῆς ἡ ἐπαγγελία τοιαύτη: κατασκευάζονται ναοὶ ὥς βωμοὶ σύμμετροι αὐτόματοι τε προάγοντες καὶ κατὰ τινας ὀρισμένους ἰστάμενοι τόπους, καὶ τῶν ἐνόντων αὐτοῖς ζωδίων ἐκαστὸν ἱδίᾳ κινεῖται πρὸς λόγον τὸν κατὰ τὴν προκειμένην πρόθεσιν ἢ μύθον ἀρμόδιοντα, καὶ εἰς τὸν ἐξ ἀρχῆς ἀποκαθοιδητὸν τόπον. τὰ μὲν οὖν τοιαύτα δημιουργήματα τῶν αὐτόματων καλεῖται ὑπάγοντα.

(3) ἔστι δὲ καὶ ἐτερον εἴδος ἐν αὐτοῖς, δὲ καλεῖται στατόν. ἔστι δὲ καὶ τούτου ἡ ὑπόσχεσις τοιαύτη: ἐπὶ τίνος κοινη- σκου πῖναξ ἐφέστηκε θώρας ἔχον ἀνοιγμένας, καὶ ἐν αὐτῷ <φαίνεται> διάθεσις ζωδίων πρὸς τινα μύθον διεσκευαζόμενων.

---


2
HERO OF ALEXANDRIA’S
ON AUTOMATA

(1) Since the subject of automata-making was favourably received by the former generations on account of both the varied types of craftsmanship in it and the astounding character of the spectacle <***>. For, to speak briefly, every part of mechanics is taken over in the very practice of automata-making, through the things which are completed in it one by one.

(2) Its scope is as follows: shrines or altars of suitable size are constructed, which move forward by themselves and stop at certain defined locations; and each of the figurines that are inside them moves by itself in accordance either with the set purpose or with the appropriate story, and <eventually> they return to their starting point. Therefore, such crafted types of automata are called ‘mobile’.

(3) However, there is also among them [the automata] another kind, which is called ‘stationary’. Its purpose is as follows: a box with open doors stands on a pillar, and inside it <appears> an arrangement of figurines prepared for the sake of some story.
(4) κεκλεισμένου οὖν τοῦ πίνακος αἱ θύραι αὐτόματοι ἀνοίγονται, καὶ φαίνεται ἡ τῶν ζωδίων τάξις γεγραμμένη· καὶ μετ’ οὗ πάλιν χρόνον κλεισθεὶσον τῶν θυρών καὶ ἀνοιχθεὶσον πάλιν αὐτομάτως, ἕτερα φαίνεται διάθεσις ζωδίων ἀρμόζουσα τῇ πρότερον φανερῇ· καὶ πάλιν κλεισθεὶσον καὶ ἀνοιχθεὶσον τῶν θυρών ἕτερα διάθεσις πάλιν φαίνεται ζωδίων ἀρμόζουσα τῇ πρότερον κειμένῃ, καὶ ἦτοι <αὕτη> ἀπαρτίζει τὸν προκείμενον μύθον ἢ πάλιν μετὰ ταῦτην ἕτερα φαίνεται, ἀρχής ἢν ἀπαρτίσθη ὁ μύθος.

(5) καὶ τῶν φαινομένων ἀπὸ ζωδίων τῶν γεγραμμένων ἐν τῷ πίνακι ἕκαστον ἐν κινήσει δύναται φαίνεσθαι, ἄν ἀπαιτῇ ὁ μύθος, ὅφει ἐπιξενθέοντα, ἀ ὀ ἄν καὶ ἐπιξενθέοντα, ἄ ὠ ἀπὸ τούτοις ἕτερα πείλησαν καθά' ἐκάστην πληγήν καθάπερ ἐπὶ τῆς ἀληθείας.

(6) δύναται ἄν καὶ ἕτερα κινήσεις ὑπὸ τὸν πίνακα γίγνεσθαι, οἷς ποῦ ἀνάπεσθαι ἢ ζώδια ἐπιξενθέοντα πρότερον μὴ φαινομένα καὶ πάλιν ἀφανίζοντα καὶ ἀπλῶς, ὡς ὧν τις ἔλθηι δύνατον ἐστὶ κινεῖν μηδενὸς προσιόντος τοῖς ζωδίοις.

(7) ἐστὶ δὲ ἡ τῶν στατῶν αὐτομάτων ἐνέργεια ἀρσαλεστέρα τε καὶ ἀκινδύνουτέρα καὶ μᾶλλον πάσαν ἐπιδεχομένη διάθεσιν τῶν ἑπαγόντων. ἐκάλουν δὲ οἱ παλαιοὶ τοὺς τὰ
(4) So, when the box is closed, the doors open by themselves, and the painted array of figurines appears; not long after, once the doors have closed and opened again automatically, another arrangement of figurines, corresponding with the one appeared before, appears; once the doors have closed and opened again, another arrangement of figurines, corresponding with the one set up before, appears again, and either <this> completes the pre-conceived story or yet another arrangement appears after this one, until the story is brought to an end.

(5) And then each of the painted figurines displayed in the box can be seen in motion, if the story requires it: for example, some sawing, some hewing with the adze, some others working with hammers or axes, so as to make noise with each blow, just like in real life.

(6) Other movements can also be performed inside the box, such as the lighting of a fire or the appearance of figurines which were not visible before, and their disappearance. In short, anyone can set the figurines in motion as they may choose with no one going closer to them.

(7) Then, the mechanism of the stationary automata is safer and freer from danger, as well as admitting of more types of arrangements than the mobile ones. Former generations used to call those crafting such automata ‘won-
τιούτα δημιουργούντας θαυματουργούς διά το ἐκπλήκτον τῆς θεωρίας.

(8) ἐν μὲν οὖν τούτῳ τῷ βιβλίῳ περὶ τῶν ὑπαγόντων γράφομεν ἐκθέμενοι διάθεσιν ποικίλην κατὰ γε ἡμᾶς, ἢτις ἀρμόσει πάση διαθέσει πρὸς τὸ δύνασθαι τὸν προαιρούμενον ἑτέρος διατίθεσθαι μηδὲν ἐπιζητοῦντα πρὸς τὴν τῆς διαθέσεως ἐνέργειαν· ἐν δὲ τῇ εἴης περὶ τῶν στατῶν αὐτομάτουν γράφομεν.

II (1) Δεῖ δὲ πρῶτον ἀπόκρυτον εἶναι καὶ ἀκλίνες καὶ ὑμαλὸν τὸ ἔδαφος ἐν δὲ μέλλει τὸ αὐτόματον ὑπάγειν, ἢν μήτε οἱ τροχοὶ αὐτοῦ καταδύνουσι πιεζόμενοι μήτε ἐμποδίζονται ὑπὸ τραχύτητάς τινος μήτε πρὸς ἀνάβασιν βιαζόμενοι εἰς τὸ ὀπίσω ἐπινευόσιν.

(2) ἐὰν δὲ μὴ ὑπάρχῃ τὸ ἔδαφος τοιοῦτον ὦν εἰρήται, δεῖ σανδίας ἀπορθόθανας ἐπὶ τοῦ ἔδαφους διατιθέναι, ἐν αἷς κατὰ μήκος ἔσονται σωλήνες δὲ ἐρήμλωτον κανόνων πρὸς τὸ τοὺς τροχοὺς ἐν τοῖς σωλῆσι κυλίσθαι. δεῖ δὲ τὰ ὑπάγοντα κατασκευάζειν ἐκ κούφων τε καὶ ἐξηρῶν ἔξωλων, κἂν ἐξ ἀλλής δὲ τινος ὑλῆς ὑπάρχῃ τι ἐν αὐτοῖς κατασκευασμένοις...
der-workers’ because of the astounding character of the spectacle.

(8) Therefore, in this book I am writing on mobile automata, setting forth a complex configuration of my own which will adapt to every other arrangement; in this way, whoever chooses to arrange differently will be able to do so, not lacking anything for the actualisation of the arrangement. In the following book I will write on stationary automata.

II

(1) First of all, the ground on which the automaton is to move must be hard, horizontal and level, in order for its wheels neither to sink when they are pressed down, nor to be hindered by any unevenness, nor to tilt backwards down while forcing their way up.

(2) But if the surface is not such as has been described, boards must be laid level on the ground, on which there will be grooves lengthwise with rods nailed on them in order for the wheels to roll along the grooves. Mobile automata must be constructed from light and dry timber, and should any other component of theirs be constructed from some other material, it will be necessary to try to make this too as light as possible in order that the auto-
νον, καὶ τοῦτο δεῖσει ὡς κυριότατον πειράσθαι ποιεῖν, ἵνα μὴ διά τὸ βάρος δυσκίνητα γένηται.

(3) δεῖ δὲ καὶ ὅσα ἐγκυκλίους στροφὰς ἢ κινήσεις ποιεῖται, ταῦτα ἐντονῶς τε ἀκριβῶς καὶ περὶ ἃ κινεῖται λεία καὶ μὴ τραχέα ύπάρχειν, οἷον οὐ μὲν τροχοὶ περὶ κνώδακας σιδηροῦς ἐμβεβηκότας εἰς ἐμπυελίδας σιδηρᾶς, τὰ δὲ ἐξὸδα περὶ ἄξονας χαλκοῦς ἐμβεβηκότας εἰς χοινικὰς χαλκὰς συνεσμηρισμένας αὐτοῖς.

(4) καὶ ἐλαίων δὲ παρεπιγείην δεῖσει εἰς ταῦτα, ὅπως κατὰ πάντα τρόπον εὐκύλιοτα πάντα ὑπάρχῃ καὶ μηδὲν παρὰ τοῦτο σφήμα γένηται· εἰ δὲ μή, οὐκ ἔσται τῶν προκειμένων κατὰ λόγον οὐδὲ ἐν. δεῖ δὲ καὶ τὰς σπάρτους, αἷς εἰς ταῦτα προσχρώμεθα, μήτε ἐπέκτασιν μήτε συστολὴν λαμβάνειν, ἀλλὰ τοιαύτας διαμένειν τοῖς μήκεσιν οἷοι καὶ ἐξ ἀρχῆς κατεστάθησαν.

(5) τοῦτο δὲ ἔσται, ἐὰν βαλόντες αὐτὰς περὶ τινὰς πασσαλίσκους, διατείναντες εὖ μάλα καὶ ἐάσαντες αὐτὰς ὅλον χρόνον πάλιν ἐπεκτείνωμεν καὶ τοῦτο πλεονάκις ποιήσαντες κηρὸν μετὰ ῥητίνης καταψηφισμένην. βέλτιον δ᾽ εἰ καὶ βάρος εξ αὐτῶν ἐξάψαντες ἐάσομεν ἐπὶ πλείωνα χρόνον. προβασανισθείσα δὲ οὕτως οὐδεμίαν ἐπέκτασιν λήγεται ἢ

---

1 καὶ Haase : εἰ a 3 δοσιν a : ὅσον ἂν Schmid : ἐγκυκλίους M : ἐνὶ κλοιοῖς A : ἐν τὶς κλοιοῖς T : ἐν τῆς κλοιοῖς G (ἀρχ. ἀποτέλεσμα ταὐτόχροα) ποιεῖται
mata may not become difficult to move because of their own weight.

(3) Furthermore, anything that makes circular rotations or movements must be accurately turned and anything around which <things> are moved must be smooth and not rough, for example, the wheels around iron pivots inserted into iron sockets, and the figurines around bronze axles fitted tightly into bronze collars.

(4) It will also be necessary to pour oil onto these tools so that they may all be easy to rotate in every possible way and there may be no jamming at all. Otherwise, nothing of what has been previously said will go according to plan. Also, the cords which we use for these purposes must neither stretch nor contract, but remain the length they were at the very beginning.

(5) This will be accomplished if we put them around some pegs, carefully stretch them to the utmost, leave them <in place> for a short time and stretch them again; and <this will be accomplished if,> after repeating the entire process several times, we smear a compound of wax and resin. It will also be better for us to hang a weight on them and leave them for a rather long time. If it [the cord] is pre-

Fig. 3 (cf. II.7)
παντελῶς βραχείαν. ἢ πάλιν ἀποκόψωμεν, ὅταν ἐξαρτή-
σαντες τὸ αὐτόματόν τινα αὐτῶν παρεκτεταμένην εὐρο-
μεν.

(6) νευρίνῳ δὲ οὐδενὶ δεῖ χρῆσθαι, ἐπειδὴ παρεκτεῖναι ἢ
συστάλλεται κατὰ τὴν τοῦ ἀέρος περίστασιν, εἰ μὴ ἄρα
ὅταν δὲ θύσιν γίνεται ὡς καθά

(7) κοινὸν δὲ ἐστὶ τοῦ κινοῦντος καὶ τοῦ κινουμένου
σπάρτος ἑξοφυς τὴν μὲν μίαν ἁρχὴν πρὸς τῷ κινοῦντι
προσδοξομένην, τὴν δὲ ἑτέραν πρὸς τῷ κινουμένῳ προσ-
ηκυλωμένην. τὸ δὲ κινουμένον ἅξων ἐστὶ, περὶ ὅν ἢ
σπάρτος περιέλθη, τὸ δὲ ὧν αὐτὸπαρασαρότες εἰσὶ τρο-
χοῖ, ὡστε τῷ ἅξωνος στρεφομένου καὶ ἀπειλεσομένης
τῆς σπάρτου συστρέψεσθαι καὶ τοὺς τροχοὺς ἐρεῖντος
ἐπὶ τὸ ἔδαιμος, τοῖς δὲ τροχοῖς περίκειται τὸ τοῦ ὑπάγοντος
αὐτομάτου πλινθίου.
tested in this way, it will stretch not at all or really very little. Or again, if we find, after getting the automaton strung, that one of those <cords> is stretched, we will cut it off.

(6) Nothing made of sinew must be used – except when it is necessary to make use of a hysplænx – as it [the sinew] stretches or contracts depending on atmospheric conditions. Let the hysplænx be just like the axle which in catapults is set in the half-spring, as will become apparent in what follows. All these mobile automata start moving by means of a hysplænx or a lead counterweight.

(7) What causes motion and what is moved have a cord in common, which has one end bound to what causes motion, and the other looped around what is moved. What is moved is an axle around which the cord is wound. Wheels are fitted to the axle so that, when the axle rotates and the cord unwinds, the wheels, resting on the ground, may rotate as well. The case of the mobile automaton encircles the wheels.
(8) τάσιν δὲ ὑσπληγγος ἢ βάρος λείας δεῖ πρὸς τὰ ὅλα ἡμόσθαι, ὡς μὴ κατακρατήσει ήτοι τὸ βάρος ἢ ὁ τοῦ ὑσπληγγος τάσις ὑπὸ τοῦ πλινθίου. αἱ δὲ ἐκτὸς τῆς πο- 

(9) ἐν δὲ τῇ σύριγγι ἐπὶ μὲν τῶν ὑπαγόντων ἢ κέγχρος ἢ

(10) αἱ δὲ ὑπὸ τῆς λείας ἐλκόμεναι σπάρτα πάσαι ἰσοτα-

1 βάρος a: corr. Haase 2 κατακρατήτη A G: κατακρατεῖται M T an τὸ

2 τῆς λείας> βάρος? ὃ am M 3 ἐκτὸς Schmidt dub. in app. crit.: ἐκ a

3 ἐπιδεικμένων a: an ἐπιδεικμένων? 6 ἀρμοστῶς A G: ἀρμοστῇ νεὶ


6 σήματα: χλα ι 10 στρατός T 11 διὰ om M (οτιδιὰν v. εἰς τῆς


8 ορτώμινοι a: hoc verbum ex glossate a G T: στάσις M 14 τέλος scrips: στάσις a hoc verbum ex glossate a G T: στάσις M 16 στρατὸς A G M: στάρτι A G T

(8) The tension of the hyspanx or the heaviness of the counterweight must be adjusted to the whole, so that neither the heaviness nor the tension of the hyspanx may be overcome by the case. Movements other than the journey [of the case] occur with all the cords, on the one hand, looped around the instruments being moved and, on the other, bound to the counterweight. The counterweight is inside a tube, in which it can also descend fittingly and easily.

(9) In the case of mobile automata, either millet or mustard is put inside the tube, since both of them are light and flow easily, whereas in stationary automata dry sand is put inside; and when these <grains> pour out through the bottom of the tube, the counterweight descends gently and brings about motions by drawing each cord. The origin of motion lies in the tension of a cord, while the end of motion <lies in> the loosening of a cord, that is, when the loop falls off the knob on the instrument being moved.

(10) Despite the fact that the cords being drawn by the counterweight are all drawn at equal speeds, they do not generate motions with equal speeds because they are not wound around equal instruments, but some are wound around bigger circles, some around smaller ones. Cords
τῶν μὴ ἀμα κινούμενον ὄργανον τὰς σπάρτους μὴ ἀμα
tetάσθαι, ἀλλὰ τῶν ὠστερον κινούμενον τὰς σπάρτους
χαλάσματα ἔχειν.

(11) τὰ δὲ χαλάσματα μηρύματα δεῖ ουδέν καὶ προσκολλ

λάν κηρῷ έντος τὸ πλινθίου κατά τὸν ἐπιβάλλοντα τό

πον, ὅπως ἡ λεία ἐπισπομένη τὸ χάλασμα πραέως τείνη

τὴν σπάρτον. προσέχειν δὲ δεὶ καὶ ταῖς σπάρτοις, ὅπως

ἐκάστη αὐτῶν τῷ ἰδίῳ ὄργανῳ προσαγκυλωθῇ καὶ μὴ ἐπ'

ἀριστέρα τὴν ἑπέλθην μάβη· μιᾶς γὰρ αὐτῶν ἀλλαγείσης

ἡ ἐπ' ἀριστέρα ἐπειληθείσης τὰ ὅλα στάσιν λήγεται.

(12) δεὶ δὲ καὶ τὰς τῶν ὀρχαίων ἐκφυγεῖν διαθέσεις, ὅπως

καινότερον τὸ κατασκεύασμα φαίνεται· δυνατὸν γὰρ, ὡς

προείρηται, ταῖς αὐταῖς μεθόδους χρόμενον ἐτέρας καὶ

ἐτέρας διαθέσεις ποιεῖσθαι. βέλτιον δ' ἐν τούτοις ἀναστρέφ

παινὸν ὑπενθυσίαν διάθεσιν. ἦν δὲ ἡμεῖς ἐκτιθέμεθα,

ἔστι τοιαύτη.

III (1) Ἐστωβάσις μῆκος ἔχουσα ὡς πήχεος, πλάτος δὲ ὡς

παλαιστῶν τεσσάρων, ὄψος δὲ ὡς παλαιστῶν τριῶν, κυ

μάτων ἔχουσα περιτρέχειν εἰς τε τὸ ἄνω καὶ τὸ κάτω μέ

ρος. ἐπὶ δὲ τῶν γονων αὐτής ἐφέστηκε κιόνα τέσσαρα,

ὄψος μὲν ἔχοντα ὡς παλαιστῶν ἵ, πλάτος δὲ παλαιστῶν

1-2 ὄργανον ...κινούμενον om G 1-2 ἀμα τετάσθαι A GTεκ.: ἀμα τε καὶ

τετάσθαι Tεκ.: ἀνατετάσθαι M: ἀνατετάσθαι Ph 4 μηρύματα AT: μηρύ

ματα G: μὴ δύματα M 5 κηρῳ A GM: κηρων T 6 ὅπως A Gεκαι MT:

ὀστέρα Gεκ.: πράσος A GT: πράσος AbAc Bbεκαι La: πράσος M Bbεκ

13 ἐτέρας Aεκαι T: ἐτέρα G 14 δ' ἐν Aεκ.: δ' αὐτοῦ Aεκ.: δ' ἐν G: δ' ἐν


for instruments which are not moved at the same time
must not be pulled taut at the same time, but cords for
<instruments> which are moved later must have slack
parts.

(11) It is necessary to make the slackenings into hanks and
.glue them down with wax onto the appropriate place in-
side the case, so that the counterweight may stretch the
cord gently while taking up the slack. Attention must also
be paid to the cords, ensuring that each of them has been
looped around its own instrument and not wound improp-
erly; for, if one of them has been changed or wound im-
properly, the whole assemblage will come to a rest.

(12) The arrangements of the ancients must also be
avoided, in order for the device to look more fresh; for it is
possible, as previously mentioned, to create many differ-
ent arrangements by employing the same methods. Whom-
ever is devising a more pleasant arrangement will perform
better in these things. The arrangement I set forth is such a
one.

III (1) <Let there be> a base having a length of approximately
one cubit, a width of about four palms and a height of
nearly three palms, with a moulding running around both
its upper and its lower parts. Four column shafts, having a
height of roughly 8 palms and a width of two palms, stand
on the corners, with little base-mouldings placed at the
δός, έχοντα ὑποκείμενα σπειρία καὶ τοῦτος ἀρμοζόσας κεφαλᾶς ἐπικειμένας. ἐπὶ δὲ τῶν κεφαλῶν ἑπικείμεινον καθάπερ ἐπιστύλιον κύκλον ὑψὸς ἔχον ὀγδόον τοῦ κίονος ἡλίου, ὡς δακτύλων ἦν.

(2) κατὰ δὲ τοῦ ἐπιστύλιου κατάστροφας σανίδια καλύπτοντα τὴν ἐπάνω ἐπιφάνειαν, καὶ περίκειται κύκλω κυμάτιον. ἐπὶ δὲ τοῦ καταστρώματος ἐφέστηκε μέσον ναίσκος στρογγυλός περιφάνης ἔχον κίονας ξε. ἐπὶ δὲ τοῦτος πυργίον κονσειδές ἐφέστηκεν ἐνεταμένη ἔχον τὴν ἐπιφάνειαν, καθάπερ εἰρήσεται.

(3) ἐπὶ δὲ τῆς κορυφῆς ἐφέστηκε Νίκη ἐκκεπετακύια τάς πτέρυγας καὶ ἐν τῇ δεξιᾷ χειρὶ στέφανον κατέχουσα. ἐν δὲ μέσῳ τοῦ ναίσκου ζῷδιον Διονύσου ἐφέστηκεν ἐν μὲν τῇ ἀριστερᾷ χειρὶ θύραν κατέχον, ἐν δὲ τῇ δεξιᾷ σκύφον. παρακαθέζεται δὲ πανθηρίσκος πρὸς τοὺς τοῦ Διονύσου ποσίν.

(4) ἐν δὲ τοῖς ἐμπροσθεν καὶ τοῖς ὑπόθεν μέρεσι τοῦ Διονύσου ἐπὶ τοῦ καταστρώματος βομβὸς ἑπίκειται ἔχον ξύσματα τῶν σανίδων] τεκτονικὰ ξηρὰ ἄστε εὐκαυστα εἶναι, κατὰ δὲ κύκνω τὸν εἰς τὸν ναίσκο τοῦ Διονύσου παρέστηκεν ἐκτὸς τοῦ ναίσκου Βάκχη διεσκευασμένη ὡς ἂν τις προαιρήται.

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1 ἀρμοζόσας A G M : ἀρμοζότης T 2 κεφαλῶν A G T : κεφαλῶν M
3 ἐπικείμενος om M <τ> Schmidt dub. in app. crit. 3 an κύκλον <παρατρέ-
4 γον>? ἐχον F (dub. in ms) La : ἔχον a 4 e a : δ’ Schmidt dub. in app. crit.
5 τοῦ ἐπιστύλιου Schmidt dub. in app. crit. : τῶν ἐπιστύλων a : τοῦ ἐπιστύλων
6 R. Schöne κατάστροφας sanidía A G M : κατάστροφας ἦν in ms)
5-6 καλύπτοντα A G : διακαλύπτοντα M : διακαλύπτοντι T 8 περιφάνης a
7 P i (in text) P i g (in text) : *περιφάνης ed. princ. : *περιφάνης P i g (in text)
8 P i g (in text) : *περιφάνης P i g (in text) P i g (dub. in ms)
9 κονσειδές A G T : κονσειδές M 10 εἰρήσεται R. Schöne : εἰρήσεται a : χάθεται Schmidt dub. in adn. crit. 11 ἐκκεπετακύια M : ἐκκεπετακύια A G : ἐκκεπετακύιας T 12 de iterant A T 19 τῶν σανί-
10 δον del. Schmidt dub. in app. crit. 20 κύκνω <καταστόν> R. Schöne
bottom and capitals in line with them placed at the top. On the capitals, all around, lies <something> like an architrave, with a height one-eighth of the whole column, approximately 5 fingers.

(2) On the architrave are laid boards covering its upper surface, and a moulding runs all around. On the covering stands prominently, in the middle, a circular shrine with six columns. On this stands a small cone-shaped cupola with a stretched surface, as will be said. 

Fig. 1 (cf. XIII.3)

(3) On the peak stands a Nike with spread wings and holding a wreath in her right hand. In the middle of the shrine stands a figurine of Dionysus holding a thyrsus in his left hand, and a cup in his right. An effigy of a panther sits by Dionysus’ side at his feet.

(4) In the spaces before Dionysus and behind him, on the covering, is an altar with woodwork shavings {made of boards}, dry enough to burn easily. At each of the columns of Dionysus’ shrine, outside the shrine, stands a Bacchante prepared in whatever way one may choose.
IV  
(1) Τούτον δὲ οὕτως ὑπαρχόντων ἐν ἀρχῇ τεθέντος τοῦ αὐτοματὸν ἐπὶ τινα τόπων καὶ ἀποστύνων <ἡμῶν> μετ’ οὗ πολὺν χρόνων ὑπάρχει τὸ αὐτοματὸν ἐπὶ τινα ὀρισμένων τόπων, καὶ στάντος αὐτοῦ ἀνακαυθήσεται ὁ κατάπροσθεν τοῦ Διονύσου βομός, καὶ ἐκ μὲν τοῦ θόρου τοῦ Διονύσου ἦτοι γάλα ἢ ὕδωρ ἐκπτενθῆσεται, ἐκ δὲ τῶν σκύφων οἶνος ἐκχυθῆσεται ἐπὶ τὸν ὑποκείμενον πανθηρίσκον.

(2) στεφανωθῆσεται δὲ πάς ὁ παρὰ τούς τέσσαρας κίονας τῆς βάσεως τόπος, αὐτὶ δὲ περικύκλῳ Βάκχαι περιελύσουνται χορεύουσαι περὶ τῶν ναίσκων, καὶ ἡχὸς ἔσται τυμπάνων καὶ κυμβάλων, καὶ μετὰ ταύτα σταθέντων τῶν ἢχων ἀποστραφήσεται τὸ τοῦ Διονύσου ἔρρητον εἰς τὸ ἐκτὸς μέρος, ἀμα δὲ τούτῳ καὶ ἐπεικείμενη τῷ πυργῷ Νίκη συνεπιστραφήσεται.

(3) καὶ πάλιν ὁ ἐμπροσθεν γεγονός τοῦ Διονύσου βομός, πρότερον δὲ ὀπίσθιος ὑπάρχον ἀνακαυθήσεται, καὶ πάλιν ἐκ μὲν τοῦ θορύσου ὁ ἀνατυποσμὸς ἔσται, ἐκ δὲ τοῦ σκύφους ἢ ἐκχυθῆσεται, καὶ πάλιν αὐτὶ Βάκχαι χορεύουσαι περιερχόμεναι τῶν ναίσκων μετὰ ψόφου τυμπάνων καὶ κυμβάλων, καὶ πάλιν σταθειός αὐτῶ τὸ αὐτοματὸν ἀναχωρήσει εἰς τὸν ἐξ ἀρχῆς τόπον.

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(1) With things in this way, at the beginning the automaton is put in a specific location and after a short time, while <we> keep away from it, it will move to some defined location. Once it has come to a standstill, the altar in front of Dionysus will flare up. Either milk or water will be made to spurt from Dionysus’ thrysus, while wine will stream out of his cup onto the panther lying beneath.

(2) Every place near the base’s four columns will be adorned with garlands. The Bacchantes all around will go around the shrine dancing. There will be a clash of kettle-drums and cymbals. Afterwards, when the noise has stopped, the figurine of Dionysus will turn towards the outside. The Nike placed on the small cupola, too, will rotate at the same time with it.

(3) Then again, the altar that is in front of Dionysus, which before was behind him, will flare up. Again there will be the spurt from the thrysus, and the stream from the cup. Again the Bacchantes will dance to the sound of kettle-drums and cymbals, going around the shrine. Again, once they have come to a stop, the automaton will move back to its starting point.
(4) καὶ οὕτως τέλος ἔξει ἡ ἐπίδειξις. τοις δὲ εἰρημένοις μέτροις ἐχρησάμεθα ἀναγκαίως: μειζόνων γὰρ γεννηθέντων ὑπόνοιαν ἔξει τὸ ὄραμα ὡς ἐντὸς τινος ταῦτα δημιουρ-γοῦντος. διὸ δὴ ἐν τε τοῖς ὑπάγοισι καὶ ἐν τοῖς στατοῖς αὐτομάτοις δεὶ φυλάσσεσθαι τὰ μεγέθη διὰ τὴν ἔσομένην ὑπόνοιαν. τῆς οὖν διαθέσεως εἰρημένης ἐξῆς τὴν κατα-σκευὴν τῶν κατὰ μέρος ἐν αὐτῇ ποιησόμεθα.

(1) Οἱ μὲν οὖν πρὸ ἡμῶν τήν ἐπὶ μίας ὄδον τῆς τε πορείας καὶ τῆς ἀποπορείας παρέδωκαν ήμῖν καὶ ταύτην κακοπαθὴ τε καὶ ἐπικίνδυνον· σπάνιον γὰρ ἐπιτυχεῖν κατακόλου-θοῦντα ταῖς ὑπ’ αὐτῶν ἀναγεγραμμέναις μεθόδοις, ὡς ἔστι φανερὸν τοῖς πεπειραμένοις αὐτῶν.

(2) ἡμεῖς δὲ ὑποδείξομεν, ὡς ἔστι τὴν ἐπ’ εὐθείας πορείαν καὶ ἀποπορείαν γίνεσθαι εὐκόπος τε καὶ ἀκινδύνος, ἐτί δὲ καὶ ὡς <ἔστιν> τὸ πληθὺν ἢ τὸ ἔξοδον κατὰ κύκλου τοῦ δοθέντος φέρεσθαι, οὐ μὴν ἄλλα καὶ ἐν παραλληλο-γράμμῳ ὀρθογωνίῳ τὸ δοθέντο φέρεσθαι.

(3) καὶ πρότερον, ὡς ἐπ’ εὐθείας, ἐροῦμεν. ἔστω γὰρ τὸ πληθὺν τὸ ἐξῆς, ἐν ὧν ἄξονι διακείσθω ἡ ἐξῆς ἐν κνώδαξι στρεφόμενος, ἐμβεβηκώς εἰς πυελίδας οὕσας ἐν τοῖς τοῦ πληθοῦς τοῖς. τὸ δὲ ἄξονι συμφυεῖς ἔστωσαν δύο τρο-
(4) In this way the performance will come to an end. I employed the mentioned dimensions out of necessity; for if they are any larger, the sight will arouse suspicion as though someone was contriving these movements from the inside. Then, as a result, in both the mobile and the stationary automata, one must watch out for great dimensions, because of the suspicion that will arise. So, the arrangement having been described, I will next construct its parts one by one.

(1) So, those who came before me have handed down to us a way of effecting forward and backward motion along a single line, though troublesome and involving danger; for success is rarely achieved by following the methods they have written down, as is clear to those who have tried them.

(2) I, by contrast, will show that forward and backward motion along a straight line can take place both easily and without danger and, in addition, that the case or the figure can be carried on a given circle, and, what is more, even along a given rectangular parallelogram.

(3) First, I will talk about motion along a straight line. Let there be a certain case, ABXY, in which let there be placed an axle, Z, turning on pivots and fitted into sockets which are on the sides of the case. Let there be two equal
χοι ἵσοι οἱ ἕη, καὶ τὰς περιφερείας εἰργασμένοι φακοειδεῖς· καὶ ἔστω κατὰ μέσον τὸν ἁζόνα ἐξελίκτα ἢ μὲν καὶ αὐτὴ συμφυῆς τῷ ἁζόνι, περὶ ἢν ἡ σπάρτος ἐπιειλθήσεται.

(4) ταύτη δὲ συμφυῆς ἔστω τύλος ὁ ἑ, περὶ δὲ τῆς σπάρτος ἀγκύλη περικείσεται. ἔτερος δὲ ἔστο τροχὸς κατὰ μέσην τὴν γὰρ πλευρὰν ὁ οὐ ἐν πήγμαι πολευόμενος τὸ ῥατί περὶ ἁζόνα τὸν ψῆ μικρὸν σφόδρα. οὕτως δὲ ἐνημισάσαν οἱ ἁζόνες τῶν τροχῶν, ὅστε τὸ πλυνθὸν ἀκλίνως καθεστάναι κατὰ πᾶν μέρος. τῆς οὖν ἀγκύλης τῆς σπάρτου περιβληθείσης περὶ τὸν τύλον, ἐπειλείσθω περὶ τὴν ἐξελίκτα ἢ σπάρτος.

(5) καὶ σύριγγος ἐπικειμένης τετραγώνου πρὸς ὅρθας κατὰ μέσον τὸ πλυνθὸν, ἢ ἔτερα ἄρχῃ τῆς σπάρτος διὰ τροχῶσκας ἀποδεδώσθω εἰς τὸ ᾧ ὁμοίος τῆς σύριγγας καὶ ἐξηθῷοι εἰς μολιβοῦν βάρος ἐνὸν ἐντὸς ἐν τῇ σύριγγῃ. οὐκόν ἐάν τις ἄφῃ τὸ βάρος ἐν τῇ σύριγγῃ καταφέρῃσθαι, τενεῖ τὴν σπάρτον. αὕτη δὲ ἀπειλομένη ἀπὸ τῆς ἐξελίκτας ἐπιστρέψῃ τοὺς ἕη, καὶ τροχοὺς· οὕτω καὶ κατὰ τὸν ἐδάφους κυλώμενου ἄξουσι τὸ πλυνθὸν, ἀρχῇ ἢ ἤτοι ἡ ἀγκύλη ἐκπέσῃ ἀπὸ τοῦ τύλου ἢ τὸ βάρος ἐπικαθῆτο τινί.

vi (1) Ἡ μὲν οὖν πορεία γίνεται τὸν εἰρημένον τρόπον, ἢ δὲ ἀποπορεία οὕτως. ἐπειληθείσης γὰρ τῆς σπάρτος περὶ τὴν
wheels, $\eta \theta$ and $\kappa \lambda$, attached to the axle, with their circumferences worked so as to be lentil-shaped; let there be a bobbin in the middle of the axle, $\mu \nu$, and let this be attached to the axle. The cord will be wound around this bobbin.

(4) To this [the bobbin] let there be attached a knob, $\xi$, around which the loop of the cord will lie. Let there be another wheel, $\omega \pi$, in the middle of side $\gamma \delta$, rotating within a frame, $\rho \pi \tau \mu$, around a very small axle, $\varphi \chi$. Let the axles of the wheels be adjusted in such a way that the case may stand level in every part. So, after the loop of the cord has been put around the knob $\xi$, let the cord be wound around the bobbin.

(5) With a rectangular tube placed perpendicularly in the middle of the case, let the other end of the cord pass through a pulley towards the upper part of the tube and be fastened to a lead weight that is inside the tube. So, if someone lets the weight go down in the tube, they will stretch the cord. This will turn the wheels $\eta \theta$ and $\kappa \lambda$ by being unwound from the bobbin; these will drive the case by rolling along the ground, until either the loop falls off the knob or the weight comes to rest on something.

(1) Therefore, forward motion occurs in the manner described, and backward motion as follows. Once the cord has been wound to a certain extent around the bobbin,
έξελίκτραν ἐπὶ τι μέρος, περιτεθείσα περὶ τὸν ζ τοῦ ἑναντία ἐπειλείσθω τῇ πρῶτον <ἐπειλήσει> περὶ τὴν ἐξελίκτραν. εἶτα ἀποδεδώθη ὁμίος εἰς τὴν λείαν κρίκος συνεχομένου αὐτῆς. πάλιν οὖν καταφερομένη ἡ λεία ἀπειλήσει τὴν πρῶτην ἐπειλήσει, καὶ τὸ πλυνθὸν πορευθήσεται.

(2) εἶτα ἀποστάσα ἀπὸ τοῦ τούλου εἰς τὰ ἑναντία ἐπιστρέψας τοὺς τροχοὺς, καὶ οὕτως ἔσται ἡ ἀποπορεία τοῦ πλυνθοῦ. εἰ δὲ βουλώμεθα πορευθῆν τὸ πλυνθὸν στῆναι ἐπὶ τινα χρόνον καὶ οὕτως τὴν ἀποπορείαν ποιῆσασθαι, ἐπειλήσαντες τὴν σπάρτον καὶ περιβαλόντες περὶ τὸν τούλον οὐκ εὐθέως τὰ ἑναντία ἐπειλήσομεν, ἀλλὰ μηρμάτιοι ποιήσαντες καὶ προσκολλήσαντες {ἐπειλήσομεν} ἐπὶ τὴν ἐξελίκτραν καὶ πάλιν τὰ ἑναντία ἐπειλήσαντες ἀποδοσομεν εἰς τὴν λείαν, καὶ ἔσται τὸ προκείμενον.

(3) εἰ δὲ καὶ πολλάκις βουλώμεθα πορεύεσθαι τε καὶ ἀποπορεύεσθαι τὸ πλυνθὸν, πλεονάκις καὶ τὰς ἑναντίας ἐπειλήσεις ποιησόμεθα καὶ τὰ διαστήματα ἡλίκα ἄν προαιρόμεθα καὶ τοὺς τῶν {δὲ} μονὸν χρόνους ποιήσομεν διὰ τῶν μηρμάτων ἡλίκος ἄν προαιρόμεθα.
having been put around the knob \( \frac{\pi}{2} \), let it be wound around the bobbin in the direction opposite to the preceding \(<one>\). Subsequently, let it be likewise attached to the counterweight with a ring joined to it. So again, the counterweight will unroll the first winding while descending, and the case will move.

(2) Then, after it [the cord] has detached from the knob, it will turn the wheels in the opposite direction, and thus the case will come back. However, if we want the case, once it has travelled, to stand still for some time and move back in this way, we will wind the cord and put it around the knob without winding it the other way around immediately. Instead, after we have formed a hank, glued it onto the bobbin and wound \(<the cord>\) again contrariwise, we will attach it to the counterweight, and what has been said before will happen.

(3) If we also want the case to move forward and backward many times, we will make alternate windings more frequently and the intervals \(<between them>\) the size we may choose; we will also regulate the timings of the pauses by means of hanks of the length we may choose.
(4) νοείσθω δὲ καὶ κατὰ κρόταφον τὸ πληνθὼν σὺν τῇ σύριγγι ὀρφεύνον, καὶ ἐστὼ πληνθὼν μὲν τὸ ῥυό, ἐξελίκτρα δὲ ἢ ἡ, σύριγξ δὲ ἢ τ’, σπάρτος δὲ ἢ ἄβι περὶ τροχόλον {δὲ} περικειμένη τὸν ζ’, λεῖα δὲ ἢ ὅ, ὁ δὲ ἐν αὐτῷ κρίκος ὁ ἔ.

vii

(1) Ἡ δὲ ἐπὶ κύκλω πορεία γίνεται τόνδε τὸν τρόπον.

ἐστὼ γὰρ κύκλος, καθ’ οὖν φέρεσθαι δεῖ τὸ πληνθὼν, ὁ ἄβη, οὖ κέντρον τὸ δ’. καὶ διήθυε τις ἢ ἂδ, καὶ <πρός> ταύτην ὁρθή ἀπὸ τοῦ ἢ εὖζ. ἢ δὲ εἰς διάμετρος ἐστὼ ἔνθες τὸν τριῶν τροχών, ἥλκου ἄν προσαράθημα. διχοτομία δὲ αὐτῆς ἔστω τὸ ὅ, καὶ εὐπεράχθησαν αἱ ὅ, ὅζ.

(2) τῷ δὲ μεγάθει τοῦ ἄξονος τῶν τροχών ἴση ἐστὼ ἢ ἄπι, καὶ τῇ εἰς παράλληλος ἢ ἀθάκτον τὸ πληνθὼν ἐστὼ τὸ μινῖς παράλληλον ἔχον τὴν νῃ τῇ ἁδ. καὶ ἡχθῳ τις εἴπερα ἢ δο, καὶ ταύτη πρὸς ὁρθῶς ἢ πρὸ δίχα τεμνομένῃ ὑπὸ τοῦ ὅ. ἐςονται δὴ αἱ τῶν τροχῶν θέσεις κατὰ διαμέτρους τάς εἰς, ὅκ, πρ, ἄξονες δὲ αὐτῶν οἱ τῷ, ὅξ.

(3) οὕτως οὖν τετάξθησαν οἱ τροχοὶ τῇ θέσει, ὡστε ἐστὸς ἐπὶ αὐτῶν τὸ πληνθὼν ἰσορροπεῖν. οἱ ἄρα κνώδακες τῶν ἄξονον ἐςονται πρὸς τοῖς ὅ, ὅ, χ. σημεῖοι. πάλιν οὖν μεταξὺ τῶν ὅ, ἢ ἢ ἐξελίκτα κηίσθω, περὶ ἤν ἡ σπάρτος

(4) Let the case, along with the tube, be conceived as seen from the side, and let there be a case, \( \psi \), a bobbin, \( \tau \), a tube, \( \tau \), a cord \( \alpha \beta \) lying around a pulley, \( \Upsilon \), a counter-weight, \( \delta \), and a ring on it, \( \varepsilon \).

(1) The motion in a circle occurs in the following way.

Let there be a circle along which the case must be carried, \( \alpha \beta \gamma \), with its centre \( \delta \). Let a certain \(<line> \alpha \delta \rangle \), be drawn, and let a \(<line> \alpha \alpha \zeta \rangle \) be drawn perpendicular \(<to> \) it at \( \alpha \). Let the diameter \( \alpha \zeta \) be \(<the \ diameter> \) of one of the three wheels, of whatever size we may choose. Let its point of bisection be the \(<point> \alpha \), and let the \(<lines> \delta \zeta \) and \( \delta \zeta \) be joined.

(2) Let a \(<line> \alpha \gamma \rangle \) be equal to the size of the axle of the wheels, and a \(<line> \gamma \delta \kappa \rangle \) parallel to \( \alpha \zeta \). Let there be a case, \( \mu \lambda \nu \zeta \), with the \(<line> \nu \zeta \rangle \) parallel to \( \alpha \delta \). Let another certain \(<line> \delta \alpha \rangle \), be drawn, and \(<let> \rangle \) a \(<line> \alpha \rho \rangle \), which is bisected by the \(<point> \alpha \), \(<be \ drawn> \) perpendicular to it. The positions of the wheels will then be along the diameters \( \alpha \zeta \), \( \delta \kappa \) and \( \alpha \rho \), and their axles will be \( \alpha \nu \) and \( \alpha \chi \).

(3) So, let the wheels be arranged in such a position that the case set on them may be in equilibrium. The pivots of the axles will then be at the points \( \tau \), \( \upsilon \), \( \omega \) and \( \chi \). So again, let the bobbin around which the cord is wound be placed
ἐπιείλεται, καὶ τὰ αὐτὰ γεγονότεω τοῖς ἐμπροσθεν εἰρημένοις, καὶ οὕτως ἐνεχθήσεται κατὰ τού ἐιρημένου κύκλου τό πλινθίον.

VIII (1) Ἡν γὰρ κόνος κυλίται κατὰ ἐπιπέδου, ἢ μὲν βάσις αὐτοῦ γράφει κύκλου, οὐ ἢ ἐκ τοῦ κέντρου ἦς ἐστὶ τῇ τοῦ κόνου πλευρᾷ, ἢ δὲ κορυφὴ αὐτοῦ μενεὶ ἀκίνητος κέντρον οὗσα τοῦ εἰρημένου κύκλου. οὐ δὲ ἢ, ἢ, πρὸ τροχοὶ ἐν κόνοις εἰσὶ δυσφ., ἡν βάσεις μὲν οὐ εἴ, πρὸ κύκλου, κορυφὴ δὲ τὸ δ ἁμείον.

(2) ὅτι δὲ οἱ κόνοι οἱ ἰσοσκελεῖς κυλιόμενοι κύκλους τε γράφουσι καὶ τὴν κορυφὴν ἢχουσιν ἀκίνητον, φανερόν κείμενος γὰρ ἢκόνος> ἐν τῷ ἐπιπέδῳ καὶ βεβηκός κατὰ τὴν ἐκατού πλευρὰν ἵσορροπός ἐστιν ἐαυτῷ· τέμνεται γὰρ ύπὸ τοῦ διὰ τῆς πλευρᾶς ἐκβαλλόμενου ἐπιπέδου ὀρθοῦ πρὸς τὸν ὀρίζοντα δῆξα. ὅταν δὲ ἐπέρα δυνάμει κατακρατηθείσης κυλίται, ἐκατον τῶν ἐν τῇ ἐπιφανείᾳ αὐτοῦ ἡμικύκλου τῶν ἐπὶ τὰ αὐτὰ τῇ ἑσθ ἀνεύρετα κατακρατεῖ τὸν λοιπὸν τοῦ αὐτοῦ κύκλου ἡμικυκλίου, καὶ οὕτως τούτο κινεῖται.

(3) ἐπινοούμενον δὲ τῶν ἡμικύκλων τῶν ἀχρί τῆς κορυφῆς, οὐ λείπεται πρὸς τῇ κορυφῇ οὔτε ἡμικύκλων οὔτε ἄλλο το διαστάτον. διὸ ἢ κινοῦσα δύναμις μηκέτι ἢχουσα τίνι κατακρατήσει τοῦ ἐπὶ τὰ ἔτερα κειμένου μέρη, ἀδύνατας κινήσει τὴν κορυφὴν ἐν τῇ κατὰ τὴν ἐπιστροφήν κινήθηκεν τὸ κύκλου ΑΤ.
between $\overline{\omega}$ and $\overline{\eta}$, and let the same happen as has been said before. The case will thus be carried along the said circle.

VIII

(1) If a cone rolls on a plane, its base will describe a circle, whose radius is equal to the side [a generatrix] of the cone, and its vertex will remain motionless, being the centre of the said circle. The wheels $\overline{\omega z}$, $\overline{\delta k}$ and $\overline{\pi r}$ are inside two cones, whose bases are the circles $\overline{\omega z}$ and $\overline{\pi r}$, and whose vertex is the point $\delta$.

(2) It is clear that the cones which are isosceles, as they roll along, describe circles and have their vertex motionless. For, when <a cone> lies on the plane and stands on its side, it is in equilibrium with itself; it is, in fact, bisected by the plane that is generated through the side perpendicularly to the horizon. When it rolls, having been overcome by another force, each of the semicircles on its surface which are on the same side overcomes with equal force the remaining semicircle of the same circle, and thus this moves.

(3) If the semicircles are conceived <as reaching> up to the vertex, there is no semicircle left in the apex, nor anything else with dimensions. For this reason, since the motive force no longer has any means to overcome what lies on the other side, it cannot move the apex during the
σει, εἰ μὴ ἁρὰ κατά τὸν προσωμὸν ἡ ἐπικράτησις αὐτῆς γίνεται.

IX (1) Ἡ δὲ ἐν τῷ ὀρθογωνίῳ παράλληλογράμμῳ πορεία τοῦ πλινθῶν ἦσται τὸν τῶν τρόπον.

ἔστω γὰρ πλινθῶν τὸ αβγδ, ἐν δὲ ἄξον ἦστο ό εἰς συμφωνεῖ δέχον τροχός τοὺς ἱ, κλ. τὸ δὲ τρίτος τροχὸς ἦστο ό μὲν. δι’ ὅν ἂ το πορεία καὶ ἡ ἀποπορεία γίνεται, ὡς προγέγραπται. ἔστω δὲ καὶ ἕτερος ἄξον ὁ ὁ εἰς συμφωνεῖ δέχον τροχός τοὺς πρ, στ καὶ ὁμοίως <***>τὸν υφ.

(2) ἐπάνω δὲ ἦστο ό ἀξον τοῦ εἰς ἄξον άκέχον ἀπὸ τοῦ εἰς ἄξον ικανόν. δυνάσθωσαν δὲ ὁ πρ, στ τροχοί σὺν τῷ ἀξον μεταφρίζονται καὶ ταπεινοῦσθαι, ὡς ἔξες ἔρομεν· ὁμοίως δὲ καὶ ὁ υφ τροχός. ἐὰν οὖν καταβιβάζο- 

μεν τοὺς πρ, στ, υφ τροχοί, ὅστε ἐπικαθίσαι τῷ ἐδάφει, μεταφράζονται οἱ ἱ, κλ., μὲ τροχοὶ ἀπὸ τοῦ ἐδάφους, καὶ ποιήσεται τὴν πορείαν τὸ πλινθῶν διὰ τῶν πρ, στ, υφ.

(3) καὶ ἀνασπασθέντος τοῦ ἀξον, ὅστε πάλιν τοὺς ἱ, κλ., μὲ ἐπικαθίσαι τῷ ἐδάφει, {καὶ} δὲ αὐτῶν τὴν ἐτέραν τοῦ παράλληλογράμμου πλευράν πορευθήσεται τὸ πλινθῶν. ἐῖτα πάλιν στάντος αὐτοῦ καταβιβαζόμενον οἱ πρ, στ, υφ, καὶ πάλιν δὲ αὐτῶν τὴν ἐτέραν τοῦ παράλλη- 

λογράμμου πλευράν ἐνεχθήσεται τὸ πλινθῶν. καὶ τούτῳ ἐναλλάξ γινομένου, ὡς καὶ ἕν προαιρόμεθα ἐλεύσεται ἐπὶ τὸ παράλληλογράμμον τὸ πλινθῶν.
rotational motion, unless perhaps it is overcome by a forward propulsion.

\section{IX}

\textbf{(1)} The motion of the case along a rectangular parallelogram will occur in the following way.

Let there be a case, $\overline{\alpha \beta \gamma \delta}$, in which let there be an axle, $\overline{\alpha \gamma}$, with wheels attached to it, $\overline{\eta \theta}$ and $\overline{\kappa \lambda}$; let there be the third wheel, $\overline{\mu \nu}$. The forward and backward motion takes place by means of these wheels, as has been written before. Let there be another axle, $\overline{\xi \sigma}$, with wheels attached to it, $\overline{\pi \rho}$ and $\overline{\sigma \tau}$, and likewise $\overline{\upsilon \phi}$.

\textbf{(2)} Let the axle $\overline{\xi \sigma}$ be above the axle $\overline{\alpha \gamma}$, at a sufficient distance from it. Let the wheels $\overline{\pi \rho}$ and $\overline{\sigma \tau}$ have the potential to be raised and lowered together with the axle $\overline{\xi \sigma}$, as I will explain next; and likewise the wheel $\overline{\upsilon \phi}$. Thus, if we lower the wheels $\overline{\pi \rho}$, $\overline{\sigma \tau}$ and $\overline{\upsilon \phi}$, so that they rest on the ground, the wheels $\overline{\eta \theta}$, $\overline{\kappa \lambda}$ and $\overline{\mu \nu}$ will be raised from the ground, and the case will effect its motion by means of $\overline{\pi \rho}$, $\overline{\sigma \tau}$ and $\overline{\upsilon \phi}$.

\textbf{(3)} When the axle $\overline{\xi \sigma}$ has been pulled up, so that again $\overline{\eta \theta}$, $\overline{\kappa \lambda}$ and $\overline{\mu \nu}$ rest on the ground, {and} the case will move over the other side of the parallelogram by means of them. Then again, once it has stopped, $\overline{\pi \rho}$, $\overline{\sigma \tau}$ and $\overline{\upsilon \phi}$ will be lowered, and again the case will be carried along the other side of the parallelogram by means of them. When this happens in an alternate sequence, the case will go along the parallelogram as many times as we may choose.
(4) πορείας δὲ μονάς ποιήσεται ώς ἂν προαιρόμεθα, διὰ τε τῶν τῆς σπάρτου ἐπειλήσεων καὶ τῶν χαλασμάτων. ἵνα οὖν μὴ τὸ βάρος τῆς λείας σφοδρότερον καταφερόμενον ἐν τῇ σύργυγι ταχείαν ποιήται τὴν τοῦ πλινθίου κίνησιν, ἐμβαλόμεν ἐν τῇ σύργυγι κούφον τι καὶ λεπτόν καὶ γλί-σχρον, οἷον κέγχρον ἡ νάπτυ, εἰς δὲ ἐπικείεσθαι ἡ λεία.

(5) τρυπήσουμε δὲ τὸν πυθμένα τῆς σύργυγος συμμέτρω τρυπήματι, ὁ κλειθρῶν ἀνοιχθήσεται τε καὶ κλεισθήσεται ἐνδεδειγμένον σπάρτῳ, ἢς τὸ ἄκρον ἐκτὸς διὰ τρυπήματος φανερόν ἦμιν ἔσται, ὡς ὅταν βουλώμεθα κινεῖσθαι τὸ πλινθίον, ἐπιλαμβανόμενοι τῆς σπάρτος {οὐ} λελιθότος ἀνοιξόμενον τὸ κλειθρίον. καὶ οὕτως τῆς κέγχρου ρεούσης ἡρέμα εἰς τὴν ύποκειμένην βάσιν, κινεῖται τὸ πλινθίον.

(6) ἢνα δὲ μὴ ἀμα τῷ ἀνοιχθήναι τὸ κλειθρίον ὀρμήν τὸ πλινθίον λάβῃ, ἔξει μικρὸν χαλασμάτων ἢ σπάρτος, ὡς ὀλίγης κέγχρου ἐκρείσθης τότε τασία κινεῖσθαι τὸ πλινθίον. ὡς δὲ δεῖ τοὺς τρεῖς τροχοὺς μεταφίλεσθαι τε καὶ ταπεινούσθαι ἐναλλάξ, νῦν ἐροῦμεν.

(1) Ἠστωσον οἱ ἐιρημένοι τροχοὶ τρεῖς οἱ ἀβ, γδ, εζ, τῶν δὲ ἀβ, γδ ἄξων ὁ ἦθ. φανερόν οὖν ὅτι οἱ πρὸς τοῖς ἦ, θ κνώδαικες ἐνημοσυνέναι εἰσίν εἰς τινα ἐμπυκλίαδα ὅτα πρὸς τοῖς τοῖς τοῦ πλινθίου. τὰ οὖν εἰρημένα ἐμπυκλί-
(4) It will produce pauses of the motion however we may choose, by means of the windings of the cord and its slackenings. So, in order for the heavy counterweight not to descend in the tube too forcefully and move the case at speed, we will put something light, fine and providing resistance inside the tube, such as millet or mustard, upon which the counterweight will come to rest.

(5) We will pierce the bottom of the tube with a hole of suitable size, which will be opened and closed by a slide fastened to a cord; the end of this will be visible to us from the outside through the hole, so that, when we want the case to move, we may grab the cord and {not} unobtrusively open the slide. As the millet gently pours out into the base below, the case moves.

(6) In order for the case not to make a rush forward while the slide is being opened, the cord will have a little slack to it, so that, when a little millet has flown out, it will be pulled taut and move the case. Now I will say how the three wheels must be alternately raised and lowered.

(1) Let there be the three stated wheels, \( \alpha \beta \), \( \gamma \delta \) and \( \varepsilon \zeta \), and \( \alpha \beta \)'s and \( \gamma \delta \)'s axle, \( \eta \theta \). It is thus clear that the pivots at \( \eta \) and \( \theta \) are fitted into certain sockets which are near the
dia ἐστω εἰς τινα κανόνια: τὰ δὲ κανόνια διὰ πελεκίνων καταβαινέτω ὀρθά εἰς τοὺς τοῦ πλινθοῦν τοίχους.

(2) ὁμοίως δὲ καὶ τὸ οὖ τρόχιον ἔστω ἐν τινι κανονίῳ ὀρθῷ διὰ τινος πελεκίνου καταβιβαζομένῳ εἰς τὸν πρός τὸν εὖ τοίχον τοῦ πλινθοῦ. ἔστω οὖν τὸ μὲν εἰρημένον κανόνιον τὸ ηθ. ἐκκομὴ δὲ ἐν αὐτῷ ἢ κλίμαν: ἐν δὲ ταύτῃ τρόχιον τὸ εὖ ἄξονα ἔχον τὸν ζο. πρὸς δὲ τὸ ηθ. ἀκρῷ τοῦ κανόνιου τύλου ἐνειλείσθω ὁ π: ἐν δὲ τὸ τοίχῳ τοῦ πλινθοῦ τὸ πρὸς τὸν εὖ ἐνειλείσθωσαν δύο γόμφοι καθάπερ κανόνια, οἱ ζο, τοῦ ἐν δὲ τούτους πολευεύσων κοχλίας ὁ φίχ, καὶ ἐμβεβηκέτω ὁ π τύλος εἰς τὴν τοῦ κοχλίου ἐλικα.

(3) ἦν οὖν τις ἐπιστρέφῃ τὸν φίχ κοχλίαν, μετεωρίσθησαν καὶ ταπεινοθήσατο τὸ ηθ. κανόνιον διὰ τοῦ π τύλου. ἦν οὖν αὐτόματον τοῦτο γίνεται, ἐπειλείσθω περὶ τὸ ἀργόν μέρος τοῦ κοχλίου σπάρτος ἐναλλάξ τὰς ἐπιλήσεις ἔχουσα καὶ χαλάσματα διαμεμηρυμένα, ἀρμοστὰ τοῖς διαστήμισιν οἷς κινεῖται τὸ πλινθόν: τὰ δὲ αὐτὰ γεγονέτο καὶ ἐπὶ τῶν λουκῶν δύο κανονίων, ἐν οἷς εἰσίν οἱ πρὸς τοῖς ηθ. θ κνώδακες:

(4) δὲ δὲ τοὺς τρεῖς κοχλίας ἵσους τοὺς πάχεσιν εἴναι καὶ τὰς ἐπειλήσεις τὰς περὶ αὐτῶν ἀκριβῶς ἴσας καὶ τὰ χαλάσματα ὁμοίως, ὅπος ἄμα τε ἐπαιρόνται οἱ τρεῖς τροχοὶ καὶ ἄμα καθιόνται: οὕτω γὰρ ἀσφαλῆς καὶ εὐκίνητος ὁ τοῦ πλινθοῦν πορεία ἔσται.
sides of the case. So, let the said sockets be on certain bar-frames. Let the bar-frames run vertically down the sides of the case by means of dovetails.

(2) Let the small wheel $\tilde{z}b$ be likewise <placed> into a certain vertical bar-frame which is made to run down by means of a dovetail to the $\tilde{b}b$ side of the case. So, let there be the said bar-frame, $\tilde{b}b$, and a mortise in it, $\tilde{b}b$. Inside this <let there be> a small wheel, $\tilde{z}b$, with an axle $\tilde{a}b$. At the $\tilde{b}$ end of the bar-frame let a block $\pi$ be screwed on. On the $\tilde{b}b$ side of the case let two dowels, $\rho\sigma$ and $\tau\eta$, be screwed on like bars. Let a screw $\phi\chi$ turn on these, and the block $\pi$ engage the thread of the screw.

(3) Therefore, if someone turns the screw $\phi\chi$, the bar-frame $\tilde{b}b$ will be raised and lowered through the block $\pi$. So, in order for this to happen automatically, let a cord be wound around the unused part of the screw, alternating windings and slack parts arranged in hanks commensurate with the distances over which the case moves. Let the same things happen in the case of the two remaining bar-frames, in which are the pivots at $\tilde{a}$ and $\tilde{b}$.

(4) The three screws must be equal in thickness, the windings around them precisely equal and likewise the slackenings, so that the three wheels may be raised and lowered at one and the same time. For the motion of the case will thus be safe and easy.
(1) Δυνατὸν δὲ ἔστι καὶ ἄλλως κάμπτειν τὸ πληθὺς, οὐ μόνον ἐν ὀρθογωνίῳ παραλληλογράμμῳ, ἀλλὰ καὶ ἐν παντὶ εὐθυγράμμῳ σχήματι: ἔτι δὲ καὶ τὴν πορείαν ὀριθῶθ  glyphicon ξυνεθεὶ τὰ ἄνευ ἐν θεόν ἐν τὴν προγεγραμμένην μεθόδου.

(2) ἔστω γὰρ τὸ πληθὺς, ἐν ὃ εἰσίν οἱ τροχοὶ, τὸ ἀβγὸ, ἐν ὃ διακείσθεσαν ἄξονες δύο οἱ ἐξ, ἦθ, ὅτι ὁ μὲν ἦθ ἐν κνώδαξιν εὐλύτως στρεφθήτω ἔχον συμφωνή τροχὸν τὸν χλ, ὃ δὲ ἐξ συναρμὸς ἐστο τὸ πληθὺς ἀπὸ τὸν ἱσοπάχης εἰργασιμένος. περὶ δὲ τούτον περικείσθε σοινικίδες δύο αἱ μὲν, ἐξ εὐλύτως καὶ ἀρμοστῶς περὶ αὐτόν στρεφόμεναι καὶ αὐταὶ ἀπὸ τὸν ἐντός καὶ τὴν ἐκτός ἐπιφάνειαν εἰργασιμέναι. ταῖς δὲ σοινικίσι συμφωνεῖς ἐστωσαν τροχοὶ ἵσοι οἱ πρ, στ.

(3) ἐὰν οὖν περὶ ἐκατέρας σοινικίδα σπάρτος περιελθείς ἀπὸ δόθη εἰς τὴν ἐν τῇ σύργη λειάν, συμβιβάσεται καταφερομένης τῆς λείας ἀπελουμένων τῶν σπάρτων ἐπιστρέφεσθαι σὺν τάς σοινικίσ τοὺς τροχοὺς καὶ οὕτως τὸ πληθὺν ἐπ’ εὐθείας πορεύεσθαι συνεπιστρεφομένου καὶ τοῦ κλ τροχοῦ.

(4) ἐὰν οὖν ἐκ τῶν πρ, στ τροχῶν ὁ πρ μὲν ἄκινητος χάλασμα ἐχθοῦς τῆς κατ’ αὐτὸν σπάρτου, ἐπιστραφῆσαι ὁ πρ τροχὸς καὶ συνεπιστρέψει τὸν χλ, ἀρχὶ ὁ τὸ ἐν τῇ μὲν σοινικίδα χάλασμα τοῦ μηρύσματος ἐπιστάσεται ἡ λεία. έίτα πάλιν τάσιν λαβοῦς τῆς σπάρτου, ἀμα οἱ πρ, στ τροχοὶ στραφῆσονται, καὶ ἐνεχθῆσαι τὸ πληθὺν ἐπ’ εὐθείας τῆς κατ’ τὴν ἐπιστροφὴ τοῦ πληθυοῦ γενιτείς της.
XI  

1. It is also possible to turn the case in a different way, not only in a rectangular parallelogram, but also in any rectilinear figure. Moreover, the motion can be snake-like and this much more easily than by the method written about before.

2. Let there be the case in which are the wheels, $\overline{\alpha \beta \gamma \delta}$, inside of which let there be two axles, $\overline{\varepsilon \zeta}$ and $\overline{\eta \theta}$; of these, let $\overline{\eta \theta}$ turn freely on pivots with a wheel attached to it, $\overline{\kappa \lambda}$, whereas let $\overline{\varepsilon \zeta}$ be fitted to the case, having been worked on a lathe to an even thickness. Let two hubs, $\overline{\mu \nu}$ and $\overline{\xi \omicron}$, be set around this [the axle], turning freely and closely around it, and these with their inner and outer surfaces worked on a lathe. Let there be equal wheels attached to the hubs, $\overline{\pi \rho}$ and $\overline{\sigma \tau}$.

3. So, if a cord wound around each hub, is attached to the counterweight inside the tube, it will happen that, when the counterweight descends and the cords unwind, the wheels will turn with the hubs, and thus the case will move along a straight line, and the wheel $\overline{\kappa \lambda}$ will rotate at the same time.

4. Therefore, if $\overline{\pi \rho}$, of wheels $\overline{\pi \rho}$ and $\overline{\sigma \tau}$, remains motionless because its cord has some slack to it, the wheel $\overline{\sigma \tau}$ will rotate and turn $\overline{\kappa \lambda}$ at the same time, until the counterweight takes up the slackening of the hank on the hub $\overline{\mu \nu}$. Then, when the cord becomes taut again, the wheels $\overline{\pi \rho}$ and $\overline{\sigma \tau}$ will turn at the same time, and the case will be carried along a straight line resulting from its own turn.

Figs. 11a-b

Fig. 12
(5) δεήσει σὺν τὸ εἰρημένον χάλασμα τοσοῦτον εἶναι, ὅστε ἐπιστραφῆναι τὸ πλινθῖον κατὰ τὴν εὐθείαν ἢν βουλόμεθα αὐτὸ ἐνεχθῆναι. τὰ δ’ αὐτὰ ἐπινοεῖσθω καὶ ἐπὶ τοῦ στὶ τροχοῦ. πλεῦνον ὁμν ἐπειλήσεσαι καὶ μημυμάτων γινομένων ἀκολούθως ταῖς εἰρημέναις εὐθείαις, καθ’ ὧς δεῖ φέρεσθαι τὸ πλινθῖον, ἔσται γεγονός τὸ προκείμενον.

(6) δεήσει δὲ τὰ τε μῆκη τῶν ἐπειλήσεως καὶ τὰ τῶν μηρυμάτων ἐξ αὐτῆς τῆς πείρας γίνεσθαι, ἀρχιμένου ἡμῶν τὰς ἐπειλήσεις ποιεῖσθαι ἀπὸ τοῦ τόπου ἐφ’ οὗ μέλλει καταλήγειν τὸ πλινθῖον· ἀνάπαυν γὰρ αὐτὸ κινοῦντες ταῖς χειρὶν, ὡς μέλλει πορεύεσθαι, ἐπειλήσομεν τὰς σπάρτους καὶ χάλασμα δοὺςεοιν· οὗτο γὰρ ἀρέζόμενον πορεύεσθαι τὸ πλινθῖον καταλήγει δεόντως εἰς τὸν τόπον ὅθεν ἤρζαμεθα ἐπεῖλειν τὰς σπάρτους.

(7) βέλτιον δὲ καὶ τὸν κλ τροχόν ἐν χοινίκίδι περικείσθαι τὸ ἰθ ἄξονι, τὸν δὲ ἄξονα συμφυὴ ὁμοίας τὸ πλινθῖον γίνεσθαι καθάπερ καὶ τὸν ἐκ καὶ πάλιν περὶ τὴν χοινίκιδα τοῦ κλ τροχοῦ τὴν σπάρτον ἐπειληθεῖσαν {καὶ τὰ χαλάσματα ἔχουσαν} τῇ λείᾳ ἀποδοθῆναι, ἡποκεῖται ὧταν βουλόμεθα κάμπτειν τὸ πλινθῖον, ἕν τὸν πρ’, στὶ τροχόν ἐστάναι, δηλοντός χαλάσματος ὅντος ἐν τῇ κατ’ αὐτῶν σπάρτῳ τῇ περὶ τὴν χοινίκίδα, τὸν δὲ κλ τροχόν μετὰ τοῦ λοιποῦ στρέφεσθαι τροχοῦ, ἡχύς ἐν τὸ πλινθῖον τὴν ἀδεούσαν λάβῃ ἐπιστροφῆν, εἰτα πάλιν ταθείσις τῆς τὸ χάλα-
(5) So, the said slack part will have to be such that the case turns in the straight line over which we want it to move. Let the same be imagined for the wheel ατ, too. Thus, if more windings take place and hanks in accordance with the said straight lines, along which the case must be carried, what has been previously stated will happen.

(6) It will be necessary to establish both the lengths of the windings and those of the hanks by actual experiment, as we begin to make the windings from the point where the case is to stop; for when we move it by hand backwards along the path in which it is meant to travel, we will wind the cords and give them some slack. For in this way the case will start moving and necessarily stop at the place where we began to wind the cords.

(7) It is better that the wheel ἱκ is also set around the axle Ν on a hub, that the axle is likewise attached to the case just as ἱκ is, and again that the cord wound around the hub of the wheel ἱκ {and with slack parts} is attached to the counterweight, ἵ in order that ἵ, whenever we want to turn the case, one of the wheels ατ and ατ comes to a stop — clearly because there is some slack in its cord around the hub — and the wheel ἱκ rotates with the remaining wheel, until the case makes the necessary turn, and then, when the
σμα ἐχούσης σπάρτου ἀμα κινούμενον τῶν τριῶν τροχῶν τὴν ἐπ' εὐθείας ὅδὸν φέρηται τὸ πλινθὸν.

(8) ἐπεὶ οὖν αἱ χοινικίδες αἱ τοὺς τροχοὺς ἔχουσαι περικείμενα τοῖς ἀξοσιν ἐν τῇ κινήσει δυσχερῶς ἐπιστρέφονται διὰ ὑπὸ τὸ ὄλον τοῦ πλινθίου βάρος ἐπ' αὐτὰς ἐπικείσθαι, ἀρέσκει ἐν τοῖς αὐτομάτοις πάντα τὰ ἐγκυκλίως κινούμενα περὶ κνόδακας στρέφεσθαι. ποιήσομεν οὖν οὕτω.

(9) γεγονέτω γὰρ τὸ πλινθίον Ἔχον> καθ' ὅν τόπον ὁ τοὺς δύο τροχοὺς ἔχον ἄξων Ψν> ὀρθὸν διάπηγμα ἀραρός· ἐν δὲ τούτῳ ἐμπυκλίῳ ἔστω ἐξ ἐκατέρου μέρους, εἰς ἃ οἱ κνόδακες ἐμβάσασθονται. δύο δὲ ἄξωνες γεγονέτωσαν συμφωνεῖ ἑξοντες τοὺς τροχοὺς, ὅτι ἐκάτερος κέισθο μεταξὺ τοῦ εἰρημένου ὀρθοῦ διαπήγματος καὶ τῶν τοῦ πλινθίου τοῖς ἐν κνόδαιν, ὡστε βεβηκέναι ἐπὶ τοῦ ἐδάφους τοὺς τροχοὺς καὶ ἐκαστὸν στρέφεσθαι ἐν τοῖς ἑαυτοῦ κνόδαιν.

(10) αἱ δὲ περὶ τοὺς ἄξωνας σπάρτοι διπλὰ ἔστωσαν, ὡστε μεσολαβεῖν τὸν τροχὸν καὶ ἐξ ὑσον στρέφειν. γεγονέτω δὲ καὶ ἑτερος ἄξων τοῦτος ὀμοίως κινούμενος ἔμπροσθεν

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cord with the slack is stretched taut again and the three wheels move at the same time, the case moves over the straight-line path.

(8) Thus, since the hubs holding the wheels and set around the axles move and rotate with difficulty because the whole weight of the case rests on them, it is recommended that, in the automata, anything that is moved in a circle turns around pivots. So, we will make <this> in the following way.

(9) Let there be the case <with> an upright partition fixed where the axle holding the two wheels <lay>. Let there be sockets on either side of it, in which the pivots will be inserted. Let there be two axles with the wheels attached to them; let each of these be set on pivots between the said upright partition and the sides of the case, so that the wheels rest on the ground and each <of them> turns on its own pivots.

(10) Let the cords around the axles be double [double-wound] so as to take the wheel in the middle [of the axle] and turn it evenly. Let there be another axle {in front of...}
τοῦ πλινθίου}, ὥστε πάλιν ἐπὶ τῶν τριῶν τροχῶν φέρεσθαι τὸ πλινθίον. καὶ περὶ τοῦτον ὁμοίως διπλή περικείσθω σπάρτος μεσολαβοῦσα τὸν τροχὸν.

(11) πάλιν οὖν τῶν σπάρτων ἐπειληθεισῶν ἐναλλάξ ὀσάκις ἐὰν βουλώμεθα καὶ τὰ χαλάσματα ἔχουσαν ός ἐὰν προαιρώμεθα διαμεμηρυκένα, ὡς εἴρηται, καὶ ἡ τοῦ πλινθίου πορεία ἔσται ὡς ἐὰν προαιρώμεθα, εὐκόπως τε καὶ εὐκυλλίστως διὰ τοὺς κνώδακας.

xii
(1) Περὶ μὲν οὖν τῆς πορείας καὶ τῆς ἀποπορείας τοῦ πλινθίου αὐτάρκως νομίζομεν εἰρηκέναι. ἐξής δὲ περὶ τῶν ἐκτός τῆς πορείας κινήσεων ἐροῦμεν· ἔστι δὲ ἡμῖν ἡ πρώτη κίνησις περὶ τῆς τοῦ πυρὸς ἀνακαύσεως τοῦ ἐν τῷ βομβῷ.
(2) γίνεται οὖν οὕτως· ἔστω γὰρ βιομός ἐκ λεπίδων χαλκών ἡ σιδήρῳ πεποιημένος ὁ ἄβγδ, τρύπημα ἔχον ἐν μέσῳ τῷ ἐπιστρώ τῷ ἔ. ὑπὸ δὲ τοῦτο λεπίδιον ἔστω τὸ ἔτη παρακτὸν ὅσπερ γλωσσοκόμου πύμα, ἐπικαλύπτων τὸ ἐ τρύπημα, ἐκ δὲ τοῦτον ἀλυσείδιον τὸ ἀπὸ ἀποδεδομένον περὶ ἀξόνιον ἐντὸς τοῦ βομβοῦ κεῖμενον καὶ εὐλάτως στρεφόμενον.
(3) ἐκ δὲ τοῦ ἁξόνιου ἀποδεδοσθείς εἰς τὴν λείαν σπάρτος <***> αὕτη δὲ μετὰ τὴν πορείαν ταθείσα ὑπὸ τῆς λείας

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the case) moving in a similar way to these, so that the case travels again on the three wheels. Let a cord be likewise laid double around this [the axle], taking the wheel in the middle.

(11) So again, when the cords are alternately wound as many times as we want with slack parts arranged in hanks however we may choose, as stated, the case will also move as we may choose, easily and smoothly because of the pivots.

(1) So, I believe that I have said enough about the forward and backward motion of the case. I will next talk about movements other than the journey. The first movement we have concerns the lighting of the fire on the altar.

(2) It takes place as follows: let there be an altar made of bronze or iron sheets, $\alpha\beta\gamma\delta$, with a hole in the middle of the hearth, $\varepsilon$. Under this [the hole] let there be a plate, $\zeta\eta$, which can be shifted aside like the lid of a chest, masking the hole $\varepsilon$; let there be a thin chain $\eta\kappa$ attached to this [the plate] around an axle set inside the altar and turning freely.

(3) Let a cord $<\text{***}>$ extend from the axle to the counter-weight. After the forward motion, this [the cord], having
ἐπιστρέψει τὸ ἀξόνιον καὶ παραλλάξει τὸ λεπίδιον, καὶ τῆς ἀγκύλης ἐκπεσοῦσας ἀπὸ τοῦ τύλου τὰ ἔξης ἐπιτελεσθή- σεται. ὑποκείσθω δὲ τῷ ε τριπτήματι λαμπτήρ ὁ μὲ τὴν φλόγα ἔχων ὑποκειμένην τῷ τριπτήματι. ἐπικείσθω δὲ, ὡς προείρηται, ἐν τῷ βωμῷ ὡλὴ δυναμένη εὐκόπως ἀνάπτε- σθαι.

(4) μάλλον δὲ τῶν ἄλλων ποιεῖ τὰ τεκτονικὰ ξύσματα. ὅταν δὲ καὶ πορεύομεν τὸ πλινθίον στή, τότε ἡ ἤκ τῆς ἀλυσιδίου σπάρτος ταθείσα ἐπισπάσεται τὸ ζη λεπίδιον, ὡστε ἀνοικήσῃ τὴν ὅπνη καὶ τὴν φλόγα ἀνέφεδεισαν ἀνακαύσει τῶν βομῶν. τὰ δ’ αὐτὰ ἐπινοεῖσθω καὶ ἐπὶ τοῦ ἐτέρου βωμοῦ, μόνον ὅτι τὸ τῆς σπάρτος χάλασμα μεῖζον εἶναι δεῖ τοῦ νῦν εἰρημένου, ὅπως κατὰ τὰς ἔξης κινήσεις ταθείσα ἀνάπτρος τὴν ἐτέραν ἔξαιρεν ποιήσεται.

XIII
(1) Μετὰ δὲ τὴν τριάδα δεῖ ἐκ μὲν τοῦ θύρου γάλα ἀνα- πτυσσθῆναι, ἐκ δὲ τοῦ σκύφους οίνον.

(2) γίνεται ὅπως καὶ τοῦτο οὕτως· ύπὸ τοῦς πόδας τοῦ Διο- νύσου συμφυής γίνεται σωλῆν ἔχων τριπτήματα ἐν τῇ ἐπι- 

1-2 τῆς...τύλου aut delere aut transponere post porciān (42.22) dub. proposuit Schmidt in app. crit. 4 ἐπικέισθω A GT : ὑποκείσθω M 9 ἀλυ- 

15-16 ἀναπτυσσθῆναι A GT : ἀναπτυσσθῆναι A GT 18 συμ- 

19 post. 

20 φέροντα A G : συμφέροντα M T
been pulled taut by the counterweight, will turn the axle and move the plate aside, and when the loop has fallen off the knob, what follows will be carried out. Let a grate \( \mu \nu \) be placed under the hole \( \varepsilon \), with the flame beneath the hole. Let flammable material, as has been said before, be set on the altar.

(4) Woodwork shavings work better than anything else. So, whenever the case, during its travel, comes to a stop, the cord <coming> from the thin chain \( \eta \theta \kappa \) will then become taut and draw the plate \( \zeta \eta \), so that the aperture may be opened and the flame may shoot upward and light the altar. Let the same be imagined for the other altar, except that the slack of the cord must be greater than the one just mentioned, in order for the cord, during the subsequent movements, to be pulled tight and produce the other kindling.

(1) After the sacrifice, milk must be made to spurt from the thyrsus, and wine from the cup.

(2) So, this takes place as follows: a pipe is attached under Dionysus' feet, with two holes near one another on its surface; from these, small pipes extend up into the inner part of Dionysus, one leading to the thyrsus, the other to the cup.
(3) ἐστὶν δὲ ἢ μὲν βάσις τοῦ Διονύσου ἡ ἀβ, ὁ δὲ συμφυὴς τούτῳ σωλὴν ὁ γῦν· τὰ δὲ ἐν αὐτῷ τρυπῆμα τὰ ἐ, ζ· τὰ δὲ ἐκ τούτων ἀνατείνοντα σωληνάρια τὰ ζη, εὖ, τὸ μὲν ζη εἰς τὸν θύρον, τὸ δὲ εὖ εἰς τὸν σκύφων. ἐστὶν δὲ καὶ ὁ ἐπικείμενος πυρὴν τῷ ναϊκῷ ὁ κλῆ. ἐντὸς δὲ τούτου ἀγγείου ἐστὶν τὸ τετέρων διάφραγμα ἔχον τὸ ὁ. καὶ ἐκ μὲν τοῦ νο ἀγγείου φερέτῳ σωλὴν ὁ πρὸς εἰς τίνα ἔτερον σωλὴν τὸν ὑπὸ συνεσμερισμὸν τῷ γῦν σωλὴν, συμφυὴ δὲ ὄντα ἐκ τῶν ὑποκάτω μερῶν τῷ καταστρόφῳ, ἐφ’ ὃ ναϊκος ἐπίκειται.

(4) τὸ δὲ τρύπημα κεῖσθω κατὰ τὸ ε. ἐκ δὲ τοῦ ζο ἀγ- γείου <³³> ἔτερος σωλὴν ὁ χύσι καὶ φέρον ὅμοιος εἰς τὸν πρὸς σωλὴνα. τὸ δὲ τρύπημα κεῖσθω κατὰ τὸ ζ. οὐ- κοῦν ἐάν τις ἐν μὲν τῷ ἄγγειοις οἴνον ἐγχέι, ἐν δὲ τῷ νο γάλα, κειμένον τῶν ε, ζ τρυπημάτων κατὰ τὰ τις ἐνε- χθήσεται ὁ μὲν οἴνος εἰς τὸν σκύφων, τὸ δὲ γάλα εἰς τὸν θύρον.

(5) ἦν δὲ στέγη τὰ υγρὰ τῶν πρότερον χρόνων, κλεῖς ἐστώ ἡ τοῦ ἀποκλειόμενα, ὡς εἰρήται, τὰ υγρὰ δι’ ἐπιτόνυ τοῦ ἁ, περὶ δ’ ἀγκύλη σπάρτου περιβεβληθὼ χάλασμα ἐξούσα καὶ ἀποδεδομένη εἰς τὴν λείαν, ὡς κατὰ τὸν δέοντα καιρὸν ταθείαν ἐπιστρέψῃ τὸ ἐπιτόνυ καὶ ἐνεχθῇ τὰ υγρά. πάλιν δὲ ἐπιστραφέντος τοῦ Διονύσου καὶ τοῦ ἐτέρου βωμοῦ ἀνακατεύθυντος, δεὶ πάλιν ῥεύσαι τὸν τι ὁι-

(3) Let there be the base of Dionysus, \( \alpha \beta \), the pipe connected to this, \( \gamma \delta \), the holes in it, \( \varepsilon \) and \( \zeta \), and the small pipes stretching from these, \( \zeta \eta \) and \( \varepsilon \theta \), \( \zeta \eta \) to the thrysus, \( \varepsilon \theta \) to the cup. Let there be a knob placed on top of the shrine, \( \kappa \lambda \mu \). Inside this, let there be a container, \( \nu \xi \), with a partition in the middle, \( \omega \). From the container \( \nu \omega \) let a pipe \( \pi \rho \sigma \tau \) lead to a certain other pipe, \( \upsilon \varphi \), fitted tightly to the pipe \( \gamma \delta \) and attached from below to the covering on which the shrine rests.

(4) Let the hole \( \tau \) be set opposite \( \varepsilon \). From the container \( \zeta \omega \) \( \chi \nu \omega \tau \), another pipe, \( \chi \nu \omega \tau \), and likewise leading to the pipe \( \upsilon \varphi \). Let the hole \( \pi \) be positioned opposite \( \zeta \). Then, if someone pours wine into the container \( \nu \omega \), and milk into \( \zeta \omega \), the wine will be conveyed into the cup and the milk into the thrysus, as the holes \( \varepsilon \) and \( \zeta \) lie opposite \( \tau \) and \( \pi \).

(5) So, to keep the liquids in at the earlier time, let there be a tap [stopcock], \( \chi \gamma \), which, as has been said, shuts the liquids off by means of a plug \( \alpha \); let a loop of cord be put around this, with some slack to it and attached to the counterweight, so that, having been pulled taut at the appropriate time, it [the cord] may turn the plug and the liquids may be conveyed. After Dionysus has rotated and the
νον καὶ τὸ γάλα· στρέφεσθαι δὲ οὕτως· Ἡμιυκλίων περιφέρεια

(6) γεγονέτω κατὰ διάμετρον τοῖς τὸ, τὸ τρήματα τὰ βῆ, γῆ, καὶ ἐκ μὲν τοῦ βῆ φερέτω σωλὴν εἰς τὸν ράδο βῆδο, ἐκ δὲ τοῦ γη τῶν σωλὴν εἰς τὸν άτα, ἐγ. τῶν ἡμ. ἡ γλ. κλεῖσιν, καὶ ἱεροὶ ὁμιλοῦσα 5 τὸ οὐκο καὶ τὸ γάλα. ἀνοίγεται δὲ ἡ κλεῖς τρέχον σπάρτως ἐπισπασμήνης τὸ ἐπιτόνον εἰς τὰ τρέχει μέρη.

(7) δεῖ δὲ τούς ρα, ψῳ σωλῆνας δὲ ἐνός κιονίσκου τῶν ἐν τῷ ναίσκῳ κοίλου ὄντος ἑνεχθῆναι ὑπὸ τὴν βάσιν τοῦ ναίσκου, ὡς ὁρανέως ὑπάρχοντω· ἐπιστρέφεται δὲ ὁ Διόνυσος σὺν τῇ ἐπικεμένῃ Νίκη τῷ πυρήνῃ οὕτως. καθείσθω ἄξον σμφυῆς ὅλη τῇ Νίκη διὰ τοῦ πυρήνου ἡ γῆ τῶν εὔλτως στρεφόμενος περὶ κνώδακα τὸν ζῶ, καὶ περὶ αὐτῶν περιειλθεῖσα σπάρτος διὰ τροχλίου του ἂν ἀποδεδόθω εἰς τὴν βάσιν τοῦ ναίσκου καὶ διὰ τροχλίου τοῦ θεὸς τὸ ὑπερέχον τοῦ γῆ σωλῆνας.
other altar has lit, wine and milk must flow yet once more; to rotate in the following way; † arc of a semicircle †

(6) Let there be other holes, \( \beta \) and \( \gamma \), diametrically opposite to the holes \( \tau \) and \( \zeta \); and from \( \beta \) let a pipe \( \beta \rho \) lead to \( \rho \sigma \), and from \( \gamma \) another pipe \( \gamma \rho \) to \( \psi \omega \). Then, after Dionysus has rotated, when the holes \( \varepsilon \) and \( \zeta \) face \( \beta \) and \( \gamma \), again the tap \( \xi \zeta \) will be opened, and wine and milk will likewise flow. The tap is opened when another cord has drawn the plug to the opposite side.

(7) The pipes \( \rho \sigma \) and \( \psi \omega \) must run through one of the shrine’s columns which is hollow under the shrine’s base, in order to be invisible. Dionysus rotates with the Nike placed on the knob as follows. Let an axle \( \xi \zeta \) be set in such a way as to be attached to the Nike through the knob, turning freely around a pivot, \( \xi \), and let a cord wound around it pass through a pulley \( \eta \) towards the base of the shrine and through a pulley \( \beta \) towards the projecting part of the pipe, \( \gamma \delta \).
(8) ούκοιν εάν ἐπιστρέφῃ τις τὸν ἓ σωλήνα, ἀπειλήσει
tὴν περὶ τὸν ἓ ἐξώνα σπάρτον καὶ ἡμα ἐπιστρέψει τὴν
Νίκην καὶ τὸν Διόνυσον· ἐπὶ τα αὐτὰ δὲ ἦστω μέρη ἡ ἐπι-
ςτροφή αὐτῶν· καὶ ἵσος δὲ ἦστω κατὰ τὸ πάχος ὁ ἓ ἐξών
τὸ ἓ σωλήνα, ὅπως ἡμα ἀποκατασταθῶσιν ἢ τε Νίκη καὶ
ὁ Διόνυσος μηδέν παραλλάσσοντες κατὰ τὴν θέσιν. ἦνα
γοῦν αὐτόματον τούτο γίνεται, ἐπειλήσθω ἑτέρα ἄλλης
περὶ τὴν ὑπεροχὴν τοῦ ἓ σωλήνος καὶ διὰ τροχήλου τοῦ ὁ
eἰς βάρος ἀποδεδόθη στὸ μ.
(9) ὁ δὲ συγκεκοιμισμένος τὸ βάρει κρίκος χειρί κατεχέτο
καὶ σχαστηρία, καθάπερ ἐπὶ τῶν καταπελτῶν γίνεται,
ὅπως τὶς σχαστηρίας ἀπολυθεῖσης ἀπὸ τῖνος σπάρτον τὸ
βάρος κατανεχθέν ἐπιστρέψῃ τὸν τε Διόνυσον καὶ τὴν
Νίκην. καὶ ὁ ἓ δὲ σπάρτος δὲ ἑτέρου κιονίσκου κρυστέ-
σθω, καθάπερ καὶ ἐπὶ τῶν σωλήνων εὑρηται.

xiv (1) Μετὰ δὲ τὸ σπεῖσαι πρῶτος τὸν Διόνυσον δείσει κυμ-
βάλοι καὶ τυμπάνοι κτύποι γενέσθαι, γίνεται δὲ καὶ
τούτῳ οὕτως· ἐν τῇ κάτῳ βάσει, ἐν ἡ εἰσὶ καὶ οἱ τροχοί,
ἀγγειὸν τίθετα ἔχον σφαιρία μολιβδονυμία συρρέειν εἰς τὸν
πυθμένα. ἐν δὲ τῷ πυθμένῳ τρήμα γίνεται εὐλύτως δυνάμε-
νον δέξασθαι τὰ σφαιρία, κλειθρῖον ἔχον ἀνοιγόμενον ὕπο
τῆς σπάρτος, ὅταν δέ. ὑπόκειται δὲ τῷ τρήματι τυμπά-
νοιν ἐπικεκλημένοιν, καὶ τούτῳ ἔζησθω κυμβάλοιν.
(8) So, if someone turns the pipe $\gamma \delta$, they will unwind the cord around the axle $\zeta \lambda \kappa$ and rotate the Nike and Dionysus at the same time; let their rotation occur in the same direction. Let the axle $\zeta \lambda \kappa$ be equally thick as the pipe $\gamma \delta$, so that the Nike and Dionysus may return together without changing anything with respect to their position. Then, in order for this to happen automatically, let another chain be wound around the jut of the pipe $\gamma \delta$ and pass through a pulley $\mu$ towards a weight $\mu$.

(9) Let a ring, which is firmly fastened to the weight, hold it with the aid of a claw and a trigger, as happens in catapults, so that, once the trigger has been released by a certain cord, the weight may descend and turn Dionysus and the Nike. Let the cord $\pi \beta$ be hidden by means of another column, just as has been said of the pipes.

(1) After Dionysus has poured a libation for the first time, there will need to be a rattle of cymbals and kettledrums. This takes place as follows: in the base below, where the wheels are too, is placed a container with small lead balls, which roll along together towards the bottom. In the bottom there is a hole that can easily receive the small balls, with a slide which is opened by the cord whenever needed. A kettledrum is placed slantwise under the hole, and a cymbal should be fastened to it.
(2) ἐκπέπτοντα ὃν τὰ σφαίρια κρύοσει πρῶτον τὸ τυμπάνιον καὶ ἐκ τούτου ἀποπέπτοντα εἰς τὸ κυμβάλλον τὸν ἤχον ἀποτελέσει. δύναται δὲ μέσον διάφραγμα λαβὸν τὸ ἄγιον δύο χώρας ποιῆσαι, ὡστε ἐν ἑκατέρα ἐναι σφαίρια <καὶ> τὰ μὲν ἐν τῇ μιᾷ χώρᾳ τὸν πρῶτον ἤχον ἀποτελεῖν, τὰ δὲ ἐν τῇ ἐτέρᾳ τὸν ἐξῆς, κλειθρίου ὁμοίως ἀνοιχθέντος.

(1) Ἐξῆς δὲ δὲὶ τὸ περιστώλιον στεφανωθῆναι τὸ ἐν τῇ βάσει.

(2) γίνεται δὲ ὀўτὸς· νοεῖσθω τὸ θωράκιον τὸ ἑπικείμενον ἐν τῷ τετραστύλῳ τῷ ἀβγῷ ἔχον ἐντὸς ἔτερον θωράκιον τὸ εξῆθο, ὡστε τὴν μεταξὺ τῶν δύο χώρων θωρακίων κενὴν ἐκ τοῦ κάτω μέρους ὑπάρχειν. γενηθὲν δὲ πλέγμα ἐκ στεφάνου τετραγώνον πλοκῆ ὡς ἢ ἄν τις βούληται καὶ πρὸς τὴν ὁψιν εὐαρμόστως καὶ τοῦτο πτυγέν ἐγκρύπτεται εἰς τὸν εἰρήμενον μεταξὺ τῶν θωρακίων τόπον τάς ἁνω ἄρχας ἐξημεμένας ἔχον ἐκ τοῦ θωρακίου.

(3) καὶ ἴνα μὴ αὐτόματον καταφέρηται, σανδίδων ἐπίμηκες ἀρμόζον τῷ μεταξὺ τῶν θωρακίων τόπῳ καθ’ ἐκάστην πλευράν τοῦ θωρακίου γίνεται, ὡστε ἐπισωμάσαι τὸ πλέγμα καὶ συσχεῖν εἰς τὸ ἁνω μέρος. ἴνα δὲ μὴ αὐτόματα τὰ σανδίδα ἀποπίπτῃ, ἐκ τῆς μιᾶς πλευρᾶς τῆς εἰς τὸ ἐντὸς τοῦ θωρακίου μέρος στροφωμάτα εὐλυτα λαμβάνει, ἴνα

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52
(2) So, as they drop, the little balls will hit the kettledrum first and, as they fall off it onto the cymbal, they will produce the sound. If the container is provided with a partition in the middle, it can form two spaces, so that there may be small balls in each one <and> those in one section may produce the first sound, those in the other the second, after the slide has likewise been opened.

(1) Subsequently, the peristyle on the base must be adorned with garlands.

(2) It takes place as follows: let a parapet \( \overline{a\beta\gamma\delta} \), which is placed on top of the four-column peristyle, be conceived as having another parapet inside, \( \overline{\varepsilon\zeta\eta\theta} \), so that the space between the two parapets may be empty on the underside. Once a wreath has been made from rectangular garlands, intertwined however one wants, in a visually pleasing fashion, and once this has been folded, it is hidden in the said space between the parapets, with its upper ends fastened to the parapet.

(3) In order for it [the wreath] not to descend spontaneously, a long board is fitted to the space between the parapets along each side of the parapet so as to cover the wreath like a lid and confine it to the upper part. In order for the boards not to fall off spontaneously, they have easily moveable hinges on the inner side of the parapet, so
οταν <ὁ θωράκιον> ἐπιπομασθῇ, ἐκ τοῦ ἑτέρου μέρους ἐπιστρεπτῷ κόρακι κατέχεται, ὡστε μὴ ἀνοίγεσθαι.

(4) ἐκ δὲ τοῦ ἑτέρου μέρους τοῦ κόρακος ἁγκύλη σπάρτον περιτίθεται, ἵτις ταθείσης τῆς σπάρτου καὶ τοῦ κόρακος ἐπιστραφέντος ἀποπίπτει. καὶ οὕτως τὸ πλέγμα καθίetai. ξεζε ἐδι τὸ πλέγμα εἰς τὰ κάτω μέρη βαρύλλια μολβά ἐκδε-

xvi (1) Τὸ λοιπὸν δὲ δὴ καταλείπεται ὑποδειξά, πῶς αἱ Βάκ-

χια χαρεώνουσι κατὰ τοῦ δέντα καιρόν. γίνεται οὖν καὶ τοῦτο οὕτως· ὁ ναῖσκος ὁ στρογγύλος, ἐν ὃ ἔστιν ὁ Διόνυ-

σος, στυλοβάτην ἐχέω στρογγύλων καὶ λειών κατὰ τὸ ὑψος.

ἐστο οὖν οὗτος ὁ ἀβγό· περὶ δὲ τούτον περικείσθω ἵτους ἢ ἐξηθλόμον ἀρμόστη τὸ στυλοβάτη, ὡστε εὐλύτως περὶ αὐτὸν στρέφεσθαι.

(2) περὶ δὲ τὸν κρόταφον τῆς κλίνιν περιφερείας ἐντετο-

νεύσθω σωλῆν, ἐν ὃ σπάρτος ἐπιληθεῖσα ἐγκεκομίσθω {εἰς τὸ βάθος τοῦ σωλῆνος}, ἥς ἢ μὲν μία ἀρχή κεκρο-

σθων δι᾽ ἐπιούρου εἰς τὸ βάθος τοῦ σωλῆνος, ὡστε μηκέτι ἐκσπάσθαι.

(3) ἢ δὲ ἑτέρα διὰ τροχύλῳ ἀποδεδῶσθω εἰς τὸ κάτω μέ-

ρος τοῦ θωρακίου καὶ ἐπειλήσθω εἰς ἑτέρον σωλῆνα ἐν-

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1 <ὁ θωράκιον> supp.lev. 2 κατέχεται a: corr. Haase μὴ <ὑπόματα>
Schmidt: dub. in app. crit 3 μέρους Αβγµτ: μέτρους τ 4 περιτίθε-
ται ... σπάρτου om. στ. 1: add. τ 2: περιτίθεται Αβγµτ: ἐπιπέδη τ P
5 τὸ om. M 6 μολβά Α G: μολβά M: *** 7 τὸ om. Gd 8 ἔθ ἐν G
M T: del. A c (ct. st. c) 9 χαρεώνουσι Α G M: χαρεόνου [***] T: χαρείς
Schmidt: dub. in app. crit. 10 δὲ om. M T: κρόταφον
Schmidt: dub. in app. crit. 11-12 τὸ ύψος a: κρόταφον
Schmidt: dub. in app. crit. 13 οὗτος om. M T: ο ἕν M T: τοῦ τοῦν
M T: τοῦ τοῦν Αξσ G T: 14 στυλοβάτη Α M X : στυλοβάτη M X : στυλο-
βατη G X : στυλοβάτης T X G: στυλοβάτως T X G: στυλοβάτως T X
16-17 ἐν-
teτοπρωνεύσθω a: corr. Haase 18 εἰς ... σωλήνος del. Schmidt: ἢς Α G M:
eis τ 21 ἀποδεδῶσθω Α G T: ἀποδεδῶσθω M 22 ἐπειλήσθω Α G T: ἐπειλήσθω M
that, when <the parapet> has been covered, they [the boards] may be held from the other side by a rotating hook, thus without opening.

(4) From the other side of the hook a loop of cord is put around, so as to fall off when the cord has been pulled taut and the hook has turned. In this way, the wreath is lowered. The wreath will have small lead weights fastened to it on the underside, so as to descend swiftly.

xvi

(1) It just remains to show how the Bacchantes dance at the appropriate time. So, this takes place as follows: let the circular shrine, where Dionysus is situated, have a circular stylobate, which is also smooth over its height.

Therefore, let this be αβγδ. Let a ring εζηθκλμν be set around it, fitting to the stylobate so as to rotate freely around it.

(2) Let a groove be turned on the lathe around the side of the arc κλμν, in which a cord, having been wound, should be put {into the depth of the groove}; let one end of this be pushed into the depth of the groove by means of a peg, so as not to be pulled out any further.

(3) Let the other end pass through a pulley towards the underside of the parapet and be wound into another groove
όντα ἐν τῷ τυμπάνῳ, ὡς συμφωνεῖ ἐστο ἄξονες εὐλάτως στρεφόμενος. τῷ δὲ ἄξονι περιελήσθω ἐτέρα σπάρτος καὶ ἀποδεδόθην εἰς τὴν λείαν. συμβῆσεται οὖν ταθείσης τὴς περὶ τὸν ἄξονα σπάρτου ἐπειλεῖθαι ἐπὶ τὸ συμφωνεῖ αὐτῷ τύμπανον τὴν ἐκ τῆς ἱππος σπάρτον καὶ οὖτως χορεύειν τὰς Βάκχας. ἔπει οὖν διὰ αὐτὰς δει χορεῦσαι, ἔχει χάλα-
σμα διαμεμρυμένον ἡ περὶ τὸν ἄξονα σπάρτος, ὡς στάσεις γένηται τῶν Βακχῶν διὰ τοῦ χαλάσματος, ταθείσης δὲ αὐτῆς πάλιν χορεύσουσιν· ἐπικείσονται γὰρ τῇ εἰρη-
μένῃ ἵππῳ αἱ Βάκχαι.

(1) Ὅσιτ δὲ σπάρτοι ἐκ τῆς κάτω βάσεως εἰς τὴν λείαν ἀποδίδονται, δεῖ ταύτας ἀφανεῖς ὑπάρχειν. γίνεται οὖν καὶ τούτῳ οὖτως:

ἐκεῖ γὰρ τὸ στόμα τῆς σύρηγος, ἐν ἡ ἔστιν ἡ λεία, τὸ ἀβγό, καὶ καθείσθω διὰ τοῦ ἐν τῇ σύρηγι στόματος διά-
φραγμα κατὰ τὴν εἰς εὐθείαν ἀπολαμβάνον τὸ δὲ διάστημα ὅτι στενότατον.

(2) ἢ μὲν οὖν κέχροις ἐμβληθῆσεται εἰς τὴν ἔξω χώραν, αἱ δὲ σπάρτοι ἐκ τοῦ κάτωθεν μέρους ἀνενεχθῆσονται εἰς τὴν ἔκ των χώραν καὶ ἀποδιδύσονται εἰς τὴν λείαν τὴν ἐν τῇ ἀβγές ἐν τῷ στραγγίλην οὕτως γὰρ ἀφανεῖς ἔστων πα-

σαι αἱ κάτωθεν ἀναφερόμεναι σπάρτοι. ἔπει οὖν πολλῶν κινήσεων γινομένων καὶ τῆς τοῦ πλυνθίου πορείας πολλῆς

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1 ἐν τῷ ἈΓΜ: [***] Τ: ἐν τῷ Schmidt dub. in app. crit. εὐλάτως ἈΓΜ: εὐλάτως Τ 2 περιελήσθω ἈΓ: περιελήσθη μ: περὶ[***]Τ 3 ἀποδεδό-
σθω ἈΓΤ: ἀποδεδόθη μ 4 συμφωνεῖ ἈΓ: συμφωνεῖ μ: [***]Τ αὐτῷ Ἀ 5 ἐπὶ G: [***]Τ 8 στάσεις ἈΓεΤ: στάσεις ζευγίῳ καθεί-
σματος Ἀρχαὶ παλαιομενεῖ στέφο αὔτοι in τῷ ἘΜίο: χάσματος Αμ: [***]ματος Τ 15 καθείσθω ὁ: καθείσθην ἈΤ: στάδομας ἈΓ: σύμματος μ: [***]ματος Τ 17 στενότατον Schmidt: στεγνότατον α 19 ἀνενεχθῆσονται ΑΓ: ἀνε-

νεχθῆσονται ἈΓΤ: ἐνεχθῆσονται Harße 22 αἱ ὀτρι ἈΤ 23 πολλῆς α: [***]Τ: μεγάλης Brinkmann
which is on the drum; a freely turning axle should be attached to this. Let another cord be wound around the axle and attached to the counterweight. So, it will happen that, when the cord around the axle has been stretched tight, the cord from the ring will be wound onto the drum that is attached to it [the axle], and the Baccantes will thus dance. Then, since they must dance twice, the cord around the axle has a slack part forming a hank, so that there may be a standstill of the Baccantes because of the slackening. When it [the cord] has been pulled taut, they will dance again. For the Baccantes will be placed on the stated ring.

XVII

(1) All the cords that extend from the base below to the counterweight must be invisible. So, this takes place as follows.

Let there be the mouth of the tube, in which is the counterweight, \( \overline{\alpha \beta \gamma \delta} \), and let a partition be set through the mouth in the tube along the straight line \( \overline{\alpha \xi} \), separating off the space \( \overline{\alpha \xi} \), which is as narrow as possible. \( \text{Figs. 24a-b} \)

(2) The millet will then be put inside the space \( \overline{\epsilon \beta} \), and the cords from below will be brought upwards into the space \( \overline{\gamma \delta \xi} \), and pass through a pulley towards the counterweight inside the space \( \overline{\alpha \beta \xi} \); for all the cords that are brought up from below will thus be invisible. Therefore, since many movements take place and the journey of the case is long,
ünde ὑπορεχοῦσις ἀνάγκη {μὴ} ἐξαρκεῖν τὸ τῆς σύριγγος ὑπὸς, δεῖ καὶ τοῦτο μηχανήσασθαι.

(3) πρὸς μὲν οὖν τὸ μήκος τῆς πορείας δύνανται οἱ περὶ τὸν ἄξονα δύο τροχοῦ αὐξανόμενοι πολὺ μήκος παρέχειν ἢ τὸ τοῦ ἄξονας πάχος ἔλασθον γινόμενον ἂπαξ γὰρ τοῦ ἄξονος στραφέντος κινηθήσεται τὸ πλινθόν τηλικῶτην ὡδὸν ἥλικη ἐστὶν ἢ τοῦ ἕνος τροχοῦ περιφέρεια. διὸ εὐλόγιος μεῖζονας αὕτου ὑπὸ πειράσθαι ποιεῖν.

XVIII

(1) Οὐ μὴν ἀλλὰ καὶ οὗτος δυνατὸν ἔστιν νοεῖσθω γὰρ τὸ τοῦ ἄξονος πάχος τὸ ἄβ, ἢ ἐκ τοῦ συμφορᾶς αὐτῷ τροχοῦ περιφέρεια ἢ γάρ, καὶ ὑπερκείσθω ἐτερος ἄξονα ἐν κνώδαξιν εὐλόγιος στραφόμενος, οὔ τὸ πάχος ἔστιν τὸ εἰς τοῦ δὲ συμφορᾶς ἔστω τὸ τύμπανον τὸ ἑπτ. καὶ περὶ μὲν τὸν ἄβ ἂξονα σπάρτος περιεπληθεῖσα ἀποδεδόθη περὶ τὸ ἑπτ. τύμπανον. ἐκ δὲ τοῦ εἰς ἂξονος ἐτέρα σπάρτος ἐκδιδθεῖσα καὶ ἐπελθεῖσα ἀποδεδόθη διὰ τροχῆλου τοῦ εἰς τὴν ἐν τῇ σύριγγι λείαν τὴν λ.

(2) συμβίσεται οὖν ἂπαξ στραφέντος τοῦ εἰς ἂξονος ὀλίγον μὲν μέρος τῆς σύριγγος κενούσθαι, τοσοῦτον ὡσὶ ἐστὶν ἢ τοῦ εἰς ἂξονος περιφέρεια, τὴν δὲ ἐκ τοῦ ἄβ ἂξονος σπάρτον ἂπαξ ἐπελείσθαι <ἐπὶ> τὸ ἑπτ. τύμπανον μεῖζον δὲ τὸν ἄβ ἂξονος, ὡσὶ πλεονάκις τὸν ἄβ ἂξονα στραφέναι σὺν τὸ γάρ τροχῷ καὶ διὰ τοῦτο πολὺ μήκος τῆς πορείας γίνεσθαι.

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58
the height of the tube must {not} suffice, and this, too, must be engineered.

(3) So, as for the length of the journey, either enlarging the two wheels around the axle or diminishing the axle’s thickness can result in a great length; for when the axle has turned once, the case will move so long a distance as the circumference of one wheel. On this account, one must reasonably try to make them [the wheels] bigger.

(1) Over and above that, it can even be done as follows. Let the thickness of the axle be conceived [to exist], $\overline{\alpha\beta}$, and <likewise> the circumference of the wheel attached to it, $\gamma\delta$; let another axle be placed above, turning freely on pivots, <and> whose thickness should be $\overline{\epsilon\zeta}$. Let there be a drum attached to this, $\eta\theta$. Let a cord wound around the axle $\overline{\alpha\beta}$ pass around the drum $\eta\theta$. Let another cord, having been fastened to the axle $\overline{\epsilon\zeta}$ and having been wound, pass through a pulley $\kappa$ towards the counterweight inside the tube, $\lambda$.

(2) So, it will happen that, when the axle $\overline{\epsilon\zeta}$ has turned once, a small part of the tube will be emptied in a way commensurate with the circumference of the axle $\overline{\epsilon\zeta}$, and the cord from the axle $\overline{\alpha\beta}$ will be wound once <onto> the drum $\eta\theta$, which is bigger than the axle $\overline{\alpha\beta}$, so that the axle $\overline{\alpha\beta}$ may turn several times with the wheel $\gamma\delta$, and thus a great length of the journey may be attained.
(3) εἰδέναι μέντοι χρή, ὅτι μείζονος λείας προσδείται διὰ τὸ τούς μείζονας κύκλους ὑπὸ τῶν ἐλασσόνων κινεῖσθαι· ταῦτα γὰρ διὰ τῶν μοχλῶν δὴ ἔστι. καὶ τὰς ἄλλας δὲ τὰς ἐξωθεὶ τῆς πορείας κινήσεις δυνατον ἔστι μεγάλας οὖσας διὰ μικρῶν διαστημάτων ἐπιτελεῖσθαι.

(4) ἐὰν γὰρ ἡ κινοῦσα τὸ ὄργανον τοῦ Διονύσου σπάρτος περὶ μείζονας κύκλους ἀποδιδότα, ἢ δὲ εἰς τὴν λείαν περὶ ἐλάσσονας ἁξονας καὶ συμφωνεῖς ὄντας τῷ μείζονι, καθά· περ καὶ ἐπὶ τῆς πορείας ὑπεδείξαμεν.

XIX

(1) Δύναται δὲ καὶ ἄλλως ἢ τε ἐπιπορεία καὶ ἢ ἀποπορεία γίνεσθαι καὶ αἰ ἐξωθεὶ < TimeInterval>κινήσεις.

ἔστω γὰρ τὸ τῆς σύριγγος στόμα τὸ ἀβεζ διαπεραγμένον δουλιαν χαίρετες τής σύριγγος τοῖς κατὰ τὰς εἰς, ἢ τε πυθείες, ὅστε διὰ τοῦ μεταξύ τόπου τῶν διαφορομάτων τάς κάτω σπάρτος ἀναφέρεσθαι καὶ ἀποδιδόσθαι εἰς τὰς λείας.

(2) ἢ μὲν οὖν ἐν τῇ ἄβεζ σύριγγι λεία τὴν τε ἐπιπορείαν ποιήσεται καὶ τὴν ἀποπορείαν, ἢ δὲ ἐν τῇ ἤθελῳ τὰς ἄλλας κινήσεις οὕτως· ἔστω γὰρ τὸ μὲν ἐν τῷ πυθμένι τῆς ἄβεζς σύριγγος τρήμα, δι’ οὐ δὲ κέγχρος ἐκρέει, τὸ κεκρέει τὸ κεκρέει, τὸ ἐν τῇ

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(3) However, one must know that a bigger counterweight is needed as bigger circles are moved by smaller ones; for these things take place by means of levers. Big as they are, the movements other than the journey can be completed through small radii.

(4) For <this happens> if the cord that moves the instrument of Dionysus passes around bigger circles, and the one going towards the counterweight passes around smaller axles, which are also attached to the bigger one, just as I have shown for the journey.

(1) It is also possible for both the forward and backward motion and the movements other than <the journey> to take place in a different way.

Let there be the mouth of the tube, $\overline{a}b\gamma\delta$, divided by two partitions through the entire height of the tube along the straight lines $\overline{ca}$ and $\overline{dh}$, so that the cords below may be brought up through the space between the partitions and attached to the counterweights.

(2) So, the counterweight in the tube $\overline{a}b\gamma\delta$ will produce both forward and backward motion, and the counterweight in $\overline{dh}\gamma\delta$ <will produce> the other movements as follows; for let there be a hole in the bottom of the tube $\overline{a}b\gamma\delta$, 

Fig. 26a-b

Fig. 27
ἡδὸ τὸ λ. ἐκατέρθωδε ἐκειθρίον γεγονέτω δυνάμενον εὐκόπως παράγεσθαι.

(3) ὅταν ὁν μέλλη πορεύεσθαι τὸ πλινθίον, παραξημεν τὸ τοῦ ἰ τρυπήματος κλειθρίον, ὡστε ἀνοιχθῆναι. καὶ ἓν <μή> εὐθέως ὅμην λαθόν τὸ πλινθίον κινηθῇ, ἔξει ἡ σπάρτος ἢ ἐκ τῶν {ὑπέρ} τροχῶν ἀποδιδομένη εἰς τὴν λείαν χαλασμάτων. καὶ δήλων ὅτι χρόνος τις ἐσται ἀποστάντων ἡμῶν πρὸ τοῦ κινηθῆναι τὸ πλινθίον, τοσοῦτος ὦσον ἦν τὸ τῆς σπάρτου χάλασμα.

(4) ὅταν δὲ δέ ὁ στῆναι τὸ πλινθίον καὶ τὰς ἄλλας ἐπιτελέσαι κινήσεις, ἔτι ἐπιπορευμένου αὐτοῦ σπάρτος τις ἐπισπάσται τὸ πρῶ τῷ ἰ κλειθρίον καὶ ἀνοίξει αὐτό. καὶ πάλιν, ἓν μή πορευμένου ἐτέρα γένηται κίνησις, ἔξει χάλασμα καὶ ἢ ἐκ τῆς ἐτέρας λείας ἐκδεδεμένη σπάρτος, ἢτις ταθείσα ἐπισπάσται καὶ τὸ πρῶ τῷ ἰ κλειθρίον.

(5) καὶ οὕτως στῆσεται τὸ πλινθίον, αὐτὸ ἐτελεσθήσονται κινήσεις, ὅταν οὖν πάλιν δὲ ἀνοιχθῇ πορεύεσθαι τὸ πλινθίον, ἐτέρα σπάρτος ἐπισπάσται τὸ πρῶ τῷ ἰ κλειθρίον καὶ ἀνοίξει αὐτό. καὶ οὕτως τὴν ἀπόπορειαν ποιήσεται.
through which the millet flows out, \( \overline{\kappa} \), and a hole in \( \eta \theta \xi \overline{\lambda} \). Let each have a slide which can be easily shifted.

(3) Then, when the case is about to move, we will shift the slide of the hole \( \overline{\kappa} \), so that it may be opened. In order for the case \( \text{<not>} \) to make a sudden rush forward and move, the cord going from the \{over\} wheels to the counter-weight will have a slack to it. It is clear that, once we have stood away before the case moves, there will be an interval as long as the slack of the cord.

(4) When the case must come to a halt and complete the other movements, a certain cord will pull the slide at \( \overline{\lambda} \) and open it while the case is still travelling. Again, in order that no other movement may occur while it [the case] is moving, the cord bound to the other counter-weight – which, when stretched tight, will also pull the slide at \( \overline{\kappa} \) – will have some slack too.

(5) The case will thus stop, and the other movements will be completed. So, when the case must come back again, another cord will pull the slide at \( \overline{\kappa} \) and open it. In this way, it [the case] will effect its backward motion.
ΠΕΡΙ ΣΤΑΤΩΝ ΑΥΤΟΜΑΤΩΝ

XX (1) Ὄσα μὲν οὖν ἔδει περὶ τῶν ὑπαγόντων αὐτομάτων πραγματευθῆναι, νομίζομεν ἢκανός ἀνεστράφθαι ἐν τοῖς προγεγραμμένοις· καὶ γὰρ εὐκόπως καὶ ἀκινδύνως καὶ ξένος παρὰ τὰ πρὸ ἡμῶν ἀναγεγραμμένα κατακεχορίκη-

ως ἢτοι δὴλον τοίς πεπειραμένοις τῶν πρότερον ἀνα-

gεγραμμένον. περὶ δὲ τῶν στατών αὐτομάτων βουλόμεθα γράφειν καινότερον τι, καὶ βέλτιον τὸν πρὸ ἡμῶν ἄμα καὶ πρὸς διδασκαλίαν <μᾶλλον> ἀρµόζον οὐδὲν εὑρομεν τῶν ὑπὸ Φίλονος τοῦ Βυζαντίου ἀναγεγραμμένων.

(2) ἦστι δὲ <ὅ> μύθος καὶ ἡ διάθεσις τῶν περὶ τῶν Νεώ-

πλων, ἐν ἧ πολλαί τε καὶ ποικίλαι διαθέσεις ὑπάρχουσι καὶ οὐ φαίλως οἰκονομοῦμεν πλή τῆς μηχανῆς τῆς περὶ τὴν Ἀθηνᾶν· ἐργοδέστερον γὰρ πῶς τὴν κατασκευὴν ἐποι-

ήσατο· δυνατὸν γὰρ ἢν χωρίς μηχανής φανῆναι αὐτὴν ὑπὸ τῶν πίνακα καὶ μετὰ ταῦτα πάλιν ἀφανῆ γενέσθαι· τὸ γάρ ἐκδίκου αὐτῆς δυνατὸν ἦστι περὶ τοὺς πόδας ἐν γγγλύμῳ κινούμενον τὸν μὲν πρῶτον χρόνον κατακεκλημένον εἶναι, ὥστε μὴ φαίνεσθαι, ἑπείτα δὲ ὅσπερ <ἐγερθέν> ὑπὸ σπάρ-

1 perī στατών αὐτομάτων A G (hunc titulum ex Philoni Byzantino promptum esse suspicor, nisi hoc loco interpolatum fuerint; vide Introductionem, pp. [x-xi]): perī στατών a [...]: T: om M 3 ανεστράφθαι A G: ανεστράφ[***] T: ἀναγεγραφθέν M 5 ζένως A G M: καινώς Diels et Weil dub. 5-6 κατα-


64
ON STATIONARY AUTOMATA

(1) So, I consider that I have adequately covered in what has been written before whatever needed to be discussed about the mobile automata; for I have recorded methods that are feasible, riskless and unusual compared to those described before us, as is clear to anyone who has tested the previously described methods. As for the stationary automata, I want to write something rather original, and I have found, of my forebears' writings, none better and at the same time <more> apt for teaching purposes than those of Philo of Byzantium.

(2) The events about Nauplius constitute <the> story and the arrangement. In it there are many and diverse configurations, which are not poorly handled except for Athena's machine. <Philo>, in fact, made its construction somewhat too laboriously. For it was possible for her to appear inside the box without a machine and then disappear again; for her figure can be moved on a hinge by its feet and initially laid down, so as not to be visible, and then, as though
τον τινὸς ἐπισπασμένης ὁρθὸν φανήναι καὶ πάλιν ὑπὸ ἐτέρας κατακλιθῆναι.

(3) ἐτί δὲ καὶ ὑποσχόμενος πρὸς τούτῳ κεραυνὸν πεσεῖν ἐπὶ τὸ τοῦ Αἰαντοῦ ξόδιον καὶ βροντῆς ἦχον γενέσθαι οὐ κατεχόμενοι: πολλοῖς γὰρ συντάγμασι περιτυχόντες οὐχ εὐρομεν τούτῳ ἀναγεγραμμένον. καὶ ἵσως δὸξεί τις ἡμᾶς καταπρέχοντας τοῦ Φίλωνος διαβάλλειν αὐτόν ὡς μη δὲνυμένον τὴν ὑπόσχεσιν ἀπαρτίσαι, ἀλλ’ οὐχ οὗτος ἔχει.

(4) πολλῶν δὲ οὕσων τῶν ἐν τῇ διαθέσει ὑποσχέσεων, ἵσως ἔλαβεν αὐτὸν ἀναγράφοντα αὕτη, ὑμνιάτων γὰρ ἐστιν ἀγγεῖον τι ἐν αὐτῷ σφαιρά ἦξον μολιβά καὶ ἔχον τετρυπημένον τὸν πυθμένα ἀποσχζεσθαι κατὰ τὸν δέοντα καιρόν, τὰ δὲ σφαιρὰ ἐμπίπτοντα διφθέρα ἐξηλεμένη, ἔρη καὶ πυκνη τὸν ἦχον τῆς βροντῆς ἀποδιδόναι· καὶ γὰρ ἐν τοῖς θεάτροις ὅταν ἔπε τὸν ὴμισσον ἦχον γενέσθαι, ἀγγεῖα ἀποσχζεται βάρη ἔχοντα, ἡνια φερόμενα ἐπὶ διφθέρας, ὡς εἰρηται, ἔρησε καὶ περιτεταμένης {τῆς βύρσης} καθάπερ ἐν τυμπάνοις τὸν ἦχον ἄποτελῆ.

(5) περὶ δὲ τῶν λοιπῶν τῶν ἐν τῇ διαθέσει τοῦ Ναυπλίου κατὰ μὲρος γινομένων εὐφρενεύμεθα ὡς ἐν τάξει καὶ εὐμεθόδος ὑπ’ αὐτοῦ ἀναγεγραμμένον: διὸ δὴ οὐ παρησάμεθα τὰ ὑπ’ αὐτοῦ περὶ ὅν εὔπομεν γεγραμμένα: οὖτως γὰρ νομίζομεν τοὺς ἐντυγχάνοντας τῆς μεγίστης ὀψελείας

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66
<roused> by the pull of a certain cord, it can appear upright and be laid down again by another <cord>.

(3) Moreover, although he promised, in addition to this, to make a bolt of lightning fall on the figurine of Ajax and to produce the sound of thunder, he did not record it; for although I have come across many of his books, I did not find this recorded. Perhaps one will think that in running Philo down I am criticising him for being unable to fulfil the promise, but it is not so.

(4) Since his promises in the arrangement are many, perhaps he forgot to write this one out. For a container with small lead balls inside and with a hole in the bottom can be opened at the appropriate time, and the small balls can make the sound of thunder as they fall on a piece of dry and dense leather which has been spread out. For in theatres, too, whenever it is necessary to produce a similar sound, containers holding weights are opened, so that, as they fall on a piece of leather, which is – as stated – dry and tightly stretched {the hide}; the weights may generate the sound, just like in kettledrums.

(5) As for the other things which take place one by one in the Nauplius arrangement, I am very happy with the orderly and well-thought-out way they have been set down by him [Philo]. For this reason, then, I have not rejected his writings about the things I said; for in this way I be-
τυχάνειν, όταν τὰ μὲν καλῶς ὑπὸ τῶν ἀρχαίων εἰρημένα παρατιθήται αὐτοίς, τὰ δὲ παραθεωρηθέντα ἢ διορθώσεως τυχόντα καταχωρίζεται. περὶ τῆς τῶν πινακίων οὖν κατα-

σκευῆς νῦν ἀρζόμεθα λέγειν.

xxi (1) Ἐστι μὲν οὖν παρὰ πολὺ τῶν ὑπαγόντων ἡ ποίησις ἀσφαλεστέρα τε καὶ ἀκινδύνοτέρα καὶ τὴν ἐπίδειξιν οὐκ ἀπίθανον ἐξουσ. τὸ δὲ πρόβλημα ἐστὶ τοιοῦτον, ὡστε πίνακος ἐπιτεθέντος ἐπὶ τι κιόνων ξύλινον ἀνοιχθῆναι τε αὐτομάτων καὶ τὰ ἐν αὐτῷ ἔξωγραφημένα φαίνεσθαι κι-


νούμενα πρὸς λόγον τῆς ὑποκειμένης διαθέσεως, καὶ πά-

λιν κλεισθέντος αὐτομάτου διαγενέσθαι ὁλίγον παντελῶς ἔρ

νόν καὶ ἀνοιχθέντος φαίνεσθαι ἄλλα τὰ ἐν αὐτῷ γε-

γραμμένα καὶ εἰς τὸ δυνατὸν πάλιν ταῦτα ἢ τινα αὐτῶν 

κινεῖσθαι καὶ τούτῳ πάλιν πλεονάκις γενέσθαι.

(2) καὶ ἐκτὸς τῶν πινάκων ἥ μηχανᾶς αἱρομένας φαίνε-

σθαι καὶ περιγραμμένας ἡ ἄλλας τινὰς κινήσεις, ἢ μὲν οὖν 

ὑπόθεσις τοιαύτη· χαριτάτους δὲ τῶν μεταχειριζόμενων ὁ 

γλαφυρωτάτην διάθεσιν ἐπινοοῦν. ὡστε προθεσμοθέτα μίαν 

τῶν διαθέσεων, ἢν μάλιστα κρίνομεν, καὶ μετὰ <ταῦτα>

1 τὰ om. M Τ εἰρημένα A^{σ}G M^{σ} : εἰρημένα Prou 2 παρατιθήται Schmidtː παρατιθήται A Graː παρατιθήται G^{σ}M aut {η} aut ηʾ <παραλει-


ψθέντα>(vel sim) Brinkmannː ἦ <δυσχερᾶς ὑπήθέντα> vel <διαμαρτηθέντα> Schmidt dub. in app. crit. 5 ἢ <**> ποίησις Schmidt, qui <τῶν στατῶν> dub. suppl. in app. crit. ἢ ποίησις <τῶν στατῶν> Prou 7 ἀπίθανον G M : ἀπείθανον A T 8 ἀνοιχθῆναι καὶ τὲ G τὲ <αὐτὸν> αὐτομάτων Schmidt dub. in app. crit. 9 ἔξωγραφημένα A^{σ}G : ἤξω γραφημένα M^{σ} 10-11 πά-


lieve that those who come across <my treatise> obtain the
greatest benefit, when things well said by the ancients are
laid before them, and those which have been overlooked
or have been corrected are also placed on record. So, I will
now begin to talk about the construction of the boxes.

(1) Therefore, the making [of stationary automata] is much
safer and freer from danger than that of mobile automata,
as well as involving a performance which is not implaus-
ible. The issue is such that, once a box has been set on a
little wooden pillar, it opens by itself and the painted fig-
ures inside it are shown moving in accordance with the
current arrangement; and again, after it has closed by it-
self, a very short time elapses and, once opened, other
figures which are painted in it appear, and as far as pos-
sible these, or some of them, move once more – and this
repeats itself several times;

(2) outside the boxes either machines are shown being
raised and turned around or some other movements. So,
such is the proposition; but the most refined of the practi-
tioners is the one who devises the neatest arrangement. As
a result, of the arrangements I will propose one which I
 ..., τὴν κατασκευὴν ἐμφανισάμεν· ἀρκέσει γὰρ περὶ ἐνὸς πίνακος <***> διὰ γὰρ τῶν αὐτῶν πάλιν τὰ αὐτά οἰκονομεῖται, καθάπερ καὶ ἐπὶ τῶν ύπαγόντων ἀπεδείξαμεν.

**xxii**

(1) Οἱ μὲν οὖν ἄρχαιοι κέρχησαν ἅπλή τινι διαθέσει· ἀνοιχθέντος γὰρ τοῦ πίνακος, ἐφαίνετο ἐν αὐτῷ πρόσωπον γεγραμμένον. τούτῳ δὲ τοὺς ὀφθαλμοὺς ἔκινε καμμὸν τε καὶ ἀναβλέπον πολλάκις, ὅταν δὲ πάλιν κλεισθῆς ἀνοιχθῇ ὁ πίναξ, τὸ μὲν πρόσωπον οὐκἐτί ἐωράτο, ζώδια δὲ γεγραμένα ἐξ ἑνα λύθην διεσκευασμένα.

(2) καὶ πάλιν οὖν κλεισθῆς ἀνοιχθῇ, διάθεσις ἅλλη ἐφαίνετο ζωδίων συναναπληροῦσα τοὺς ὑποκειμένους μύθους τοὺς ἐξῆς, ὡστε τρεῖς μόνον κινῆσεις διαφόρους ἐπὶ τοῦ πίνακος γίνεσθαι, μίαν μὲν τῶν θυρῶν, ἄλλην δὲ τῶν ὑμ-μάτων, τὴν τρίτην <δὲ> τῶν ἐπικαλυπτόντων. οἱ δὲ καθ’ ἡμᾶς μῦθους τε ἐμβεβλήκασιν εἰς τοὺς πίνακας ἀστείους καὶ κινῆσει κέρχησαν πολλάκις καὶ ἀνομοίας.

(3) καθ’ δὲ προεθέμην, ἔρω περὶ ἐνὸς πίνακος τοῦ δοκούντος μοι κρείττονος, μύθους μὲν ἢν τεταγμένον ἐν αὐτῷ ὁ κατὰ τὸν Ναόπλιον. τὰ δὲ κατὰ μέρος εἶχεν οὕτως· ἀνοιχθέντος ἐν ἀρχῇ τοῦ πίνακος ἐφαίνετο ζώδια γεγραμένα δῶδεκα· ταύτα δὲ ἢν εἰς τρεῖς στήχους διηρημένα· ἢσαν δὲ ὡστοί πεποιημένοι τῶν Δαναῶν τινές ἐπισκευάζοντες τὰς ναύς καὶ γνώμενοι περὶ καθολίκην.
particularly rate, and after <this> I will explain its construction. It will be enough <***> about only one box; for again the same things are handled by the same methods, just as I have proved for the mobile automata.

xxii

(1) So, the ancients employed a certain simple arrangement: when the box opened, a painted face appeared in it. This moved its eyes, closing and opening them several times. When the box closed and opened again, the face was no longer seen, but painted figurines <were seen>, prepared for the sake of some story.

(2) And again, when it [the box] closed and opened, another arrangement of figurines appeared, completing the current stories one after another, so that only three different movements would take place in the box, one of the doors, another of the eyes, and the third of the coverings. On the other hand, our contemporaries have inserted stylish stories inside the boxes and have made use of many and disparate movements.

(3) As I proposed, I will talk about one box which seems superior to me. The story set in it was the one about Nauplius. The individual scenes went as follows. At the outset, when the box opened, twelve painted figurines appeared: these were divided into three rows; they were made to represent some of the Greeks refitting their ships and busy launching them.
(4) ἐκινεῖτο δὲ ταῦτα τὰ ζόδια τὰ μὲν πρίξοντα, τὰ δὲ πε- 1
λέκεσιν ἐργαζόμενα, τὰ δὲ σφύραι, τὰ δὲ ἄριστοι καὶ τρυ- 4
πάνοις χρώμενα ψόφων ἐποίου πολύν καθάπερ επὶ τῆς ἄλλης 5
γίνοιτο. χρόνου δὲ ἰκανοῦ διαγενομένου κλεισθεῖσι πάλιν ἤνοιγησαν ἀι θάρα, καὶ ἦν ἄλλη διάθε- 6
σις· αἱ γὰρ νῆς ἐφαῖνοντο καθελκόμεναι ὑπὸ τῶν Ἀχαιών. 7
κλεισθεῖσι δὲ καὶ πάλιν ἄνοιχθεισόν, οὐδὲν ἐφαίνετο ἐν 8
tῷ πάνακα πλὴν ἀέρος γεγραμμένον καὶ θαλάσσης. 9

(5) μετὰ δὲ οὐ πολὺν χρόνον παρέπλεσαν αἱ νῆς στολοδρο- 10
μοῦσαι· καὶ αἱ μὲν ἀπεκρύπτοντο, αἱ δὲ ἐφαίνοντο. πολλά- 11
κις δὲ παρακολύμβουν καὶ δελφῖνες ὅτε μὲν εἰς τὴν θάλα- 12
ταν καταδυόμενοι, ὅτε δὲ φαινόμενοι, καθάπερ ἐπὶ τῆς ἄλ- 13
ληθείας, κατὰ μικρὸν δὲ ἐφαίνετο χειμέριος ἢ θάλασσα, 14
καὶ αἱ νῆς ἔτρεξεν συνεχῶς. κλεισθέντος δὲ πάλιν καὶ 15
ἀνοιχθέντος, τῶν μὲν πλεόντων οὐδὲν ἐφαίνετο, ὁ δὲ Ναῦ- 16
πλίος τὸν πυρσὸν ἐξηρίκος καὶ Ἡ Ἀθηναῖα παρεστώσια· 17

(6) καὶ πῦρ ὑπὲρ τὸν πάνακα ἄνεκαθή, ὡς ἀπὸ τοῦ πυρ- 18
σοῦ φαινομένης ἄνω φλογός. κλεισθέντος δὲ καὶ πάλιν 19
ἀνοιχθέντος, ἢ τῶν νεῶν ἐκπτωσὶς ἐφαίνετο καὶ ὁ Ἁῖας 20
νηχόμενος, μηχανῇ τε {καὶ} ἀνωθὲν τοῦ πάνακος ἐξήριθ
These figurines moved, some sawing, some working with axes, some with hammers, some others using bow-drills and augers, and they made a lot of noise, just like in real life. After sufficient time elapsed, the doors closed and opened again, and there was another arrangement; the ships, in fact, were shown being launched by the Achaeans. After they closed and opened again, nothing appeared in the box except painted sky and sea.

Not long after, the ships sailed in line ahead, and some were out of sight, some in view. Often dolphins swam alongside, too, sometimes plunging into the sea, sometimes visible, just like in real life. The sea gradually grew stormy, and the ships ran uninterruptedly. After it closed again and opened, none of the sailing ships was seen, but Nauplius holding up the torch and Athena standing beside him were seen;

fire blazed up above the box, as if a flame appeared on high from the torch. After it closed and opened again, the wreck of the ships appeared, and Ajax swimming; and a machine was raised above the box, and as
καὶ βροντῆς γενομένης ἐν αὐτῷ τῷ πίνακι κεραυνὸς ἔπεσεν ἐπὶ τὸν Ἀιαντα, καὶ ἠφανίσθη αὐτοῦ τὸ ἔμμηδιον. καὶ οὕτως κλεισθέντος καταστροφῆν εἰχὲν ὁ μῦθος. ἢ μὲν οὖν διάθεσις ἢν τοιαύτη.

και βροντής γενομένης ἐν αὐτῷ τῷ πίνακι κεραυνὸς ἔπεσεν ἐπὶ τὸν Ἀιαντα, καὶ ἠφανίσθη αὐτοῦ τὸ ἔμμηδιον. καὶ οὕτως κλεισθέντος καταστροφῆν εἰχὲν ὁ μῦθος. ἢ μὲν οὖν διάθεσις ἢν τοιαύτη.

(2) τὸ δὲ ἔδαφος τοῦ πίνακος δεῖ καθαρμόζειν εἰς τὸ πλινθίον μέσον, ὥστε δὲ τὸ κάτω μέρος τοῦ πλινθίου θοράκιον κολλὸν ύποπτώς ἀφανές εἰς τὸ ἔμπροσθεν μέρος, ἓ<ν> φο καθαρμοσθεῖσαν τῶν θυρῶν καταβήσονται οἱ στροφεῖς μῆκος ἔχοντες ὅστε καὶ τούτων κάτωθεν ἐπιστρεφομένων ἀνοίγεσθαι καὶ πάλιν κλείσεσθαι τὰς θύρας.

(3) ἐστώ οὖν τὸ θοράκιον ἐκ τῶν ἔμπροσθεν θεωρούμενον τὸ οἵ, στροφεῖς δὲ οἱ ἐκ τῶν θυρῶν καταβεβήκτοις οἱ γ, δ. οὐκοῦν εἰναὶ τις ταῖς χερείς ἐπιστρέφη τοὺς στροφεῖς ἐφ’ ἐκάτερον μέρος, ἀνοίξει καὶ κλείσει τὰς θύρας. ἢν οὖν

1-3 τῷ πίνακι... μῆθος aicio loco iterant codices (τῷ πίνακι iterata esse noluerunt Prou et R. Schöne vide infra, 3-4) 1-2 ἐπάνω om. aicio loco 2 aicio loco; aicio loco 3 aicio loco; aicio loco; aicio loco ordinem capitum anteae confusum restituit Wel: post μῆθος in codicibus sequuntur II. 80.1-84.11 οὕτως γίνεται... τοὺς ἐκπεποιηθέντας οὕτως. deinde iterum sequuntur III. 1-3 τῷ πίνακι... μῆθος et II. 74.3-78.19 ἢ μὲν οὖν διάθεσις... διδοῦσα. deinceps codices pergunt usque ad finem (II. 84.12-110.15 κλεισθέντος δε... διαλύσονται) : similiiter etiam R. Schöne, qui solum II. 1-3 κεραυνὸς... μῆθος iterata cens. (hunc ordinem rec. Schmidt); vide Introductionem, p. xlvi–xlvii n. 84 5 caput distincto. Schmidt: δὲ om. G ἔγγραφον A G M : an ἰδιογράφατον? 6 τὸν A G : τὸν M T μηδέν A G M : μῆκες Schmidt dub. in app. crit. 7 πήγαντα Schmid dub. in app. crit. πήγας A G T : πήγας M πήγαντα R. Schöne 8 τὸ ἐκ τῶν μέρους Schmid dub. in app. crit. τοῦ ἐκ τῶν μέρους A G M : τοῦ ἐκ τῶν μέρους Schmid in textu 12 ἀφανὲς A G M : ἀφανὲς Brinkmann ante eis leviter interpunx. Prou : ἐμπροσθεν Schmid dub. in adh. crit. prob. Olivieri : ἐπίσημον A G M · φο Schmid dub. in app. crit. χρ. A G M Phyl. in textu; δ Ta; χρ. Phyl. in σημ. 17 καταβεβήκτος A G M : καταβεβήκτος T 18 τοὺς A G M M t: τοῦ G
Book Two

thunder rumbled in the box itself a bolt of lightning fell on Ajax, and his figure vanished. Thus, when the box closed, the story came to an end. So, such was the arrangement.

XXIII

(1) It is necessary to construct a frame the size one would want to make the box, as I have illustrated, and to build it out of exceptionally lightweight boards; let the boards be one-sixth as wide as the length of the longer sides.

(2) The backdrop of the box must be fitted into the middle of the frame, and under the lower part of the frame a hollow enclosure must be attached, which is invisible from the front; after the doors have been fixed <to> this, pivots will run down such a length that, when these are turned from below, the doors open and close again.

(3) Thus, let there be the enclosure seen from the front, $\overline{a\beta}$, and pivots going down from the doors, $\gamma$ and $\delta$. Then, if someone turns the pivots on each side by hand, they will open and close the doors. So, in order for this to happen
τούτο διὰ τῆς σπάρτου γίνεται αὐτόματον, ἐλκυμένης αὐτῆς ὅπως τῆς λείας ἐν τῇ σύριγγι οὐσίας ἐπὶ τῆς ψάμμου, παρατίθημε τοῖς στροφεῖσιν ἄξονα πλάγιον ἀφεστῶτα μικρὸν τῶν στροφέων τὸν ἐκ, στρεφόμενον εὐλύτως.

(4) ἐπίσημα δὲ ἐκάτερον τῶν στροφέων καὶ λαβὼν σπάρτον ἐπείλημα διηλίκαν καὶ ἐνέβαλον τήνδε ἀπλῆν εἰς τὸ τρύπημα καὶ ἐπίουρον μετὰ κόλλης ἐνέκρουσα καὶ ἀπέλαβον αὐτήν, ὥστε μηκέτι ἐκπαύσαται, ἀλλὰ μένεν ἀραρτος τούτοις, τούτῳ δὲ ποιήσας ἀποκατέστησα τὰς ἀρχὰς περὶ τὸν ἄξονα τὴν μὲν κατὰ τὸ γό χαλαθείν τοῦ ἄξονος, τὴν δὲ κατὰ τὸ εὖ κάτωθεν.

(5) τριπτήσας ὁμοίως τὸν ἄξονα ἐκάστην ἀρχὴν ἀπέλαβον ἐπιούροις ἀραρτος τισίν, ἢ διατείνας eιδικοι τάς σπάρτους, τὴν <μέν> κατὰ τὸ ἔ, <τὴν δὲ> κατὰ τὸ χ. αἱ δὲ σπάρτοι ἐπιστρέφουσι τούς στροφεῖς καὶ ἀνοίξουσι τὰς θύρας, ὅταν δὲ πάλιν τὰ ἐναντία ἐπιστρέφον τὸν ἄξονα, ἡμαῖς μέντοι ἀνεθήσονται, ἢ δὲν κλεισθήσονται αἱ θύραι.
Book Two

automatically by means of the cord, when it is pulled by
the counterweight which is on the sand in the tube, I place
a freely revolving axle \( \xi \), across the pivots and at a small
distance from them.

(4) I bored a hole in each of the pivots and, taking a cord,
wound it double, put this single cord into the hole, drove a
peg in adding glue and secured it, so that it would not pull
out any further, but remain tightly fastened. Having done
this, I laid the ends around the axle, one over \( \gamma \) from
above the axle, the other over \( \epsilon \) from below.

(5) After likewise piercing the axle, I secured each end
firmly with some pegs, carefully <stretching> the cords
<to the utmost>, one at \( \xi \), <the other at> \( \epsilon \). The cords will
rotate the pivots and open the doors. Whenever I turn the
axle the other way around, \( \dagger \) and in fact they [the cords]
will be slackened, <\(*\)> whence the doors will close.
(6) οὗτος οὖν ἀπὸ μιᾶς κινήσεως ἅμα ἀμφότερα αἱ θύραι
<ὅτε μέν> κλεισθήσονται, ὅτε δὲ ἀνοιχθήσονται. ἦνα οὖν
dιὰ τῆς λέιας <ἀυτόματον> τοῦτο γίνεται, ἐνέπεξα τύλους
eis τὸν ἄξονα ἀνωθέν ἐφ᾽ ὅποι ὄποι ἐκ τῆς 
καὶ κάτωθεν ἐφ᾽ ὅποι 
θ, καὶ λαβὼν σπάρτον καὶ καταμετρησάμενος τὸ μῆκος
πρὸς τὴν σύριγγα τὴν ἤχοςαν τὴν ψάμμον καὶ <ἡν>
λειάν, ἐν ὑποίκοις δὲν ἦ διαστήμασιν, ἦσαν άγκύλαις. καὶ
ἔστω σπάρτος μὲν ἢ ἰ, ἄγκυλαι δὲ αἰ 

(7) τὴν πρώτην οὖν άγκύλην τὴν ἀπὸ τοῦ ἰ περιτίθημι
περὶ τὸν τύλον τὸν πρώτον τὸν ἀπὸ τοῦ ἴ, ἐφ᾽ <ὑ><ὑ> τὸ ἰ, 
τὴν δὲ ἐχομένην ἄγκύλην περὶ τὸν κάτω τύλον τὸν θ καὶ
οὕτως ἐξῆς πάσας προσκολλῶν αὐτὰς περὶ τὸν ἐξ ἄξονα
κηρὸ {τε} μετὰ ῥητίνης. {ἔστι δὲ κεκαλυμμένον τούτο
παρακόλυμμα.}

(8) καὶ τὰ παραχαλασμάτικα αὐτῶν πρὸς τὸν ἄξονα προσ-
κολλῶ, ἵνα μὴ τινὰ αὐτῶν ταραχθέντα διασέρειαν παρέχη-
ται. ὅταν οὖν ἡ ἀρχή τῆς σπάρτου, ἐφ᾽ ἡς ἔστι τὸ ἰ, ἐκδε-
θέει ἐκ τῆς λειάς ἔλκηται πράως, ἀνοίξει καὶ κλείσει τὸν
πίνακα χρόνους καὶ διαλεύματα διδοῦσα.

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1 ἀπὸ A G M: ἵππο Brinkmann 2 <ὅτε μέν> Schmidt: ὅτε A G: ὅτεν M T
3 <ἀυτόματον> Schmidt seclusus Haase (huc transposito ex post γίνεται)
6 <ἡν> Schmidt dub. in app. crit. 7 δὲν (=δὴ ἄν) Brinkmann: δὲ ἄν a: δ'
ἄν Ta: ἦσαν A G: ἦσα M: cor. Schmidt: 8 ἀγκύλην A Gdp M: ἀγκύλη-
ναι G: ἀγκύλει Schmidt dub. in app. crit. 9 A G: δ M: 9 πρώτην Prou
dub.: α' Mdp: a A GT: peritíthēμι A G: περὶ τύμημα M (ἐν q) 10 τὸν
<ἄνω> τύλον Schmidt dub. in app. crit. πρώτον Bb: α' Tb: a a ἐφ'
Brinkmann: ἐστι a: perit Schmidt dub. in app. crit. <ὑ><ὑ>Brinkmann: τὸ A
G M: τὸν Schmidt dub. in app. crit. 11 ἐχομένην Schmidt dub. in app. crit.: ἐχομένην a: ἐχομένην Prou τὸν Adp M: τὸ G 13 τὸ del. Schmidt:
13-14 ἐστὶ...παρακόλυμμα delen cum Schmidt (dub. in app. crit.), prob.
Olivieri: κεκαλυμμένον A G: καλυμμένον Mdp
toūto <ὑ><ὑ> Schmidt dub.
in app. crit. 15-16 προσκολλῶ A G: προσκολλῶ T: προσκολλῶ M: 16 τα-
ραχθέντα Schmidt: παραχθέντα a: παραχθέντα Prou 17 τῆς A G: τοῦ M
18 τῆς λειάς Mdp: τὴν λειάν A GT

78
(6) So, in this way both doors will close <at one moment>, and open at the next, simultaneously with one motion. Thus, in order for this to happen <automatically> by means of the counterweight, I thrust knobs into the axle — above where the <points> π’s <are> and below where the <points> υ’s <are> — and having taken a cord and measured its length against the tube containing the sand and <the> counterweight, I made loops at intervals of whatever size. Let there be a cord, κ, and loops, λ’s.

(7) Therefore, I put the first loop from the <point> κ around the first knob from ε, where the <point> π <is>, and the next loop around the lower knob υ, and thus gluing them all one after another around the axle εκ with a compound of wax and resin. {This gluing has been concealed.}

(8) I also glue their slack parts onto the axle, so that none of them may become tangled up and hamper the mechanism. So, whenever the end of the cord (where the <point> κ is), is pulled gently being fastened to the counterweight, it will open and close the box, providing the timings and intervals.
(1) ταύτα μὲν οὖν οὕτως γίνεται, γενομένης <δε> τῆς πρώτης ἀνοίξεως Ἡμίν ἐστὶ ποιεῖν τῷ πίνακι φανεῖσθαι ζώδια τεκταίνοντα, περὶ <δε> ἐμφανίσαι δεῖ τίνι τρόπῳ τῇ κίνησιν λαμβάνει. δεῖ οὖν τὰ μὲν ἄλλα πάντα μέρη τῶν ζώδιων ἐν τῷ ἔδαφει τοῦ πίνακος γεγραφθαί διαθέσεις ἔχοντα πιθανοτάτας, τὰς δεξιὰς δὲ χεῖρας μὴ γεγραμμένας <ἐναι> ἐν τῷ πίνακι, προσκείσθαι δὲ κερατίνας εἰς ἐλαφρῶν κεράτων λεπτὰ εἰ μᾶλλα κατειργασμένας, ίνα προσπίπτωσι καὶ μηδὲν δῆλον ἀπόστιμα ἔχωσι.

(2) δεῖ δὲ καὶ τὰ ἄρμενια, ἐν οἷς ἐργάζονται, κεράτινα εἶναι, προσκείσθαι δὲ ἐν ταῖς χερσὶ καὶ ἀπογεγράφθαι τὰς χεῖρας ὁμορρόδους τοῖς ἄλλοις σώμασι, καὶ τὰ ἄρμενια ὡς προσηκόν ἔστιν.

ἐστω οὖν ἡ χείρ ἡ ἄβ. ἐτρύπησα οὖν αὐτὴν κατὰ τὸν ὦμον καὶ ἐποίησο τὸ τρύπημα τετράγωνον, ὡς γέγραπται, καὶ λαβὼν κεράτινον ἐπίουρον ἐνῆρμοσα εἰς μὲν τὸν ὦμον

1 caput distinx. Schmidt: <ταύτα μὲν οὖν> Schmidt: <καὶ ταύτα μὲν>
(1) So, this takes place in this way. After the first opening of the doors, it is for us somehow figurines carrying out joinery work to appear in the box; and it is necessary to explain how they receive their motion. Thus, while all the other parts of the figurines must be painted on the backdrop of the box and arranged in the most convincing way, the right arms must not be painted on the box, but attached to it and very carefully wrought out of thin pieces of light horn, so as to fit closely and leave no visible gap.

(2) The small tools, with which they work, must be of horn too and set in their hands, and the hands painted the same colour as the rest of the body, and the small tools as is appropriate.

So, let there be the hand and arm, oβ. Thus, I pierced it with a hole through the shoulder and made the hole square, as has been illustrated, and after taking a horn peg and squaring it off I fitted it into the shoulder and glued it
τετράγωνον ποιήσας καὶ ἐνεκόλλησα, τὸ δὲ λοιπὸν τοῦ ἐπιούρου <ἐποίησα> στρογγύλων καὶ λειῶν καλῶς.

(3) τρυπήσας δὲ κατὰ τὸν δεξιὸν ὄμον ἐδίωσα τὸν ἐπίουρον καλῶς, ἦσθ', ὅπως προσκαθήσῃ τὸ χέριον εἰς τὸ ζῷον. ἐὰν οὖν καταλάβημεν τοὺς δακτύλους ἐκ τῶν ὁπίσθεν μερῶν τοῦ πίνακος τὸ ύπερέχον τοῦ ἐπιούρου στρέψοντες, κινήθησατο τὸ χέριον. ὅπως οὖν ὑπὸ τῆς λείας αὐτομάτον κινήτα, ποιῶ κανόνιον τὸ γῦ καὶ τρυπῶ κατὰ τὸ θ καὶ τὸν ἐπίουρον τὸν ἐκ τῆς χειρὸς ὑπερέχοντα εἰς τὸ ὁπίσθεν μέρος τοῦ πίνακος ἐναρμόζω εἰς τὸ τοῦ κανονίου τρύπημα ἀραρότως καὶ ἐγκολλῶ, ἵνα κινουμένου τοῦ κανονίου κινήτα καὶ τὸ πρὸς τὸν ὀμφ.

(4) τὸ δὲ κανόνιον τοῦτο καλεῖται ὑσπλήγγιον. εἰς τὸ ἐν οὖν μέρος τοῦ ὑσπληγγίου τρυπήσας ἐξέδρα σπάρτον καὶ ἐκρέμασα λείαν μολυβδήνῃ τὴν ἅ καὶ ὑπέπεξα ἐπίουρον ὑπὸ τὸ ἀκρὸν τοῦ ὑσπληγγίου, τὸν ἵ, ἵνα ἐπαναπαύηται τοῦ ὑσπλήγγιον τὸ ἀκρόν. οὐκόνεν ἐὰν τὸ δακτύλῳ καταβαρῇς οὐκ ὑσπλήγγιον κατὰ τὸ γ’ μέρος, μετεωρισθήσεται τὸ δ’ μέρος σὺν τῇ λείᾳ· ἐὰν δὲ ἄφωμεν, καταπεσεῖται ἐπὶ τὸν ἐπίουρον ἐπισκυμένης τῆς λείας καὶ ψόφων ποιήσει.

(5) ἐπιδίδει δὲ καὶ τῇ χειρὶ τὴν κίνησιν ἐν τῷ ἐμπροσθεν μέρει τοῦ πίνακος. ἵνα οὖν πυκνῶς καὶ αὐτομάτως κινήται,
on; <I made> the rest of the peg rounded and thoroughly smooth.

(3) Having bored a hole through the right shoulder, I thrust the peg in properly, until the small arm has drawn near to the figurine. So, if we seize the projecting part of the peg with our fingers from the back of the box and turn it, the arm will move. Therefore, in order for it to move by itself under the impulse of the counterweight, I make a bar, $\gamma\delta$, pierce it with a hole at $\theta$, insert the peg jutting out from the arm towards the back of the box tightly into the hole of the bar and glue it on, so that, as the bar moves, that <which originates> in the shoulder may move too.

(4) This bar is called hysplângion. So, after boring a hole at one side of the hysplângion, I fastened a cord to it, hung a lead counterweight, $\iota$, and fixed a peg under the extremity of the hysplângion, $\zeta$, so that the end of the hysplângion may come to rest on it. Then, if we will press down the $\gamma$ side of the hysplângion with our finger, the $\delta$ side will be raised together with the counterweight; and if we let it go, it will fall down on the peg as the counterweight pulls it, and it will make a noise.

(5) It will also transmit movement to the arm at the front of the box. So, in order that it may move frequently and
παρατίθημι {τὸν} ἀστερίσκον στρεφόμενον περὶ ἐπίουρον ἐμπεπηγότα τῷ ἐδάφει τοῦ πίνακος ἀραρότως. ἔξει δὲ ὁ ἀστερίσκος προσόντα αὐτῷ προσφυή τροχίλον τὸν ἦ, περὶ δὲ καὶ μὴ στάτος περιελθείσαι πολλάκις ἀποδοθῆσεται τῇ λείᾳ, ἕνα ἐπισπομένη ὡς ἄρα κατὰ μικρὸν ἐπιστρέφῃ τὸν ἀστερίσκον καὶ ὁ ἀστερίσκος ταῖς στροφαῖς τὸν ὕσπληγα κρούῃ πυκνά.

(6) τὸ δὲ ἔσχατον μέρος τῆς στάρτος ἀγκυλωθέν περὶ τὸν τύλον περιτίθεται ἐφ’ οὗ τὸ ἦ, ὅταν <***> μηκέτι τὴν χεῖρα κινεῖσθαι, ἀποσκαθεύει ἀπὸ τοῦ τύλου ἱππεύονης.

xxv (1) Τὰ μὲν <ὑπ> περὶ τοὺς τεκτονεύοντας οὗτος <γίνεται> κλεισθέντοις δὲ καὶ μετὰ ταῦτα ἀνοιχθέντος <τοῦ πίνακος>, δεῖ τοὺς μὲν τεκτονεύοντας μηκέτι φαίνεσθαι, τὰς δὲ ναῦς καθέλκομένας.

(2) γίνεται οὖν καὶ τούτῳ, καθάς μέλλομεν λέγειν. ὅθονον δεῖ λαβεῖν λεπτὸν καὶ πυκνόν, ὅσον ἔχον μέγεθος τοῦ τοῦ πίνακος ἐδάφει, τούτῳ δὲ χρίσαντας ὑγροτάτῳ λευκῷ χρω-
automatically, I place {the} a starwheel revolving around a peg securely fixed to the backdrop of the box. The starwheel will have a pulley \( \ddot{\eta} \) tightly fastened to it; having been wound several times around this [the pulley], the cord will be attached to the counterweight, so that, as the counterweight draws <the cord>, it may slowly turn the starwheel and the starwheel may hit the hysepianx repeatedly while rotating.

(6) Having been looped, the furthest end of the cord is put around the knob where \( \ddot{\eta} \). When <***> no longer to move the arm, it [the cord?] having been released off the knob.

xxv

(1) <So.,> woodworkers’ activities <take place> in this way. After <the box> has closed and subsequently opened, the woodworkers must no longer be seen, but the ships <must be seen> as they are launched.

(2) This too, then, occurs, as I am going to say. It is necessary to take a thin and closely woven piece of linen cloth, which is the same size as the backdrop of the box, and after dying this with white and exceedingly fluid paint, so
ματίῳ, ἵνα εὐλόγτως δύνηται συνειλεῖσθαι, ἣς ὑπογραφῆσαι τάς καθελκομένας νάυς καὶ προσθέντας πρὸς τὸν πίνακα τὸ μὲν ἰνωῦ μέρος προσθέλονται κεντροῖς πρὸς τὸ τοῦ πίνακος ἐπίσεδεν ὑπ’ αὐτὴν τὴν τοῦ πλυνθῆνες πλευράν, πρὸς δὲ τὸ κάτω μέρος τοῦ ὄθωνίου προσάψαι χαλκοῖν ὀβελίσκον δι’ ὅλου πάχος ἐχοντα ὑπόμετραν,

(3) ἵνα εἰλοῦντες περὶ τὸν ὀβελίσκον τὸ ὄθωνιον εἰς τὸ ἰνωῦ μέρος τοῦ πίνακος καὶ συντρέψαντες καλώς κρατήσωμεν ὑπὸ τὴν πλευράν τοῦ πλυνθῆνες καὶ, ὅταν θουλώμεθα, ἀφόμεν ἀφεθέν δὲ τὸ ὄθωνιον ἔξελισσεται ὑπὸ τῶν βάρους τοῦ ὀβελίσκου καὶ συντόμως ἀπειλισσόμενον καλώσει τὰ ἐν τῷ πίνακι γεγραμμένα.

(4) τοῦτο ὁν δεὶ γενέσθαι κεκλεισμένον τοῦ πίνακος αὐτόματον. ἐν δὲ τῷ πρότερον δεὶ μένειν αὐτὸ συνειλεῖσμον ἰνο. γίνεται ὁν ὀὐτῶς. ὅταν εἰλήθη καλῶς εἰς τὸ ἰνωῦ μέρος καὶ τεθῆ ὑπὸ τὴν πλευράν τοῦ πλυνθῆνες, ὑποκάτο τοῦ εἰλήματος παρ’ αὐτῷ ἐτριπθῆ εἰς τὸ ἐδάφος τοῦ πίνακος ἐρφίμα, καὶ ἀθήνη διὰ τοῦ τρυπήματος ἐκ τοῦ ὀπισθοῖ κέρας τοῦ πίνακος εἰς τὸ ἐμπροσθὲν μέρος ἀγκύλης σπάτου, ἕως μὲν προσχὴ σύμμετρον τὶ διάστημα καὶ ἐπιουρῷ ἀποληψθῆ ἰραρότως.

1 συνειλεῖσθαι Μ : συνειλεῖσθαι A Gαδ T : συνειλεῖσθαι Gκ
2 προσθέντας Schmidt : προσθέντας a 3 προσθέλοντας Ta : προσθέλοντας a κεντροῖς Prou : κεντροῖς a 5 προσάγα μ Aαγ : προσάγα μ Aαγ : προσάγα μ Aαγ T 8-9 κρατήσωμεν AαγGM ε : καταθέμεν Schmidt dub. in app. crit.
that it may easily be rolled together, *<it is necessary>* to paint the ships being launched; holding it against the box, *<one must>* tack its upper part to the surface [the backdrop] of the box under the side itself of the frame, and fasten a bronze rod that has an entirely appropriate thickness to the underside of the cloth,

**(3)** so that, when we wind the cloth around the rod towards the upper part of the box and when we roll it up completely, we may hold it *<in place>* under the side of the frame, and let it go whenever we want; once released, the cloth will be unrolled by the weight of the rod, and by being unrolled in a trice it will cover the figures painted in the box.

**(4)** So, this must happen automatically, with the box closed. At the beginning it [the cloth] must remain rolled together above. It takes place as follows. When *<the cloth>* was wholly wound towards the upper part and put under the side of the frame, *<a hole>* was bored below the roll near it into the backdrop of the box, and a loop of cord was pushed through the hole from the back of the box to the front, until it jutted out a moderate distance and was firmly secured with a peg.
(5) ἡλίκον δὲ δεῖ εἶναι, αὐτὸ τὸ πράγμα δεῖξει. εἰτα κατ’ αὐτὸ τὸ ἐν τῷ ἑδαφεὶ τρύπημα τρυπῶ παρὰ τὴν πλευρὰν τοῦ πλυνθοῦ τρύπημα εὐρύτερον τοῦ κάτω καὶ διαρρινὸν αὐτὸ, ἃπωκ πλεῖστον. 〈*⁺⁺⁺〉καὶ περὶ τούτῳ εἰλημένου τοῦ ὀδονίου περισφύγαξε εἰς τὴν ἀγκύλην καὶ διόδως διὰ τρυπηματίου τὸ ἐν τῇ πλευρᾷ καὶ ἀνωθεν περόνιον διώσας διὰ τῆς ἀγκύλης.

(6) μένει οὖν συνεσφηγμένον τὸ εἴλημα τοῦ ὀδονίου συνεχόμενον ὡς’ αὐτής. ὅταν δὲ δεῖ καλυφθῆναι τὰ ἐν τῷ πίνακι, κεκλεισμένων τῶν θυρῶν, ἐκσάψαι τὴν σπάρτον τὴν προσδεμένην τῇ περόνη, ἀποδεδομένην δὲ εἰς τὴν λεῖαν. οὕτως οὖν πάντα τὰ ἐπικαλύπτοντα ἐποιεῖτο, συνεκληθέντα καὶ ἐξῆς ἀνω ἐπάλληλα τεθέντα καὶ ἐκαστὸν αὐτοῦ ἀγκύλην καὶ περόνην λαβόν.
(5) The particular case will indicate how great <the distance> must be. Then, over against the hole itself in the backdrop I pierce a hole, wider than the one below, in the side of the frame and file it down thoroughly † so that more†. <***> and after the cloth has been rolled around this [the rod?], press it close to the loop and drive a pin through the hole in the side and from above, having pushed it through the loop.

(6) Thus, the roll of cloth remains bound together as it is held by it [the loop]. When the figures in the box must be covered, the doors being shut, draw the cord which is fastened to the pin and attached to the counterweight. So, all the coverings were made in this way, after they had been rolled together and placed aloft one after another in a row, each of them with <its own> loop and pin.
(7) ὣςον δ᾽ ἄν τόπον καταλάβῃ τὰ εἰλημένα τῶν ὀδονίων, ἡ τοσοῦτον ἀντιφράσειν σανίσει, ἵνα μὴ βλέπηται. τὸ δὲ σανίδιον γίνεται ύπέρθυρον {τῶν θυρῶν}. δεῖ δὲ ἐν αὐτῷ ποιῆσαι ἐπιστύλιον στρογγυλόλυπον, ἵνα ἔχῃ λειαν ὑπιν.

xxvi
(1) Ταύτα μὲν οὖν οὐτός γίνεται. κλεισθέντος δὲ καὶ ἀνοιχθέντος τοῦ πάνακός φαμεν μηδὲν φαύνεσθαι πλὴν ἀέρος καὶ θαλάσσης γεγραμμένοι καὶ μετὰ ταύτα παραπλεύν τὰς ναῦς.

ποιήσομεν οὖν καὶ τὰ περὶ τὸν πλοῦν οὗτος. ἐξ ἐκατέρου μέρους τῶν θυρῶν παρὰ τοὺς στροφεῖς ἔζει ὁ πίναξ τόπους κενοὺς καταπεφραγμένους ἐκ τοῦ κατάπροσθεν ἰδίως ἀπεργαζομένους οἶνον παραστάδων.

(2) ἐν δὲ τοῖς κενόμασι τούτοις ὑποπεφραγμένα σανίδια ἐπιτίθεται κανόνια ἔχοντα μέσα τετράγωνα ἱσόπλευρα εἰργασμένα καὶ ὄρθα, ὅν αἱ γαλαζίαι ἔσονται καταδεδεμέναι. ἔσονται δὲ ταύτα ἔλατην, ἵνα μὴ λεπτά ὄντα διαστρέφωνται. καὶ κάτωθεν μὲν αὐτῶν ἔσται προσκείμενα πυρηνίδια χαλκὰ ἔντορνα, οἷς ὑποκείσονται ἐμπυκελίδια, ἱνα

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(7) Screen off with boards the space that the rolls of cloth take up, in order that they may not be seen. The board serves as lintel {of the doors}. On this, it is necessary to make an architrave with rounded carvings, so that it may have a fine appearance.

xxvi (1) So, this takes place in this way. After the box has closed and opened, I say that nothing appears but painted sky and sea, and after this the ships sail by.

Thus, we will make the sailing scene as follows. On each side of the doors, near the pivots, the box will have shielded empty spaces, peculiarly finished over the outside like <those> of pilasters.

(2) Within these empty spaces are placed blocked boards, with bars in the middle constructed <so as to be> quadrangular, equilateral and upright, and the angles of which will be tied down. These will be of fir, in order not to warp because they are thin. Attached to the underside of them will be little bronze knobs turned on the lathe, with sock-
όσιν εὐστροφα, ἀνοθευ δὲ <***> στρογγύλα ἐργασθέντα καὶ λεία.

(3) καὶ ἀνόθευ τρυπηθείσης τῆς πλευρᾶς τοῦ πλαισίου διωσθήσεται, ὡστε μη σφήγγειν μήτε λιαν εὐλυτα εἶναι ός στρέψθαι. τούτων γενομένων δεὶ χάρτην λαβόντα λεπτότατον τῶν βασιλικῶν καλομένων ἀποτεμείν αὐτοῦ τὸ μῆκος, ἥλικον ἀν περίχερ ὑψος τὸ τοῦ πίνακος ἔδαφος ἐς τῶν θυνίων τῶν συνελημένων καὶ ἀποτεμόνια τὸν ὅμοφαλὸν τοῦ χάρτου προσκολλῆσαι αὐτὸν πρὸς τὸν κανόνα τὸν ἐκ δεξιῶν τοῦ πίνακος,

(4) ὡστε ἀντὶ τοῦ ὅμοφαλοῦ τὸν κανόνα προσκολλῆσθαι, καὶ οὕτως ἐπιστρέφοντα τὸ ὑπερέχον τοῦ πίνακος περιελείν τὸν χάρτην περὶ τὸν κανόνα κεκλεισμένου τοῦ πίνακος. τούτω δὲ ἐπιστρέφεται, ἦς ἄν ἐπικαλυφθῇ ὅλον τὸ ἔδαφος τοῦ πίνακος τῷ χάρτῃ. <νυκ> ἦσται δὲ τοῦτο, ἦς ἄν ἐπί τὸν τὸν ἑτέρου κανόνος τόπον ἐγγύνης <***> πεπληρωκέναι τε καὶ οὕτως, ἕαν τι πλεονάζῃ, ἀποτέμενειν.
ets below them to turn easily; at their upper ends <***>
made round and smooth.

(3) When the side of the frame has been perforated at the top, they [the bars] will be driven through, so that they are neither caught nor too loose for turning. After these things have been done, one must take an exceptionally thin scroll of the so-called ‘royal papyrus’ and cut a length of it which may cover in height the backdrop of the box, up to the rolled-up cloths; and trimming off the roller of the scroll <one must> glue it [the scroll] onto the bar on the right-hand side of the box,

(4) so that the bar is glued on in place of the roller, and thus, by turning what sticks out from the box, one may wind the scroll around the bar when the box is closed. This is turned until the entire backdrop of the box has been covered by the scroll. This will <not> take place until you draw near to the region of the other bar <***> to have filled up and thus, if something is in excess, to trim it off.
(5) δεὶ δὲ ὑποκολλήσαι ὑπὸ τὴν ἄρχὴν τοῦ χάρτου κανόνα σφόδρα λεπτὸν εἰργασμένον. Ἐστιο οὖν τὸ εἰλημένον παρὰ τὴν παραστάσα κεκριμένον, ὡστε ἀνεωγμένον τοῦ πίνακος μὴ ὀρᾶσθαι. Ἐναρτῶ οὖν σπάρτους λεπτὰς εἰς τὸ κανόνιον τὸ πρὸς τῇ ἄρχῃ τοῦ χάρτου προσκεκολλημένον <μίαν μὲν> κάτωθεν παρὰ τὸ παραστάδιον τοῦ πίνακος, ἄλλην δὲ ἄνωθεν παρὰ τὸ ὑπερθύριον καὶ ἀποδόδωμι εἰς τὸν ἄλλον κανόνα τὸν ἐν τοῖς εὐωνύμοις μέρεσιν.

(6) οὐκοῦν ἐὰν περιάγωμεν τὸν κανόνα, ἐπισπάσταις τὰς σπάρτους· ἐπειληφθῶσιν γὰρ αἱ σπάρται ἔξηρτημέναι εἰς τὴν ἄρχῃν τοῦ χάρτου, καὶ ἀκολουθήσῃ οἴ τις θάρσης. κεκλεισμένου οὖν τοῦ πίνακος ἐξ οὗ τοσοῦτον ἐπιστρεφθεῖτο, ἦς ἐν ἑπίκαλυφθη ὁλὸν τὸ ἔδαφος τοῦ χάρτη. Ἐσται δὲ οὕτως ἀέρα καὶ θάλασσαν ἔχον γεγραμένα. Ἡν οὖν αὐτόματος παραγένηται οἱ χάρτης καὶ τῆς λείας βαρεώς ἐπισπωμένης ταχεία παραγωγὴ γίνεται πρὸς τὸ πολὺ πλήθος τῶν πλοίων παραπλεύσας, δεὶ προμημανήσασθα ταῦτα.

(7) Ἐστω γὰρ κατὰ τὸ ὅπισθεν μέρος φανόμενος ὁ πίναξ ὁ ἁβγό, καὶ τοῦ κανόνος, περὶ οὖν ἐλίσσεται οἱ χάρτης, τὸ ὑπεράνοι μέρος ἐξελίκτην τετορυμενήν τὴν ἐν <ἐχέτω>, καὶ πρὸς τὸν πίνακα ἐπάνω τῶν ὑπελειμμάτων καὶ τῶν ἀστερίσκων τῶν τὰ χέρια κινοῦντος ἀποσπάσας μι-
(5) It is necessary to glue a bar worked very thin under the extremity of the scroll. So, let the roll be hidden near the doorjamb, so as not to be seen when the box is open. Therefore, I fasten thin cords to the bar glued to the extremity of the scroll, <one> below near the doorjamb of the box, another above near the lintel, and attach them to the other bar on the left.

(6) Then, if we turn the bar, it will pull the cords; for the cords attached to the extremity of the scroll will be wound up, and the scroll will follow them. So, when the box is closed, let it [the bar] rotate up to the point where the whole backdrop has been covered by means of the scroll. This will have sky and sea painted <on it>. These mechanisms must be engineered in advance, in order that the scroll may move by itself and, despite the counterweight pulling it slowly, its sliding may occur rapidly, so that a great number of ships sail by.

(7) Let there be the box seen from behind, αβγδ, and <let> the upper part of the bar, around which the scroll is rolled, <have> a lathe-turned bobbin, ζη; against the box, above the hysplàngia and after I have drawn it a little bit away from the starwheels that move the arms, I place a drum ὅκ.
κρόνον παρατίθημι τύμπανον τὸ θ. ἐχέτω δὲ τὸ τύμπανον κατὰ κορυφὴν {μέρος} κύκλῳ τετορνευμένον τροχύλον.

(8) καὶ περὶ τὸν άξονα τοῦ τυμπάνου ἄλλον περιτίθημι άξονα μικρὸν προσαραρότα τῷ άξονι τὸν ἰ, ὅπως {συμφωνή ὡς} ἦν στραφηκέντα <ἀυτῷ> μείζονι τυμπάνῳ. περιελήςας οὖν σπάρτων περὶ τὴν ἑξελίκτραν, ὡς μέλλει ἑξελίσσειν τὸ πόλυ, ὥσπερ <τὸν> ἐτερον τροχύλον <***> τῷ πρῶτῳ τυμπάνῳ τὸν ἰ, περὶ εἰς τὴν εἰς τὴν λείαν ἀποδεδομένην σπάρτων. ἔστω δὲ ἢ ν.

(9) δήλου οὖν ὅτι μικρὸν τῆς σπάρτος ἐλευθερίας ὑπὸ τῆς λείας πολὺ μέρος τοῦ χάρτου καὶ ταχὺ ἀπεληφθέντα. άξον δὲ, ἐν ὃ ὁχεῖται τὸ τύμπανον, <ἔστω> ὃ ᾠκ. χρῆ δὲ τοὺς ἀστερίσκους καὶ τὸ τύμπανον ἀνεμισσόντως κινεῖσθαι.

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Let the drum have at its vertex {part} a pulley turned on the lathe all around.

(8) Around the axle of the drum, I set another axle, small and firmly fitted to the axle, $\mu$, so that {attached like} it will rotate together with <the> bigger drum. So, after winding a cord around the bobbin $\eta\nu$, as much as is expected to unroll the scroll, † which † I pass <***> I wind the cord going to the counterweight around <the> other pulley $\mu$ <***> with the first drum; let it [the counterweight] be $\nu$.

(9) So, it is clear that, when the cord has been pulled by the counterweight just a little, a large portion of the scroll will be unwound, and swiftly. <Let there be> an axle, on which revolves the drum, $\xi\xi$. The starwheels and the drum must move unhampere.
(2) καταλαβών σανίδα ἔγραψα τα δελφινάρια, ἥλικα βουλόμαι, καὶ περιέτεμον καὶ περιερρήσα τὴν ἐκτὸς γραμμήν. ἦστω δὲ ἀξόνιον ὑπὸ τὰ στέρνα τοῦ δελφιναρίου, ἐν ὧν ἦπερα περόννει σιδηρᾶν· καὶ <***> εἰς τὰ στέρνα τοῦ δελφιναρίου. ἦστω εἰς τὴν ἐκκοπὴν ὄχρομενος εἴ ἐνὸς μέρους τροχίλος καθάπερ τὸ ὑπογεγραμμένον· ἢ δὲ ἐκκοπη ἢ ἐκ τῆς πλευρᾶς <Ἑστω> ἢ ἤβι, ἄξονες δὲ ὧν, τροχίλος δὲ ὧν εἰς τὸ δελφιναρίον.

(3) τρυπῶ ὅν τὸν ἄξονα κατὰ τὴν ἐκκοπὴν <Κατὰ> τὸ ὑπὸ καὶ ἐνεπιξά τὴν περόννη τοῦ δελφιναρίου. οὐκοῦν ἐὰν τις περιάγῃ τὸν τροχίλον τῇ χείρι, ὦτ ὅν καταδύσει ὁ δελφινικὸς κάτω διὰ τῆς ἐκκοπῆς εἰς τὸ θωράκιον, ὦτ ὅν ἀναδύσει ἐν τῷ πίνακι.

(4) ἢνα ὅν αὐτόματον <ὑοῦτο> γέννηται, σπάρτων ἀπαγκυλούσας περιτίθημι περὶ τὸν τύλον τὸν ἐνόντα ἐν τῷ τρο-
(1) So, the coasting voyage takes place in this way. The dolphins will now plunge, now come into view in the way described below. On the lower side of the frame, which is fitted to the enclosure, having left a small interval from the pivots, I made narrow notches like <those> for tenons, in such a way that they allow light through to the enclosure below.

(2) After taking a board, I drew the dolphins of the size I want, cut around their outlines and filed them down. Under the dolphin’s chest let there be an axle, in which I fixed an iron pin; and <***> to the dolphin’s chest. Let there be a pulley inside the notch driving on one side, as illustrated below. <Let there be> a notch on the side, \( \overline{ab} \), an axle, \( \overline{gh} \), and a pulley, \( \overline{ce} \). Fig. 31

(3) Thus, I pierce the axle with a hole <ab>\( \overline{d} \) opposite the notch and fixed the dolphin’s pin <in it>. Therefore, if someone turns the pulley by hand, the dolphin will dive down through the notch into the enclosure at one time, and come up inside the box at the next.

(4) So, in order for <this> to happen automatically, I make a loop in a cord, put it around the knob which is on the pulley, \( \overline{c} \), and after winding it around the pulley, I attach it
χίλιον τὸν ἵκον καὶ περιελίξες τὸν τροχίλον ἀπαθιόνμενον εἰς τὴν λείαν. ὁ δὲ δεξαμενίσκος οὕτως ἐμπεπηγός ἦσσαι εἰς τὸν ἄξονα ὡς ἐφ’ οὔ το κ. πρὸς ὀρθὰς ὁν τὸν ἄξονα, ὁ δὲ γὰρ ἄξον τρὸς ὀρθὰς τῷ θωραικῷ.

(1) Πέρας οὖν ἐχοντος τοῦ παράπλου κλεισθῆσονται πάλιν αἱ θύραι, καὶ ἡ σπάρτας ἐξκυθείσα ἐκπάσει τὸ περόνιν καὶ καταρρίψει τὸ ὀθόνιν, ἐν ὧν ἦσσαι ὁ Ναύπλιος γεγραμμένος ὁ τὸν πυρὸν ἄρκος καὶ ἡ Ἀθηνα. καὶ ἀνοιχθέντος τοῦ πίνακος αἱ μὲν νῆς ὀφθαλμονται, τὰ δὲ προειρήμενα. δεήσει δὲ καὶ τὸν πυρὸν εὐθές ἀνακαίεσθαι.

(2) ποιήσομεν οὖν καὶ τὰ κατὰ τὸν πυρὸν οὕτως· ἦσσαι ἡμῖν ἐπὶ τοῦ ἐπιστούλου καὶ τῶν τριγλύφων σανίς ἐπισκοποῦσα δι’ ἑνὸ τοῦ πίνακος, ἢτοις ἐπικαλύπτει τὴν τε ἐξελέκτρας τὴν τῶν παράπλου ἁγγοῦσαν καὶ τὴν τοῦ πυρὸς πραγματεύσαν καὶ τὴν τῆς μηχάνης ἐπαρασίν, ἵνα μηδὲν τῶν προειρήμονον εἰς τὸ κατάπροσθεν μέρος τοῦ πίνακος φαίνησαι.

(3) ὅπος δὲ μὴ ἀλλόγος ἡ σανίς ἐπικείμενη <ὑ>, ἀντὸς προστίθεται αὐτὴ καθάπερ δὴ ναίσκος· τὰ δὲ ἀπολειπόμενα

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to the counterweight. The dolphin will thus be fixed to the axle like <***> at \(\overline{r}\), being at right angles to the axle, and the axle-\(\gamma\delta\) at right angles to the enclosure.

XXVIII

(1) So, when the voyage comes to an end, the doors will close again, and the cord, having been pulled tight, will draw out the pin and bring down the cloth, on which will be painted Nauplius, holding up the torch, and Athena. Once the box has opened, the ships are not in sight, but what has been said before. It will also be necessary for the torch to blaze up promptly.

(2) Therefore, we will make the mechanisms for the torch as follows: on the architrave and triglyphs we will have a board overshadowing the whole box, which will conceal the bobbin that triggers the voyage, the fire-lighting device and the lifting of the machine, so that none of the above may be seen from the front of the box;

(3) but in order for the board not <to be> set in place without apparent reason, a pediment is added to it just like
έκατέρωθεν πετρύγια τῆς σανίδος ἐπιφόρεται μέλαιν ἤ ἀερι. τίθεται δὲ ἐχομένη τῆς ἐξελίκτρας ἢ μηχανή. τῆς δὲ μηχανῆς ἐκ τοῦ ἄλλου μέρους ἢ τοῦ πυρσοῦ γίνεται κατα-
σκευή τοιαύτη οὕσα. ἐκ λεπίδων χαλκῶν δεῖ ποιῆσαι κα-
θάπερ κιβωτάριον πῶμα μὴ ἔχον, ἄλλα ἄχανες.

(4) τούτῳ δὲ δεῖ στήσας ὅπιον ὅπιον τῆς σανίδος τῆς ἐπι-
καλυπτούσης καὶ καθηλώσαι πρὸς τὴν πλευρὰν τοῦ πλαι-
θιοῦ. ἐχέτε δὲ τὸ μὲν ἔδαφος τὸ κιβωτάριον πρὸς τῇ 
σανίδι, τὸ δὲ χάσμα ἐξω βλέπον τῆς σανίδος. ἐκ δὲ τῆς ἀνο
πλευρᾶς τοῦ κιβωταρίου ἐκκεκόφθοι ὅπη διαφαίνουσα 
ώσηι υπορίς, ὅστε ὅταν λύχνου καυσμένοις τεθῇ ἀεὶ τὸ κιβω-
τάριον, τὸ τῆς φλογὸς αὐτοῦ διήκειν ἄκρον εἰς τὸ ἀνο 
μέρος τοῦ κιβωταρίου διὰ τῆς ὅπης. τούτου δὲ ὑπάρχων-
tος, ὁ λύχνου ὑποκείμενο καυσμένος.

(5) ἄλλῳ δὲ λεπίδῳ χαλκῷ τριγώνῳ κατασκευάζομεν τὴν 
ὅπιν, ὅστε ἀποκεκλείσθαι τὴν φλόγα. ἐπάνω δὲ τοῦ κιβω-
tαρίου καὶ τῆς πεπομασμένης λεπίδος ἐπιτίθημι ξύσματα 
tεκτονικὰ ἐξορᾶτα, οὐκοῦν ὅταν ἀποσπᾶσω τὸ λεπίδιον 
tὸ πεπωμακός τὴν ὅπιν, ἢ φλόξ τοῦ λύχνου ἁγεῖται τῶν 
ξυσμάτων, καὶ εὖθες ἀνακαυθήσεται. πρὸν δὲ τὰ ξύσματα 
καυσθήναι, οὐ βλέπεται ἡ τοῦ λύχνου φλόξ κεκρυμμένη ἐὰ 
τὸ κιβωταρίῳ.

(6) καὶ γάρ ἔξολον ἐπιούριον ἔξει, ἐὰν βουλώμεθα τε-
λείος πάντοθεν ποιμάσαντες ἀδρατον ποιῆσαι τὴν φλόγα.

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1 ἐπιφόρεται Schmidt dub. in app. crit. : ἐπιφόρεται a : ἐπιστρέψει R. Schöne
2-3 ἀνα. ἐκ δὲ τοῦ ἄλλου μέρους τῆς μηχανῆς? 9 βλέπον A GMT*: βλέπον
Ττιαλ 10 κιβωταρίου Τττιαλ: κιβωταρίου Μ : κιβωταρίου νελ κιβωταρίου Ἀφ
Γρ: κιβωταρίου Ττιαλιαν : κιβωταρίου ἘαLb 11 eis om M T 13 τούτου A G
τούτο M T : τούτο M T δὲ <σπάσω> Schmidt dub. in app. crit. 13-14 post ὑπάρχων-
15 κατασκευάζομεν Μ* : κατὰ ποιμάζομεν ἈΤ : κατὰ ποιμάζομεν G
20 εὖθες <σπάσω> Schmidt dub. in app. crit. 23-4 aut καὶ γάρ... φλόγα
dedere aut epoúron om in łeśPihr 4 mutare dub. proposuit Schmidt in app. crit.
γάρ ΑΓ: τὸ M T ἐπούριον A M T : ἐπούριον G
to a shrine. The remaining wings on either side of the
board are painted black or the colour of the sky; the ma-
chine is positioned next to the bobbin. On the other side of
the machine is the torch, which is constructed as follows.
It is necessary to make a kind of small chest out of bronze
sheets, with no lid, but wide open.

(4) This must be stood upright behind the covering board
and nailed down onto the side of the frame. Let the small
chest have its bottom against the board, and its opening
looking out from the board. Let an aperture be cut out of
the upper side of the small chest, letting light through just
like a little window, so that, when a lamp has been lit and
put into the small chest, the tip of its flame reaches into
the upper part of the small chest through the aperture. As it
stands, let the lighted lamp be set beneath.

(5) We cap the aperture with another triangular bronze
plate, so as to close off the flame. Above the small chest
and the capping plate, I place especially dry woodwork
shavings. Therefore, when I draw away the plate that cov-
ers the aperture, the flame of the lamp will set the shavings
on fire, and they will immediately flare up. Until the shav-
ings catch fire, the flame of the lamp is not seen, being
hidden in the small chest;

(6) for it will have a little wooden peg, if we want to make
the flame invisible by capping it off completely from all
ἐνα δὲ ἀσφαλῶς μὲν ὁ λόγχος ἐν τῷ κιβωταρίῳ, περόνιον ἐστο ὑπερέχων ἐκ τοῦ κάτω μέρους. ὃ δὲ λόχνος ἐστω τὸν εἰς τοὺς λαμπτήρας ἐμβαλλομένον καὶ περιτιθεμένον περὶ περόνην. ἦν οὖν περὶ τὸν καθήκοντα καιρὸν αὐτόματον ἀνοιχθῇ τὸ λεπίδιον, παρατίθημι ἀξίων ἄπέχον ἀπὸ τοῦ πυρὸς.

(7) ἐκ δὲ τῆς λεπίδος ἀλυσείδιον ἀνάψας ἐξέδησα εἰς τὸ ἀξίων, ὅπως ἦτο ἐπιστραφῇ τὸ ἁζίων, περιελήθη τὸ ἀλυσείδιον καὶ ἐπισπάσηται τὸ λεπίδιον. ἐπιστρέψει δὲ ὁμοίως τὸ ἀξίων σπάρτος ἐκ τῆς λείας περὶ τύλουν.

{ἐστο δὲ τὸ λεπίδιον τὸ α, ἀλυσείδιον δὲ περὶ τοὺς τύλους τὸ β, ἄρον δὲ τὸ γ, τύλους δὲ τὸ δ, σπάρτος δὲ ἢ περὶ τὸν τύλου τὸ ε.}

(1) Φανέρων δὲ τῶν προειρημένων καὶ τοῦ πυρὸς ἀνακαυθέντος, κλεισθῆται πάλιν ὁ πίναξ. καὶ εἰσπάσασα ἡ σπάρτος τὴν περόνην καταρρήσει τὸ όδον, ἐν δὲ ἢ ἔσται γεγραμμένη ἡ ναυαγία τῶν νηῶν καὶ τὸ τοῦ Αἰαντος ἁζόδιον νηχόμενον. ἐν δὲ τὸ πίνακι φανήσεται ἡ Ἀθηνά. ἔσται δὲ ἡ βάσις αὐτὴς ἔχουσα ἐν τοῖς προσήκουσι τόποις τύλους.

(2) καὶ μία μὲν σπάρτος ἑγερεῖ αὐτὴν ἐπισπασμένη ἐκ τοῦ ὅπως μέρους τοῦ ἱσχαρίου κατὰ τὸ σήκωμα αὐτῆς· ἀποσχισθέισης δὲ ταὐτῆς ἄλλη περιεκμένη περὶ τὸ θωράκιον περιάξει αὐτὴν, ἔως ὅτι ἐλθῇ ἐπὶ τὸν αὐτὸν τόπον,
sides. In order that the lamp may remain steady inside the small chest, let there be a pin projecting from the under-
side. Let the lamp be <one> of those placed in lanterns and
set around a pin. So, in order for the plate to open by itself
at the proper time, I place an axle at a distance from the

(7) After fastening a thin chain to the plate, I bound it to the axle, so that, when the axle rotates, the thin chain may
be wound and may draw the plate. A cord <attached> to the counterweight <and looped> around a knob will like-
wise turn the axle. {Let there be the plate, α, a chain around the knobs, β, an axle, γ, a knob, δ, and the cord around the knob, ε.}

(1) After the previously mentioned effects have been seen and fire has blazed up, the box will close again. When the
cord has drawn out the pin, it will bring down the cloth, on
which will be painted the wreck of the ships and the figur-
ine of Ajax swimming. Athena will appear in the box. Her
base will have knobs in appropriate places.

(2) One cord will raise her up by pulling from behind the joint [mechanical element] in accordance with her coun-
terbalance. When this has been released, another <cord>
lying around the enclosure will turn her around, until she
reaches the same place from which she set off. When this
όθεν ἔξηλθεν· ἀποσχαθείσης δὲ ταύτης ἡλία σπάρτος ἐπισπάσεται ἐκ τοῦ ὑπηθήθην μέρους τοῦ ἱσχαρίου καὶ οὕτω κατακλινεῖ τὴν Ἀθηναί.

XXX (1) Λοιπὸν δὲ ἔστιν ἡμῖν διηγησάσθαι, τίνι τρόπῳ ὤ τε κεραυνὸς ἐν τῷ πίνακι πεσεῖται καὶ τὸ τοῦ Ἀλάντος ἥδιον ἀφανισθήσεται. γίνεται οὖν καὶ ταύτα, καθάπερ μέλλομεν ἐξηγεῖσθαι κατὰ μέρος ὡς τοῦ ἔδαφος τοῦ πίνακος, ἑσταὶ γεγραμμένον τὸ ἥδιον· κατʼ αὐτό δὲ ἔστω ἐκκοπή ἐν (ες) τῇ ἄνω πλευρᾷ τοῦ πλυνότος πεποιημένη καὶ ἐν τῇ κάτω, καθάπερ καὶ ἐπὶ τῶν δελφίνων ἐδηλώσαμεν.

(2) κατατείνονται οὖν ἐκ τῆς ἄνωθεν πλευράς τῆς ἐκκοπῆς χορδάς δύο λεπτοτάτα τῶν εἰς τὰς σαμβύκας ἐμβαλλόμενον ἐς κάτω εἰς τὸ θωράκιον διὰ τῆς ἄνω οὕσης ἐκκοπῆς ἢ να δὲ ἐν τῷ ναόκορ ὄσι τεταμέναι, καθάπερνταν εἰς κολλάβους δύο ἐκ τοῦ ἄνωθεν μέρους, ἢν ἐπιστρεφομένοι τῶν κολλάβων τὴν τάσιν ἔχοσιν.

(3) ἔγραφεν δὲ σανίδιον λεπτὸν καὶ ὑπόμηκες, ὡς τε χορεῖν αὐτὸ διὰ τῶν ἐκκοπῶν εὐκόπως καὶ σταθέν ἐκ τοῦ ὑπερθύρου μὴ ὑπερέχειν αὐτὸ τὸ ὑπερθύρον εἰς τὸν πίνακα (κάτω) τρυπηθήν ἔτ' ὅσι τρυπήμασι κατὰ μήκος περιλαμ-
has been released, another cord will pull from behind the joint and thus lay Athena down.

xxx

(1) It remains for us to detail how the bolt of lightning will fall inside the box and the figurine of Ajax will vanish. So, these effects take place just as I am going to spell them out one by one. The figurine will be painted where the backdrop of the box <s>. Across from it, let there be a notch made <both> in the upper side of the frame and in the lower one, just as I have shown for the dolphins.

(2) So, two extremely thin gut strings of the kind placed on sambucus are stretched tight from the upper side of the notch down into the enclosure through the notch above. In order for them to be stretched taut inside the shrine, they are fastened to two pegs on high, so as to obtain tension when the pegs are turned.

(3) Once a thin and longish board has been raised, so that it passes through the notches easily, and once it has been made to stand beyond the lintel, so as not to jut out from the lintel itself into the box <***>. Having been pierced lengthwise with two holes, it encases the strings by means
βάνει τὰς χορδὰς ἐπιούρις· προσκολλάται δὲ καὶ ὀψις εν τοῦ σανιδίου {τὸ} μολύβδιον λεπτόν, ὡς βάρος ίσχι.

(4) ἔλαυνον ἄγωμεν τῇ χειρὶ τὸ σανιδίον ἄνω διὰ τῆς ἔκκο-

πῆς, ἀποπεσεῖται διὰ τοῦ πίνακος φερόμενον ὅρθιον, ὡς ἄν

περὶ τὰς χορδὰς περικείμενον. αἱ μὲν ὀνόι χορδαὶ μέλαι

μολύνονται, ἵνα μὴ δῆλαι ὅσι· τὸ δὲ ὑποσανιδίον ἐκ μὲν

τοῦ κάτω μέρους χρυσοῦται καὶ λειωῦται ὡς μάλιστα. ἐκ

δὲ τοῦ ἄνωθεν ὑπογράφεται τι πυροεἰδές, ὡς τὴν τοῦ κε-

ραυνοῦ φαντασίαν ποιεῖν.

(5) φέρεται δὲ τούτῳ, ὅταν ἀφεθῇ, κατὰ μέσον τὸ ζόδιον,

ὡς τεταμέναι εἰσίν αἰ χορδαῖ. τούτῳ δὲ ἄνω μένει περονίω

κρατούμενον, καθάπερ καὶ τὰ ὀδόνια, ὅπως ὤταν καθῆκον

ἡ, ἢ σπάρτος ἐπισπασμένη τὸ περόνιον ρίψῃ τὸν κεραυ-

νόν. τὸ ζόδιον πεσόντος τοῦ κεραυνοῦ ἀφανίζεται οὕτως·

ἐστὶν ἔτερον ὀδόνιον πεποιημένον καθάπερ καὶ τὰ ἄλλα

τὰ ἐπικαλύπτοντα, μικρὸν δὲ, ὡς αὐτὸ τὸ ζόδιον ἐπικαλύ-

ψηται τὸ ὀδόνιον. ἐν δὲ τούτῳ γέγραφται θάλασσα ὀμοίᾳ

τῇ περιγραφῇ τὸ ζόδιον καὶ τὰ κύματα.

1 ἐπιούρις Śmidt: dub. in app. crit. 2 τὸ δελεῖ: t

Schmidt: dub. in app. crit. μολύβδιον M: corred: μολύβδιον T: μολύβδιον

A G: τμολύβδιον Schmidt: dub. in app. crit. 4 ἀποπεσα-

ται Prou: ἀποπέση a: ἀποπέση Schmidt: dub. in app. crit. 7 καὶ λειωῦται om. T1: add. T2

ante hoc vertum dub. suppl. in app. crit. 8 ὑπογράφεται A

GM: ὑπογράφεται Prou πυρειδές A2 G: πυρειδές M 10 μέσον τὸ

A2 M: μέσο G2: μέσο Gκ 11 τεταμέναι Schmidt: τεταμέναι a μένε

R. Schöne: βλέπει a 12 καθῆκον GM: καθῆκον A2 T 13 ἢ A G: ἢ

T ἐπισπασμένη M: ἐπισπασμένη A2 GT περόνιον G: περόνιον A T

βίψη A G: βίψα M 14 τὸ Ἐλαζότος ζόδιον (sic) Prou: τὸ Ἐλα

Schmidt: dub. in app. crit. 16-17 ἐπικαλύπτεται Prou: ἐπικαλύπτεται A2 G2 M

17 τοῦτο G: τοῦ A: τοῦ M T
of pegs; {the} a thin lead weight is also glued onto the back of the board, so that it may acquire heaviness.

(4) Thus, if we drive the board upward through the notch by hand, it will fall full pelt straight through the box, as it lies around the strings. So, the strings are dyed black, in order not to be conspicuous. The underside of the board is gilded and polished to the utmost over its lower part. On the upper surface, something resembling fire is traced out, in such a way as to create the image of lightning.

(5) Once released, this falls in the middle of the figurine, since the strings are pulled taut. This [the board] remains held up above by a pin, just like the pieces of cloth, so that, when it is convenient, the cord may draw the pin and hurl the lightning bolt. As soon as the bolt of lightning falls, the figurine disappears as follows: there is another piece of cloth made just like the other coverings, but small, in order that the cloth covers exactly the figurine. On this, sea is painted like that which surrounds the figurine and the waves.
(6) καὶ εἰ τι ἄλλο φαινόμενον ἐστὶ τῶν ἔγγρον, προσαπονε-νέμειται, ὡς ἐπικαλυφθέντος τοῦ ζωδίου τὸ <ὁθόνιον ἦ> ὦμοιον. καὶ ἐκ τὸν ὁπίσθεν δεῖ τὸ ὦθόνιον ὄμοιος θαλασ-σοειδεὶς χρώματι προσαποκεχρώθη, ἵνα δὲ ἔπικαλυπτό-μενον καὶ κρατεῖται ὑπὸ τῆς μιᾶς περόνης, ὑφ᾽ ἢς καὶ ὁ κεραυνὸς κρατεῖται, ἠστε ἐκλυσθείσης αὐτῆς ἀμα τε τὸν κεραυνὸν ἐνεχθῆναι ἐπὶ τὸ ζωδίον καὶ καλυφθῆναι αὐτὸ ὑπὸ τοῦ ὦθόνιον, ἠστε δοκεῖν πληγέν αὐτὸ ὑπὸ τοῦ κε-ραυνοῦ ἴσωμισθαι.

(7) τὰ μὲν οὖν κατὰ τὸν πίνακα οὕτως οἰκονομεῖται. ὄμοιος δὲ καὶ αἱ ἐν τοῖς ζωδίοις καὶ αἱ τῆς πορείας κινή-σεις διὰ τοιοῦτον ὄργανον πάσαι γίνονται, οἱ τε πίνακες πάντες ὄμοιος διὰ τούτων οἰκονομοῦνται, πλὴν ὅτι διαλ-λάσσονται

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(6) If anything else, of the things nearby, is seen, it is added, so that, when the figurine has been masked, <the cloth may be> all alike. The cloth must likewise be additionally painted the colour of the sea on the underside. In order for the cloth not to be seen at all {when covered}, it is rolled up aloft and propped up by the one pin which also supports the bolt of lightning, so that, when it is dragged out, the lightning bolt falls on the figurine and this is covered by the cloth at one and the same time, with the result that it [the figurine] seems to vanish being struck by lightning.

(7) Therefore, the effects in the box are managed in this way. The movements of the figurines and those of the journey all occur in a similar way through such instruments, and all the boxes are likewise managed by these means, except that they differ <***>
COMMENTARY ON BOOK ONE

1 [2.3-6.8] Preface

In a succinct preface, Hero presents the subject matter of the treatise. The incipit is conventional in both form and content (see Alexander 1993: 71, 75-7), but the presence of a lacuna hinders comparison with similar openings. Stationary automata (1.3-6) are given more space than their mobile counterparts (1.2), possibly because of the author’s stated preference for the former type (1.7 ἕστι δὲ... ὑπαγόντων). The words with which the opening sentence now closes are repeated at the end of 1.7 and create an inclusio. As a result, the last paragraph (1.8) presents itself as an independent unit, in which Hero can affirm his editorial authority (Mansfeld 1998: 52).

1.1 [2.3-4] Τὴς αὐτοματοποιητικῆς... ἡξιωμένης. For a similar opening, cf. Spir. 2.4-5 Τὴς πνευματικῆς πραγματείας σπουδῆς ἡξιωμένης πρὸς τῶν παλαιῶν φιλοσόφων τε καὶ μηχανικῶν, etc. (with Mansfeld 1998: 51; correct πρῶτερον to πρῶτερον? see below). As first noted by Baldi 42n. 1, there is no main clause following this genitive absolute. Previous translators have obviated the problem by rendering the genitive absolute as an independent sentence. Schmidt rightly suspected a lacuna after θεωρίας (1.1 [2.5]; cf. Catoptr. 318.11). Comparison with other scientific prefaces, most notably Hero, Dior. 188.3-9 and Spir. 2.4-10 (see Alexander 1993: 70 with n. 6), indicates that here, too, the author’s intention to write would have been expressed in the first main clause of the preface, and that such a clause would have followed the opening subordinate clause. However, nothing suggests that the main clause here should coincide with Spir. 2.7-10 ἀναγκαίον ὑπάρχειν νομίζομεν καὶ αὐτοὶ τὰ παραδοθέντα ὑπὸ τῶν ἀρχαίων εἰς τάξιν ἀγαγεῖν, καὶ ἡ ἡμεῖς δὲ προσευρήκαμεν εἰσθέασθαι, as tentatively proposed by Schmidt in his app. crit. This is not because, as has been asserted by Olivier (1901: 434), Hero draws on Philo exclusively for Book Two, but because in the Automata, just as in the Dior. (cf. Dior. 188.5-9 ἀναγκαίον... προάξαι), he prioritises improving and ameliorating earlier models over order and inventiveness.

For the use of the term πραγματεία (and its corresponding verb πραγματεύομαι) in scientific prefaces, see Alexander (1993: 96-7), where the
present passage, Hero, Dioptr. 188.3 (Τής διοπτρικῆς πραγματείας) and Spir. 2.4 (quoted above) are cited among others (add XX.1 [64.3] πραγματευθήναι). The term clearly refers to the subject of the treatise rather than to the treatise itself (‘Il Trattato delle Machine Se moventi’, Baldi 16; amplified in Couture 243). Murphy 11 (‘The study of automaton-making’) overemphasises its theoretical connotations. Schmidt’s translation is more puzzling: ‘Die Schaustellung der Automaten (Automatentheater)’ (339). For the term in a more concrete sense (‘device’; not recorded by LSJ s.v.), cf. XXVIII.2 [100.15].

I prefer πρότερον (GM) to πρότερον (AT), which has been adopted by Schmidt. Nowhere else in the Heronian corpus does the substantivised adverb occur with reference to predecessors. When referring to predecessors, Hero uses either prepositional phrases (οί πρὸ ἐμοῦ: Dioptr. 188.5-6; οί πρὸ ἡμῶν: V.1 [20.8], XX.1 [64.8], Bel. 73.6, Dioptr. 188.11, 292.22, Metr. 4.6) or substantivised adjectives (οἱ ἁρχαῖοι: II.12 [14.11], XX.5 [68.1], XXI.1 [70.4], Def. 104, Metr. 72.29, Spir. 2.9, Stereom. 1.21.3; οἱ παλαιοὶ: I.7 [4.22]; cf. Bel. 112.9-10; οἱ πρότεροι: Dioptr. 292.24-5).

I.1 [2.4-5] τὸ ποικίλον τῆς ἐν αὐτῇ δημιουργίας. Tybjerg (2003: 458-9) has argued that Hero exploits the metaphorical meaning of the term ποικίλος (‘artful’, ‘wily’, LSJ s.v. III.3.c) in order to establish a connection between mechanical craftsmanship, cunning intelligence (μῆτας) and the production of wonder. To support her argument, she cites Hes. Th. 511 and A. Pr. 308, where the term refers to Prometheus’ cunning. However, she ignores the fact that the notion of ποικίλα is strongly associated with μῆτας only in the Archaic and Classical periods (see Grand-Clément 2015: 407-10, citing Deltanne-Vermant 1974: 25-31). Rinaudo (2009: 59 with n. 141) has pointed out that from the fourth century onwards ποικίλος usually means ‘diverse’ or ‘various’ (Grand-Clément 2015: 407 misunderstands this to mean that ‘by the Hellenistic period the adjective retains only the meaning of “varied”’), and it is in this sense that Hero primarily uses the term. What is even more interesting to note is the aesthetic effect that Heronian ποικίλα produces upon the audience. Several sources attest to the pleasure arising from ποικίλα, and Ps.-Plu. Lib. Ed. 7b explicitly mentions its relieving effect in connection with dramatic performances (Bevegni 2014: 322-4; cf. Arist. Po. 1459b26-31, with Micalella 2009: 247-8). Hero’s references to πολλαὶ τε
καὶ ποικίλαι διαθέσεις (XX.2 [64.12]; cf. Spir. 2.18, with reference to the natural elements) and to a broad range of dissimilar movements (XXII.2 [70.16]; cf. Spir. 28.14-15) suggest the intentional use of kinetic varieties to entertain and captivate the audience. Hero’s own arrangement is, after all, one full of delight (II.12 [14.14-16]; cf. XXI.2 [68.17-18]). Another aspect of ποικίλα is its ability to stimulate more than one sense (see Grand-Clément 2015: 413-15). Hero’s descriptions of the devices engage the reader’s imagination not only on the visual level, but also on the auditory and tactile levels (Roby 2016: 116-18). Information about sound effects (woodworking sounds: I.5 [4.13], XXII.4 [72.3], XXIV.4 [82.20]; kettledrums and cymbals: IV.2 [18.10-11]ευς, IV.3 [18.19-20], XIV.1 [50.16-17], XIV.2 [52.2] and [52.5-6]; peal of thunder [or similar]: XX.3 [66.4], XX.4 [66.14], [66.15] and [66.18], XXII.6 [74.1]), along with tactile and material indications (e.g. lightness: II.2 [6.18] and [8.1], II.9 [12.9], IX.4 [32.5], XXIII.1 [74.7], XXV.1 [80.7]; smoothness: II.3 [8.4-5], VI.1 [54.11], XXIV.2 [82.2], XXVI.2 [92.2]), contributes to recreating a multi-sensory experience for the reader, thus enhancing (syn)aesthetic appreciation of the work; on aesthetic-oriented descriptions in the treatise, see Roby (2016: 146 with n. 25), citing, among others, II.12 [14.12] and XV.2 [52.12-14] (add XXVI.1 [90.12-13] τόπους κενούς... ἰδίως ἀπεργαζομένους).

1.1 [2.5] τὸ ἔκπληκτον τῆς θεωρίας <***>. This expression is not easy to translate, mainly because θεωρία has multiple meanings. Alexander (1993: 59; cf. 97-8) interpreted the term to mean ‘intellectual study pursued for its own sake’ (see LSJ s.v. III.2.b), whereas other scholars, including editors and translators, understood it as ‘spectacle’ (Baldi 16; Schmidt 339; Murphy 11, adapted by Tybjerg 2003: 451) or ‘sight’ (‘vista’, Cambiano 1994: 621; cf. LSJ s.v. III.3). The latter sense is certainly the primary one, as confirmed by the reference to the notion of ἔκπληξις, strong emotional impact upon the audience (cf. esp. Anon. Vit. Aesch. 14 and Pl. Ion 535b2-3, with Pace 2008: 232-3; on the adjective ἔκπληκτος, see below). In order to uncover deeper levels of meaning, we must turn to Hero’s concept of wonder.

According to Tybjerg (2003: 449, 463-4), Hero’s concept of wonder is two-fold: on the one hand, it refers to ‘intellectual surprise’, that is to say, the kind of wonder experienced when learning about the causes of mechanical phenomena...
(Mech. 2.33 = 172.4-11 Nix); on the other hand, it refers to Aristotle's aporetic wonder (Metaph. 982b12-21 and 983a11-21, where he mentions automata), which the philosopher describes as leading to knowledge. Tybjerg (2003: 464) implies that the latter form of wonder is particularly characteristic of automata (see already Meißner 1999: 58-9, cited by Roby 2016: 147), insofar as it stems from an epistemic disparity between the uninformed audience and the experienced mechanician. Hero's wonder, however, is much more than this. As shown by Nightingale (2001: 49-53; 2004: 261-5), in the Parts of Animals (645a7-23) Aristotle conceives of an aesthetic form of wonder that accompanies, rather than precedes, the contemplation (theoría) of animals. What is most relevant here is that, in order to illustrate the investigation of the animal world, Aristotle adduces the example of artistic representations (PA 645a11-15):

καὶ γὰρ ἂν εἰς παράλογον καὶ ἄτοπον, εἰ τὰς μὲν εἰκόνας αὐτῶν [i.e. τῶν ζῴων] θεωροῦντες χαίρομεν ὅτι τὴν δημιουργήσασαν τέχνην συνθεωροῦμεν, ὅσον τὴν γραφικὴν ἢ τὴν πλαστικὴν, αὐτῶν δὲ τῶν φύσει συνεστὸτον μὴ μᾶλλον ἀγαπῶμεν τὴν θεωρίαν, δυνάμενοι γε τὰς αἰτίας καθοράν.

It would be strange, and contrary to reason, if we take pleasure in contemplating representations of these things [i.e. the animals] - because we are gazing at the art which fashioned them, as, for instance, painting or sculpture - but do not take more delight in the contemplation of those things formed by Nature, despite being able to observe the causes.

Commenting on this passage, Nightingale (2001: 50; 2004: 263) notes that both artistic and philosophic contemplation entail the theoretical apprehension (“viewing”) of a technical design. This aspect is brought out most clearly by the phrase τὴν δημιουργήσασαν τέχνην συνθεωροῦμεν (the verb συνθεωρέω here ‘indicates the desirability... of an aesthetic experience of mimetic art’, Haliliwell 2002: 181). In order to properly understand Hero’s notion of wonder, we must therefore take into account the fact that automata are, by definition, mimetic objects (Gem. ap. Procl. in Euc. 41.13-14; cf. Papp. 1024.26-7; Cambiano 1994: 624-5; Introduction, pp. lxvii-lxviii with n. 107). Another Aristotelian
passage helps us gain a clearer insight into the ways in which aesthetic wonder would have arisen from the θεωρία of automata. In the Poetics (1448b15-19), the Stagyrite distinguishes between the pleasure derived from recognising and understanding a mimetic work qua representation and the pleasure taken in technical craftsmanship (ἀπεργασία), colour and other material properties. As Halliwell (2002: 185) cautions, however, such distinction is possible only as a result of an imperfect aesthetic experience. The passage cited above from the Parts of Animals, by making repeated reference to theoretical activity, indirectly confirms this. Thus, just as mimetic works are the product of a δημιουργήσασα τέχνη (PA 645a11), Hero’s automata are δημιουργήματα (I.2 [2.14]), and it is telling that at 1.7 [4.22-6.2] the reason adduced to explain why the crafters of automata (οἱ δημιουργούντες) would traditionally have been called ‘wonder-workers’ is, indeed, τὸ ἐκπληκτον τῆς θεωρίας (Cambiano 1994: 621). In this way, Hero creates a link between everlasting, if not ever-growing, wonder (cf. Aristotle’s definition of ἐκπληξίς as θαυμασία... ὑπερβάλλουσα, Top. 126b17) and the aesthetico-cognitive apprehension of the automata as both mimetic artworks and crafted artefacts, an experience that allows the audience to take ‘ekplectic’ pleasure in the recognition and understanding of intricate mechanical devices as representational objects and, at the same time, to luxuriate in artistic and material features (e.g. technical accuracy: XXIV.1 [80.8], XXVI.1 [90.13]; colour: XXIV.2 [80.11-13], XXVIII.3 [102.1-2], XXX.4 [108.5], XXX.6 [110.3-4]). Wonder in the Automata can, but does not necessarily have to, arise from ignoring the mechanical causes behind the spectacles. Ripe with meaning, the expression τὸ ἐκπληκτον τῆς θεωρίας would have alerted the reader to the aesthetic sense of wonder felt, in varying degrees, when ‘viewing’, ‘contemplating’ and ‘studying’ the automata. All in all, Hero’s wonder does not merely concern, as Berryman (2009: 51-3) maintains, the spectators’ perceptions of mechanics, but first and foremost its ‘theory’ in both its visual and philosophical sense.

For ἐκπληκτος in the active sense of ‘astounding’, LSJ s.v. IV cite only RFIC 53 (1925) 208 = SEG 3.774.5 = IC 3.4.38.5 = Ep. 44.5 Martínez Fernández γλάθαις ἐκπλήκτους (first century BCE c.). Unsurprisingly, Crönert (app. crit. to SEG 3.774.5) glosses it as follows: ὡστε ἐκπλήττεσθαι πάντας ὀρόντας. According to Levi (1925: 209), who first published the Cretan inscription, the ad-
jective bears this sense also at Orph. H. 39.10 (erroneously cited as 38.10) ψυχής ἐκπλήκτου. But the meaning will most certainly be passive there; see LSJ s.v. II; Fayant (2014: 334), translating ‘épouvantée’.

On the lacuna, see note on 1.1 [2.3-4].

1.1 [2.6-7] ἄστι γάρ... παραλαμβανόμενον. This powerful rhetorical statement presents automata-making as an encapsulation of mechanics (Roby 2016: 266-7; ‘sintesi e coronamento di tutta la meccanica’, Ferrari 1985: 266). Roby (2016: 266) finds it remarkable that mechanics is explicitly described as consisting of ‘parts’. But cf. Ph. Bel. 78.26 (ἄλλο μέρος τῆς μηχανικῆς, in reference to pneumatics) and Hero, Bel. 72.5-6 (artillery-construction).

Note the use of the phrase ὃς συνελόντι εἰπεῖν, which adds rhetorical force to the statement (pace Alexander 1993: 94, who, however, omits the present passage from his list of expressions for ‘briefly’ in scientific writings). Cf. 1.6 [4.17] (ἄπλως).

1.1 [2.7-8] διὰ τὸν... ἐπτελουμένον. The verb ἐπτελέω ('complete', 'finish') occurs four other times in the treatise, three times with reference to mechanical movements (XVIII.3 [60.5], XIX.4 [62.10], XIX.5 [62.16]; cf. LSJ s.v. I.1), once with an indeterminate and neuter subject (XII.3 [44.2]). The latter occurrence (τὰ ἐξ ἑκείνῃ ἐπτελεσθήσεται) clearly refers to the sequence of mechanical movements described at XII.4 [44.8-11]. Here, therefore, Hero appears to use the verb to refer not to mechanical knowledge as such (Roby 2016: 266-7, who takes the participle to refer to the ‘parts’ of mechanics; so also Murphy 11), but rather to the various processes involved in the construction of automata, processes which, as a whole, reflect the application of a number of different mechanical principles (cf. ‘was... ausgeführt wird, zur Anwendung’, Schmidt 339). This understanding of the verb also agrees with the immediately following context (I.2-6 [2.9-4.19]), where stress is repeatedly laid on the automatic movements that take place in both the mobile and the stationary automaton.

For κατὰ μέρος, cf. IV.4 [20.7] (components of the mobile automaton), XX.5 [66.20] and XXII.3 [70.19] (both referring to the scenes of the Nauplius play), XXX.1 [106.7] (description of the disappearance of Ajax).
I.2 [2.9] ἡ ἐπαγγελία. The term ἐπαγγελία occurs only twice in Hero, here and at Dio. 286.20-1 (διοπτρικάς ἐπαγγελίας), where it seems to be used synonymously with πρόβλημα ('dioptreischen Problemen', Schöne 1903: 287; so also Lewis 2001a: 281). Here the term refers to that which automata-making 'promises' (so Baldi 16 and Schmidt 339; cf. 'quod hinc expectatur', Couture 243; LS] s.v. 3) to accomplish, and hence to the 'subject' (or, perhaps better, 'scope', as I have translated) of automata-making (Murphy 11 freely translates 'topics to be discussed'). The relationship between these two meanings is close. Note especially Gal. Libr. Propr. 91.9-10 and 92.11 Müller, where the term is used synonymously with ἐπάγγελμα ('subject' of a treatise, LS] s.v. ἐπαγγελία 6). LS] s.v. ἐπάγγελμα 2 understand the meaning of the term as 'that which it [i.e. the treatise] purports [sic] to contain'. The connection is further strengthened by the use of ὑπόσχεσις at XXI.2 [68.17] (cf. LS] s.v. II.3; Verhasselt 2015: 614-15, on S.E. M. 3.3 = Dicaearch. fr. 78 Wehrli). In a similar sense, I.3 [2.17] (ὑπόσχεσις) and XXI.1 [68.7] (πρόβλημα).

I.2 [2.9-10] κατασκευάζονται ναοί ἢ βαμβάκι σώματοι. There is no need to emend ἢ to καί, as tentatively suggested by Schmidt in his app. crit. The context makes it clear that Hero is referring to the types of mobile automata that can be built rather than, as Schmidt's proposal implies, to Dionysus' shrine and its associated altars (see already Baldi 42' n. 2). Hero does not go into detail about the arrangement of his mobile automaton until ch. III., and the opening sections of the treatise are not devoid of general considerations. For more specific references (introduced by οἶνον), cf. I.5 [4.12-13] and I.6 [4.16-17] (both referring to the figures in the stationary automaton).

By the adjective σῶματος, Hero here intends to denote proper proportion between the parts of automata ('proportionati', Baldi 16; 'of appropriate size', Murphy 11; cf. 'apte', Couture 243) rather than moderate size ('von mässigem Umfange', Schmidt 339). The adjective recurs in the same sense at IX.5 [32.7-8] (of the hole through which the millet flows) and XXV.2 [86.6] (of the thickness of a rod). The emphasis Hero lays on proportionality and suitability recalls Philo's descriptions of artillery engines, the components of which are repeatedly qualified as 'proportionate' (Schiefsky 2015: 625-6 with n. 23, citing Ph. Bel. 53.24-5, 54.15 and 54.21 [σωμάτωος]; cf. also 63.28, 66.7 and 67.12-13). Vit-
ruvius, too, uses the concept of ‘symmetry’ to refer to proportionality in machines: Vitruv. 10.10.1 (ballistae and catapults). On Vitruvius’ concept of symmetry, see Lefas (2000).

For σύμμετρος as indicating a moderate size, cf. XXV.4 [86.20] (of a gap, as at Dioptr. 242.1).

I.2 [2.10-11] αὐτόματοι... τόπους. On Hero’s notion of αὐτόματος, see Berryman (2002: 245), who, drawing upon Galen’s comparison between living organisms and theatrical devices (Foet. Form. 4.688-9 Kühn), stresses that it is the internal constitution of the devices that allows a sequence of causally dependent movements to take place ‘automatically’ (namely, without constant human intervention); see also Berryman (2003: 365; 2007: 39; 2009: 142 and, more generally, 201-5). This conception emerges most strikingly in XXVI.6 [94.14-17], where Hero emphasises the centrality of mechanical design to the automatic rolling and unrolling of a scroll of papyrus (Fig. 30): ἕνα οὖν αὐτόματος παραγένθαι ὁ χάρτης... δει προμηχανίσασθαι ταῦτα, with which cf. Ph. Bel. 74.16-18 ἢν δὲ μεμηχανόμενον, ὡστε αὐτομάτην [sc. τὴν χεῖρα]... ἀποσχάζεσθαι. At the heart of any automatic sequence of movements, then, is not external agency (cf. IX.5 [32.9-12]), but a ‘stored power source’ (Berryman 2009: 202-3) that Hero calls ἐνέργεια (I.7 [4.20]; cf. TGL s.v. αὐτόματος: ‘[α]ὐτόματοι αὐτομέχαναι δικαίως αἱ καθ’ αὐτὰς ἐνεργοῦσαι’). For the use of the term in its original sense of ‘spontaneous’, ‘acting of one’s own will’ (Belardi 2005: 44-7 with n. 21), cf. XV.3 [52.17] and [52.20] (both negated).

I follow Brinkmann in emending προσάγονται to προσάγοντες in preference to Diels’ emendation προσαγόμενοι, printed by Schmidt. The middle voice of the verb προσάγω never means ‘move forward’ (‘heranbewegen’, Schmidt 339; so also Murphy 11), but ‘bring to (oneself)’, ‘bring over to one’s side’, ‘take to oneself’, ‘take up’ (LSJ s.v. B.l-II; used only once at Dioptr. 190.16 προσάγομενοι [sc. μηχανήματα] τοῖς τείχεσιν). By contrast, the verb προάγω – which Hero uses elsewhere in the figurative sense of ‘advance’ (Metr. 2.7) – can be used intransitively to mean ‘lead the way’, ‘make an advance’ (LSJ s.v. II.1; cf. Evans 1954: 9). LSJ s.v. II.1 compare the Platonic instances of the verb (Pl. Phdr. 227C1 and Phd. 90b5) with X. An. 6.5.6, where it refers to the march of Cyrus’ army, and Bailly s.v. adds Plb. 14.10.1 (προάγον ἐπὶ θάλατταν).
The corruption of προάγοντες to προσάγονται probably arose under the influence of κατασκευάζοντα in the preceding line. For the scribal confusion between προάγο and προσάγο, see LSJ s.v. προάγο 1.2.c (Ruf. fr. 68 Daremberg-Ruelle =Äët. 5.84) and II.3 (Hdt. 9.92).

With κατά τινας ὁρισμένους... τόπους, cf. IV.1 [18.3-4] (ἐπί τινα ὁρισμένον τόπον).

1.2 [2.11-12] τῶν ἐνότων... κινεῖται. The reference is to mechanical human figures of the kind one finds in Hero’s automata. The participle τῶν ἐνότων no doubt means ‘being in(side)’ (so Schmidt 339 and Murphy 11) rather than ‘being on (top of)’ (‘che sopra vi sono’, Baldi 16); see LSJ s.v. ἔνειμι I.1.a. Couture 243 translates more vaguely ‘ibi dispositorum’.

As noted by Baldi 42c-v n. 3, Hero generally uses the term ζῷόδιον to refer to human-shaped figures. Nowhere in the text does the word refer to animal figures (pace Rossi-Pagano-Russo 2010: 155, who translate ‘figurines representing animals’; cf. rather Spir. 136.23, 138.3, 144.10, 328.2). Hero’s use conforms to the primary usage of the word (on which, see Kosmetatou 2004: 481: ‘the term ζῷόδιον... refers primarily, though probably not exclusively, to statuettes of human figures’ [my emphasis]).

The adverb ἓδη appears to be used synonymously with αὐτόματος/αὐτομάτως. For the same sense, cf. Diopt. 194.15-16 (ἕδη στραφήσεται τὸ τυμπάνον). Elsewhere Hero uses it in the sense of ‘separately’ (Geom. 322.23, Spir. 112.14 and 270.27). Previous translations have placed emphasis on the distinctiveness of each figure’s motion. Couture 243 has ‘proprio et sibi singulares motu’, whereas Murphy 11 believes that the figures move ‘indifferently’ of one another. More neutrally, Baldi 16v (‘con un proprio moto’) and Schmidt 339 (‘für sich’). Note, however, that the figures of Dionysus and Nike are described as moving together (IV.2 [18.13-14], XIII.7 [48.13-14], XIII.8 [50.2-3] and [50.5-6]).


Baldi 16v (‘propositione... che s’ha innanzi’) translated the words προκειμένην πρόθεσιν correctly, but he misconstrued the syntax, taking
ἀρμόζοντα as referring to λόγον. This led him to misunderstand the term πρόθεσις - additionally translated as ‘proposito’ (‘purpose’, cf. LS s.v. II.1) - as denoting the ‘story’ (Baldi 42 n. 4), and to take προκειμένην as referring both to πρόθεσιν and to μόθον. But ἕ is clearly disjunctive. At any rate, Baldi’s translation is more accurate than Schmidt’s ‘dem vorliegenden Plane’ (339). Murphy 11 mistranslates, omitting the participles: ‘according to the argument of the arrangement or story’ (my emphasis). Couture 243 omits even more: ‘qualem [i.e. motum] exigit fabula’. For πρόθεσις as denoting advance planning, cf. GEL 30.63. (The idea is here brought out by the use of the verb πρόκειμαι, as at I.4 [4.8].)

The term μόθος is used elsewhere in the treatise to refer to the stories enacted in stationary automata (generic references: I.3 [2.19], I.4 [4.8] and [4.9], I.5 [4.12], XXII.1 [70.9], XXII.2 [70.11] and [70.15] [both plural]; Nauplius play: XX.2 [64.11], XXII.3 [70.18], XXII.6 [74.3]). The use of the word here suggests that mobile automata, too, would somehow have allowed the (re-)enactment of polyscenic mythical narratives. For the distinction between monoscenic and polyscenic narrative regarding Hero’s automata, see Prou 138 and Cambiano (1994: 614), both of whom speak of ‘acts’ (but see the caveat in Marshall 2003: 261-2 n. 3).

I.2 [2.13-14] εἰς τὸν...τόπον. Cf. Spir. 278.15-280.1 εἰς τὸν ἐξ ἀρχῆς τόπον ἀποκατασταθήσεται [sc. τὸ ὕδωρ]. For this sense of ἀποκαθιστάμαι (‘return’), see also XIII.8 [50.5] (rotating Nike and Dionysus), Spir. 8.6-7 and 8.10; other comparable passages cited by LS s.v. ἀποκαθιστήμι II.1 (add Ph. Bel. 71.14 ἐπὶ τὸν ἐξ ἀρχῆς ρυθμὸν ἀποκαθιστάματι). The use of the verb in XIII.8 [50.5] parallels its use in geometry, where the verb describes figures, both plane and solid, completing a full rotation: DGE s.v. I.3 (Archimedes; but the usage is already attested in Euclid: Heath 1897: clxix); compare especially Hero, Def. 7, 27bis, 76, 83, 95 and 97, Metr. 126.15. For ἀποκαθιστήμι in the (unusual) sense of ‘lay’, cf. XXIII.4 [76.9].

On the lacuna suspected by Schmidt after τόπον, see note on III.2 [16.8-10].

I.2 [2.14-15] δημιουργήματα. Qua nomen rei actae in -μα, the word denotes the automata as the result of the crafting process (δημιουργεῖν: I.7 [4.22-6.1], IV.4
[20.3-4]). According to Chantraine, DELG s.v. δημιουργός, the term δημιουργήματα, meaning ‘work of art’, is attested late; but see, for instance, Aesop. 102, D.H. Comp. 1 and 10, [Longin.] Subl. 13.4. As noted by LSJ s.v., the word is used in a biological context (Hierocl. El. Eth. col. I 11) to designate a living ‘creature’. On the possible Chrysippian origin of this meaning, see Bastianini-Long (1992: 375), who recall the contrast drawn by Porph. Gaur. 47.12-13 between the ἔργα of nature and the δημιουργήματα of a shipbuilder. With this passage one should compare Plu. Ser. Num. 559d = Posidon. fr. 367.27-8 Theiler τὸ γεννηθὲν οὐχ ὡς τι δημιουργήματα πεποιθεμένον ἀπῆλλακται τοῦ γεννήσαντος: ἐξ αὐτοῦ γὰρ οὐχ ὡς ἀυτῷ γέγονεν.

1.3 [2.17] ὑπόσχεσις. Note the variation with ἐπαγγελία (I.2 [2.9], on which see note ad loc.).

1.3 [2.17-18] ἐπὶ τινὸς... ἔχειν. At first sight, it seems strange that a three-dimensional object such as the stationary automaton is designated by the word πίναξ (‘board’, ‘plate’ or ‘tablet’; on the meanings of the term, see Pritchett 1956: 250). The word has received various translations. Paradigmatically, Schmidt renders it as either ‘Tafel’ (cf. ‘tavola’, Baldi; ‘tabula’, Couture), ‘Bühne’, ‘Spielhaus’ or ‘Automatentheater’; cf. ‘(toy) stage’ or ‘(toy) theatre’ (Murphy; evidently based on LSJ s.v. 8); ‘scène’ or ‘théâtre’ (Prou). More recently, Marshall (2003: 261, 263) has rightly argued that the πίναξ is a ‘box’ (cf. XXIII.1 [74.5-7] and note on II.7 [10.18-19]), while also drawing attention to the use of the term in the context of Hellenistic theatre. With its painted backdrops (cf. esp. XXIV.1 [80.4-5], XXV.2 [84.15-86.2], XXV.6 [88.12-13], XXVI.6 [94.9-14], XXVIII.1 [100.7-8], XXIX.1 [104.16-18], XXX.5 [108.15-18]), Hero’s stationary automaton recalls the changeable scene panels placed in the so-called thyromata (‘openings’) of Hellenistic and Roman theatres: for details on the location of the πίνακες, see Penny Small (2013: 116), with further references. More specifically, it calls to mind some descriptions of painted panels in the Delian temple inventories (after 166 BCE). Among the types of Delian panels originally studied by Vallois (1913) and lately reviewed in a more systematic fashion by Jones (2014) appears the shuttered panel, which could rest on a base: [πίνακα ἐπὶ β]άσεως τεθυρωμένον (ID 1417 A col. I 11; further references in Jones 2014:
304*** s.vv. τεθυρωμένος [add 1414 b col. I 21-23] and ἐπὶ βάσεως. It thus becomes evident that what Hero means by κιονίσκος is, indeed, a pedestal supporting the automaton (for this suggestion, see Baldi 42 n. 5, who translates ‘piedistal letto’; cf. also XXI.1 [68.8]). The connection between the nomenclature chosen for the stationary automaton and the Hellenistic tradition of panel painting is strengthened by Hero’s description of the primitive type of device (XXII.1-2 [70.4-14]), a πίναξ equipped with shutters and with a face painted on it (πρόσωπον γεγραμμένον). This description not only harks back to the καλύμματα προσώπων (IG 4².1.102 A col. I 57 and 68; cf. A col. I 58-9 and 102 B col. I 77) that were set into ceiling coffers in the Sanctuary of Asclepius at Epidaurus in the early fourth century BCE (on these, see Hellmann 1992: 92 with n. 23), but also evokes the portraits (πίνακες εἰκονικοί) so frequently mentioned in the Delian inscriptions; cf. esp. ID 1403 Bb col. I 57 πίνακα πρόσωπα ἔχοντα τρία (erroneously cited by Jones 2014: 304*** s.vv. πρόσωπα ἔχοντα τρία as 1403 B.1.28).

For the derivative πινάκιον, cf. XX.5 [68.3].

1.3 [2.19] <φαίνεται> διάθεσις ζωδίων. I agree with Schmidt that a lacuna should be supplemented with <φαίνεται> (he prints a lacuna in the Greek text, but nonetheless translates his proposed supplement: ‘siet man’, 341). Brinkmann’s proposed <γέραπται> might seem equally attractive, especially since the following reference to the arrangement of figures (1.4 [4.2]) is to ἡ... τάξις γεγραμμένη (note the presence of the article). As the passage goes on, however, the emphasis is on the spectator’s viewpoint, as indicated by the reiteration of the perceptual verb φαίνομαι and its compounds. (Tuberg 2003: 457 n. 46 erroneously refers to eleven occurrences of φαίνω [sic] within the portion 1.3-5 [2.17-4.20] as against nine, including ἐπιφαίνεσθαι and ἀφανίζεσθαι, within the same portion: cf. Cambiano (2011: 31). A further argument against Brinkmann’s proposal is that the passive of γράφω is never used of διάθεσις in Hero. The omission of φαίνεται is easily explained palaeographically (the form occurs twice in close proximity: 1.4 [4.2] and [4.4]).

The term διάθεσις, corresponding to the Lat. dispositio, appears to be used in three different ways in the treatise. In a technical sense, as an inheritance from professional criticism (cf. Vitr. 1.2.1-2 and, most relevantly, Plin. Nat. 35.80,
with Pollitt 1974: 23, 163-4), it refers to the position of the figures (or parts thereof) in relation to one another (here, as at I.4 [4.4] and [4.6], XXII.2 [70.10], XXIV.1 [80.5]; cf. I.4 [4.9]). This sense is closely related to the basic meaning of the word (‘arrangement’, LSJ s.v. 1, citing Aristotle’s definition of διάθεσις as τοῦ ἔχοντος μέρη τάξις, Metaph. 1022b1; cf. I.4 [4.2], quoted above). In a broader sense, as an extension of the previous meaning, it signifies the scenic ‘arrangement’ (cf. ‘subject’, ‘content’ of a painting: Pollitt 1974: 162-3, with references) and/or the theatrical ‘(re)presentation’ (LSJ s.v. I.2.a, citing XX.2 [64.11]; cf. also I.7 [4.22], I.8 [6.5] and [6.7], II.12 [14.11], [14.14] and [14.15], IV.4 [20.6], XX.4 [66.9], XX.5 [66.19], XXI.1 [68.10], XXI.2 [68.18] and [68.19], XXII.1 [70.4], XXII.4 [72.5], XXII.6 [74.4]). This meaning overlaps, at least to some extent, with the rhetorical use of the term (‘delivery’ of a speech, LSJ s.v. I.2.a; cf. Tybjerg 2003: 455 with n. 41, who, however, also cites in this connection XXIV.1 [80.5]); in this sense, therefore, διάθεσις can be understood to denote the spectacle (ἐπίδειξις) as delivered to the watching audience (‘disposizione scenica esibita davanti a un pubblico’, Cambiano 1994: 613; on ἐπίδειξις, see note on IV.4 [20.1]). In a narrower sense, it refers to configurations of a mechanical nature (1.8 [6.4] and XX.2 [64.12]). This meaning is brought out most clearly in XX.2 [64.12-14]: πολλαὶ τε καὶ ποικίλαι διαθέσεις... οὐ φαύλως ὁικονομοῦμενα πλὴν τῆς μιχανής τῆς περὶ τὴν Ἀθηνᾶν (Schmidt 405 mistranslates here ‘Aufführungen’; cf. ‘scenes’, Murphy 28). For διάθεσις as mechanical ‘arrangement’, ‘design’, cf. Ph. Bel. 56.14, 59.28, 68.16-17, 68.20, 72.22-3, 76.21, 77.11-12, 78.23; Hero, Bel. 73.7 and 112.10.


I.4 [4.1-2] ΚΕΚΛΕΙΣΜΕΝΟΥ...ΑΝΟΙΓΟΝΤΑΙ. H. Schöne proposed adding <ἐξ ἀρχῆς> after οὖν. This supplement is unnecessary because the context makes it clear that Hero is referring to the first opening of the doors. The πύναξ is presumed to be initially closed also at XXI.1 [68.7-9] and XXII.3 [70.19-20] (ἀνοιχθέντος ἐν ἀρχῇ τοῦ πύνακος).
1.4 [4.3-4] καὶ μετ’ οὖ... αὐτομάτως. The doors of the πίναξ have not previously been described as closing automatically. I have therefore transposed the words πάλιν αὐτομάτως, making them follow ἀνοιχθεὶσαν (cf. αἱ θύραι αὐτόματη ἀνοίγονται, I.4 [4.1-2]) instead of τῶν θυρῶν ('die Thüren wieder von selbst geschlossen und geöffnet', Schmidt 241; Murphy 11 has it the other way around, while Baldi 167 unmistakably takes πάλιν to refer to ἀνοιχθεὶσαν). The πίναξ is initially described as having open doors (θύραι ἔχων ἀνοιγµένας, I.3 [2.18]), which, however, is easily explained by the general and introductory character of the passage. The initial position of the πίναξ no doubt presupposes closed doors (κεκλεισµένου οὖν τοῦ πίνακος, I.4 [4.1]; see previous note). For this closing and opening of the doors, cf. ΧΧΙ.1 [68.10-12] (where πάλιν is perhaps better taken as referring to φαίνεσθαι).


1.4 [4.5-7] καὶ πάλιν... κεµµήν. A careless repetition of the immediately preceding lines (I.4 [4.3-5]), according to Baldi 427 n. 7. This could possibly explain why Couture 244 omits translating these words, which, however, do not seem redundant. Each appearance of the figures as described at I.4 [4.2-9] (cf. ΧΧΙ.1 [68.9-14]) corresponds to a separate scene in the stationary automaton. From ΧΧΙΙ.1-2 [70.4-12], it is obvious that the earlier prototype of πίναξ displayed no less than three scenes, which were later expanded into a five-scene sequence (cf. Introduction, p. lxxx n. 144). The omission of these words would therefore result in an incomplete succession of scenes, with the third and potentially final scene described as optional (I.4 [4.8-9]).

1.4 [4.7-9] καὶ ἢτοι... φαΐνεται. The manuscripts read ἀπαρτίζουσα instead of ἀπαρτίζει (R. Schöne), an obvious enough emendation (also adopted by Schmidt). Schmidt's tentatively suggested addition of «αὐτη» (referring to ἑτέρα διάθεσις in the previous clause) seems necessary to make the clause more intelligible. Cf. Spir. 180.11-182.3 ἀνοιχθήσονται αἱ θύραι· ἢτοι γὰρ ἀὐταί δι’ ἑαυτῶν αὐτοµάτως ἀνοιχθήσονται... ἡ ἑξοσκεῖ τι ἀντισπευδόν βάρος τὸ ἀνοίγον αὐτάς.
The phrase τὸν προκείμενον μύθον denotes the ‘story’, or perhaps even (dramatic) ‘plot’ (LSJ s.v. μύθος II.5; so Landels 1978: 204), that has been ‘set forth’ (so Baldi 17* and Coutre 244), with adverbial prefix προ- presumably meaning both ‘forth’ and ‘beforehand’ (LSJ s.v. πρό D.III.2 and 5): cf. ‘the planned story’ (Murphy 11). A less faithful interpretation in Schmidt 341: ‘das zu Grunde liegende Stück’. On πρόκειμαι as denoting foreplanning, see note on l.2 [2.12-13].

1.5 [4.10-11] τὸν φανομένων... ἔκαστον. There appears to be no need to adopt, as Schmidt does, R. Schöne’s conjecture ἐν (πίνακι ἐν ἔκαστον), originally meant to correct the letters which in Α are found in margin and in Τ and Μ in text. Schmidt failed to notice that Α corrects πίνακι to πίνακα. The marginal letters να are therefore probably intended to repeat the correction for reasons of clarity. Instead of breaking the word at the end of the line, the scribe writes the last two letters slightly above the line and partially into the margin, which can possibly explain what we find in Μ, namely the reduplication of the i and the subsequent intrusion of ἐνα. Cf. also l.2 [2.11-12] τὸν... ζυθίων ἔκαστον.

1.5 [4.12-14] ἀ μὲν πρίζοντα... ἄληθείας. These lines lend themselves to close comparison with XXII.4 [72.1-4] τὰ μὲν πρίζοντα... ἄληθείας. Based on the resemblance between the two passages, Schmidt hesitantly proposed adding ἀτε ἀρίστη καὶ τρυπάνοις χρώμενα> after 1.5 [4.13] ἐργαζόμενα and <τὰ δὲ σκεπαρνίζοντα> after XXII.4 [72.1] πρίζοντα. Tempting though it may seem, restoration of either passage need not be urged. The two textual portions do exhibit a high degree of formal correspondence, but this does no more than point to a common source. Assuming that XXII.4 [72.1-4] are more or less directly derived from Philo, we could explain the present passage as a citation from memory or, perhaps more pertinent, as a revised quotation of the Philonic text.

Note how the lines under discussion display a carefully balanced structure and rhythmic character (but π and ρ are also repeated throughout XXII.4 [72.1-4], with ρ occurring two more times). The alliteration of π, ρ and κ, along with the homoteleuton (πρίζοντα... σκεπαρνίζοντα, picked up by ποιοῦντα), evokes the pounding sound of the woodworkers’ tools and thereby adds to the vividness of the description. Hero's use of such literary devices must be seen as part of a larger ekphrastic strategy of visualisation (on Imperial technical ek-
phasis as drawing on contemporary rhetorical theories of enargeia, see Roby 2016: 90-1). In this connection, Roby (2016: 116-17) draws attention to how detailed descriptions of the auditory features of the machines in both the Pneumati
c and the Automata stimulate the reader’s imagination and enable him or her not only to ‘see’ but also to ‘hear’ the device described (see note on 1.1 [2.4-5]). Hero’s insistence that the figures produce noise καθ’ ἐκάστην πληγήν will surely serve a similar function. What brings Hero’s description closer to rhetorical ekphrasis, however, is not just the inclusion of specific (auditory) de
tails (note the variety of carpentry tasks mentioned in the first part of the clause), but a more general concern with verisimilitude (on the introduction of vivid de
tails as a rhetorical strategy of verisimilitude, see Schmitz 2000: 63-8). By stat
ing that the noise-making of the figures takes place καθάπερ ἐπὶ τῆς ἀληθείας (repeated twice more: XXII.4 [72.3-4] and XXII.5 [72.12-13], both already cited in Cambiano 2011: 31; Marshall 2003: 274, who likens the language of XXII.5 [72.10-13] to that of poetic ekphrasis), an expression which may rightly be re
garded as belonging to what Halliwell (2002: 155) calls ‘the traditional Greek language of “likeness(es)”’ (for a list of relevant expressions, see Halliwell 2002: 20 n. 48), Hero appears to conform to the requirements of rhetorical enar
gēia: cf. esp. [Longin.] Subl. 15.8 and Quint. Inst. 6.2.30, with Webb (2009: 101-3 with n. 41, and 168). It is in this light that we can better understand both Hero’s claim that the painted figures of the woodworkers must be arranged in an ‘utterly plausible’ pose (XXIV.1 [80.5-6] διαθέσεις...πιθανοτάτας, cf. XXI.1 [68.6-7], with a litotes, and not a positive adjective, as suggested by Tybjerg 2003: 455 n. 41) and the occurrence of the word φαντασία with reference to the sketch of the lightning (XXX.1 [108.8-9]). As variously observed in previous studies (Cambiano 1994: 625 with n. 54; Tybjerg 2003: 455-6 with n. 41; Berry
man 2009: 140), Hero holds credibility and persuasiveness close to his heart, and this is where lifelikeness comes into play. Aiming for fictional plausibility, Hero combines the exercise of rhetorical effects with an explicit interest in descriptive vividness and verisimilitude. If it must have cost the reader little trouble to ima
agine the Greek sailors noisily repairing their ships, the watching audience would certainly not have doubted the credibility of the representation (cf. XXIV.1 [80.9], where the flushness of the arms contributes to this effect).
1.6 [4.15-17] δόναντα δὲ... ἀφανίζοντο. I take ὑπὸ to mean ‘under (shelter of)’ and hence ‘in(side)’ (cf. the mathematical use: LSJ s.v. C.2.b). In his app. crit. Schmidt hesitantly proposes emending to ὑπὲρ, a reading found in the margin of manuscript La (the letter πι is here realised neither as π nor as μ, but looks like ι, in a rather compressed form; for this n-shaped πι, cf. Thompson 1912: 189, 191-4; Gardhausen 1913: 180, 196, and Pl. 4b coll. 12-13). In support of his conjecture, Schmidt cites XXII.6 [72.17] ὑπὲρ τὸν πίνακα (of fire coming out of Nauplius’ torch) and [72.20] ἀνωθὲν τοῦ πίνακος, which he takes to refer to the lifting of Athena’s machine. While the torch is placed immediately above the πίναξ (XXVIII.2 [100.11-15]; but perhaps the σεντέ ἐπισκοποῦσα mentioned there can be regarded as part of the overall structure), the figure of Athena is said (XX.2 [64.15-16]) to appear ὑπὸ τὸν πίνακα (ὑπὸ MT : ὑπὲρ AG), and Hero details the mechanisms for its appearance inside the box (XXIX.1 [104.18]). Schmidt 406-7 himself prefers ὑπὸ (‘auf’) to ὑπὲρ (‘über’) at XX.2 [64.15], but warns that the prepositions are frequently confused by the scribes (Supplementum 112). Even assuming that the prepositions have been inadvertently swapped, ὑπὲρ does not give a satisfactory sense as no figure appears outside the πίναξ. Despite being found elsewhere (XXX.7 [110.11]), κατά (Diels) is palaeographically implausible.

Other interpretations of ὑπὸ prove infelicitous. Baldi 17 (‘dietro la tavola’), followed by Couture 244 (‘pone tabulam’), appears to translate the phrase by analogy with ὑπὸ σκηνήν (cf. Schmidt’s suggested ‘hinter der Scene’ [341 n. 1]), whereas Murphy 11 renders it as ‘below the stage’ (cf. ‘under the platform’, Rossi-Pagano-Russo 2010: 156). I cannot find any reference either to the lighting of a fire or to the appearance of figures behind/below the πίναξ. (Note, however, that the dolphins are made to disappear into a chamber underneath the πίναξ (Fig. 31: XXVIII.3 [98.16-18].)

1.6 [4.17] ἀπλῶς. On the adverb as conveying the idea of brevity, see LSJ s.v. II.3. See also Diopt. 234.14. For brevitas as a stylistic device, see note on I.1 [2.6-7].

1.6 [4.17-18] ὡς ἄν τις ἔληται. I follow Schmidt in retaining the manuscript reading ἔληται. H. Schöne proposed emending to προῆλεται. However, Hero never
uses the aorist of προαρέομαι, preferring instead the present. For similar expressions, cf. Ph. Bel. 62.7 and 66.21-2.


1.7 [4.20-2] ἵστι δὲ... ὑπαγόντων. Hero’s preference for stationary automata is reiterated in a similar fashion at XXI.1 [68.5-7] (but καὶ... ἐξουσία is probably best understood outside the boundaries of comparison). To substantiate his preference, Hero cites two reasons: (1) the safety of the mechanism; (2) a higher degree of scenic flexibility. The first reason is clear. Because stationary automata do not involve locomotion, their operation, as well as their construction (ποιήσις, XXI.1 [68.5]), is safer compared with that of mobile automata (Cambiano 1994: 615; for some of the problems associated with mobile automata, see synopsis on II). The second reason is less clear, particularly because at I.8 [6.4-7] Hero praises the scenic adaptability of the Dionysiac arrangement. Cambiano (1994: 615) takes the words μᾶλλον... διάθεσιν to mean the ‘possibilità spettacolari’ of the πίναξ, which he explains by virtue of the dramatic nature of the performance. However, there is no hint anywhere in the text that suggests that the two types of automaton are compared in terms of spectacular outputs and/or variety of movements. Hero’s aim, as Cambiano (1994: 619-20) himself recognises, is to transmit procedural knowledge (II.12 [14.12-14], XXI.2 [70.1-3]), one that can be applied to the construction of other devices and arrangements. The higher degree of scenic flexibility of stationary automata is therefore best explained by the relative ease with which the automata-maker (re-)arranges and prepares the πίναξ for performance (‘facilité qu’il [i.e. le théâtre fixe] offre aux combinaisons scéniques’, Prou 139).

On ἐνέργεια as ‘mechanism’, ‘action’, see LSJ s.v. I.1.a, who cite only the present passage. The term occurs also at I.8 [6.7], where it appears to refer to the actualisation of the arrangement. The latter usage recalls the philosophical use of the term. Cf. especially the description of the motion of the parts of the automata in terms of ‘potentiality’ (δύναμις) and ‘actuality’ (ἐνέργεια’) in Arist. GA 734b10-13.
1.7 [4.22-6.1] ἐκλογαὶ . . . θαυματουργοὶ. For the inclusion of automata-makers (or automata-making) in the category of wonder-working, cf. the classifications of mechanics found in Papp. 1024.12-1026.4 and Procl. in Eucl. 41.3-18 (Introduction, pp. Ixvi-Ixix). The term θαυματουργός nowhere else refers to makers of devices, and in fact in Pappus (Syn. 1024.25) and Philoponus (in GA 77.16, 77.21, 77.23-4, 77.27, 78.17) it is replaced, respectively, by θαυμασιουργός and θαυματοποιός. Berryman (2009: 50) points out that the latter terms are commonly used in late Greek to refer to ‘makers of theatrical devices’, but θαυμασιουργός is found only in Pappus in this sense (and elsewhere only at Eust. Antioch. Engrastr. 15.2 and Georg. Tom. Or. Georg. Xiph. 2.7). (Berryman 2009: 53 n. 136 erroneously refers to Francis 1995 for details on the use of θαυμασιουργός to denote sorcerers and wonder-workers; his study focuses instead on the word θαυματοποιός and its derivatives.) Another term employed in connection with mechanics, and one which carries associations with trickery and magic, is μαγγανάριος (Papp. 1024.14 and 1028.16; Hultsch 1877: 118).


1.8 [6.4] ἐκθέμενοι . . . ἡμᾶς. I follow Schmidt in retaining the manuscript reading ἐκθέμενοι. H. Schöne’s conjecture ἐκτιθέμενοι is tempting but unnecessary. The aorist participle may simply express a logical rather than a temporal anteriority. For ἐκθέμενοι as denoting time, cf. Dioctr. 190.22 and Metr. 126.9 (both accompanied by πρότερον).

The most fitting interpretation is one that reads γε as emphatic (‘my own complex scenario’, Murphy 11) rather than limitative (‘Darstellung... welche wenigstens nach unserer Meinung manngfaltig ist’, Schmidt 343); on emphatic γε, cf. Denniston, GP 115-40. The particle is altogether omitted in translation by Baldi 17° (‘dispositione varia secondo noi’) and Couture 244 (‘certa (?) quam elegimus dispositione’).

1.8 [6.4-6] ἢτις . . . διατίθεσθαι. Brinkmann proposed emending διατίθεσαι to προθεσθεί, citing 1.2 [2.13] (τὴν προκειμένην πρόθεσιν) in support. This emend-
ation is unnecessary and arbitrary. Hero’s point here is obviously to stress the scenic flexibility of his configuration; see note on I.7 [4.20-2].

I.8 [6.7-8] ἐν δὲ... γράφομεν. I adopt Schmidt’s tentatively proposed emendation of γράφομεν to γράψομεν. This slight emendation is justified by Hero’s reference to the ‘following book’ (τῷ ἔξης). In addition to the passage cited by Schmidt in his app. crit. (Spir. 28.13-14), cf. esp. Bel. 112.8 (ἔξης καὶ τὰ μέτρα ὑπογράψομεν) and Metr. 46.20-1 (ἔξης δὲ περὶ τῶν ἱσοπλεύρων τε καὶ ἱσογωνίων εὐθυγράμμων γράψομεν).

II [6.9-14.16] Constructional preamble
Before detailing the construction and operation of the mobile automaton, Hero sets out a series of conditions for achieving mechanical success, each of which is introduced by δὲ (II.1, 2bis, 3, 4, 6, 8, 10, 11bis, 12) or ἀπέργητον (II.2, 4). There are concerns with stability and weight distribution (II.1, 8); concerns with materials and their properties (II.2, 3, 5-6, 9); concerns with (mechanical) implements and their basic arrangement, with recurring emphasis on cords (II.4-5, 7-8, 10-11); concerns with friction (II.1, 4) and jamming (II.4 σφίγμα, 11), and with some of the principles underlying (different types of) motion (II.7-10); see Cambiano (2011: 31-2 with n. 13). Despite the relative lack of (interest in) constructional details, much of what comes later in the treatise (especially, but not exclusively, in Book One) relies heavily on the information contained in this preamble. Cambiano (2011: 31) argues, somewhat tentatively, that the use of the future form ἀπέργητον (but cf. also II.4 ἔσται, 5 ἔσται, ἐσόμεν, ἐλιγμεν, ἀποκόμηκεν, 11 ἐλιγμεν, 12 ἀναστρέψαται) suggests that Hero’s preliminary instructions presuppose the absence of an already constructed prototype, but the claim that the mechanical components will have to be lubricated (II.4 καὶ ἔξης... ταῦτα) clearly implies a completed device (as also recognised by Cambiano 2011: 32). In the concluding paragraph (II.12), Hero, by creating a link back with I.8, reaffirms the superior aesthetic (cf. χαριστέραν... διάθεσιν) and mechanical status of his own model over the ancients.

II.1 [6.9-13] Δὲὶ δὲ πρῶτον... ἐπινεύσωσιν. The carefully balanced and repetitive structure emphasises the significance of the characteristics of the ground and, in
particular, their role in averting potential stability issues. Note especially the repetition of μήτε and the almost chiastic relationship between καταδύνωσι πιεζόμενοι and βιαζόμενοι... ἐπινεύσων (with a contrasting pair of phrases symmetrically attached: πρὸς ἀνάβασιν... εἰς τὸ ὅπισθω).

The ideal ground surface is likely to be paved with stone slabs: cf. Sor. Gyn. 2.44.2 στερεόν δὲ καὶ ἀπόκροτον τὸ ἔδαφος, ὡς ἂν κατὰ τὸ πλεῖστον λίθος ἐστρωμένον, where the phrase λίθος ἐστρωμένον seems to be used instead of λιθόστρωτον, a late term usually denoting paved streets (on which, see Lolos 2003: 161-2). For ὀμαλός as synonymous with ἴσος, cf. S.E. M. 3.95-6 τὸ ἔχον ἐξ ἴσου τὰ μέρη κείμενα, τοιτέστι τὸ ὀμαλόν· οὕτω γοῦν τὸ ἴσον ἔδαφος καλοῦμεν ἀντὶ τοῦ ὀμαλόν’. The flatness and evenness of the surface serve not only to prevent overload and loss of equilbrium but also to minimise friction.

II.2 [6.14-15] ἀλλὰ δὲ μὴ... διατιθέναι. A similar point about the need to compensate for uneven ground is made by [Apollod.] Poliorc. 173.9-12 (where a siege tower is provided with a separate base, ὑπόθεμα); on this passage, see the brief comments of Whitehead (2010: 119).

I follow Schmidt in emending the nonsensical ἀποθάσαντας (AG) to ἀπορθάσαντας. In support of this emendation, Schmidt (app. crit. ad loc.) quotes Papp. 166.2 (τύμπανον πρὸς κανόνα ἀπορθωμένον), but cf. also Spir. 204.5, where the verb refers to evening out a surface. In his app. crit. Schmidt tentatively suggests adding <ὑπαλλείπει> before the participle, but this supplement seems somewhat redundant in the context. The participle ὑποθήσαντας (‘having placed under’) which the second hand of M wrote in the margin is tempting, especially in light of Ps.-Apollodorus’ usage of ὑπόθεμα, but would probably require a dative or ὑπὸ + accusative (perhaps something like ὑποθήσαντας τὸ αὐτομάτῳ or ὑπὸ τὸν αὐτόματον). Prou’s ἀποθήσαντας (‘having thrust away’, ‘having pushed back’) is not only implausible, but also contradicts the statement that the boards should be placed on the floor.

II.2 [6.15-17] ἐν αἷς... καλλίσθαται. For the use of railways in theatrical settings, see Introduction, pp. lxvii-lxviii. (Prou 143-4 was naïf enough to think that the system described here had been invented by Hero.) There is no need to emend ἐν
to ἐφ’ (Prou). Hero uses ἐν + dative in the same sense (‘on’, ‘over’) at XXV.7 [90.3-4] (ἐφ’ Prou); but cf. also Bel. 105.4 (ἐν τῇ σανίδι).

The adjective ἑφηλιώτικός, formed from ἑφηλίω (ἐπί + ἥλιον, ‘nail on’), is a hapax legomenon. Baldi 43’ n. 10 corrected the manuscript reading at his disposal (it is unclear whether he found διεφηλιωτῶν or διεφηλιωτῶν, as he mistakenly cited both) to διεφηλιωτῶν, probably intending διεφηλιωτῶν (but neither διεφηλιώτικός nor διεφηλίω is ever attested). It is difficult to see how such a reading, if acceptable, could make sense grammatically, since it has the disadvantage of eliminating διά and making the genitive διεφηλιωτῶν depend on σωλήνες (‘canaletti di regeletti imbroccati’, Baldi 17’).

II.2 [6.17-18] δὲ δὲ τὰ... ξύλων. Hero does not specify here the kind of wood to be used, but later on he mentions fir (XXVI.2 [90.17]). (The use of lightweight wood is not limited to mobile automata: XXIII.1 [74.7].) Other woods, such as cedar and pine, may have been a viable alternative (Thphr. HP 5.7.1, on shipbuilding), although fir has the advantage of being lighter (Thphr. HP 3.9.7; see Meiggs 1982: 118). For a contrast between ‘sturdy’ (ἐκτονα) and ‘light’ (κούφα) wood, cf. Bel. 102.5-7 (where the latter is recommended for components not subject to wear). This contrast is reminiscent of Bito’s more explicit instructions: ὅσα γὰρ εἰς τὰ ἐπιμήκη καὶ τὰς σανιδόσεις, ἢτοι πεύκινα ἢ ἑλάτινα ἢ πιτύνιναι ὅσα δὲ εἰς τοὺς ἄξονας καὶ τροχοὺς, δρύινα ἢ μελέινα, τὰ δὲ αὐτὰ καὶ εἰς τοὺς κανόνας καὶ τὰ ὑποστυλῶματα (Constr. 52.3-5).

II.2 [6.18-8.2] κἂν ἐξ... γάνηται. ‘Le caisson roulant doit être du moindre poids possible, afin de ménager l’effort moteur’ (Prou 159). Lightness of construction (to paraphrase Prou’s words) provides mechanical advantage as it lessens the effort required to overcome the weight of the device, the forces of inertia and friction (see Pauwels 1980: 149). The amount of friction depends, in fact, on the load applied to the bearings. On the different types of bearing, see note on II.3 [8.5-7].

II.3 [8.3] ὅσα... ποιεῖται. I follow Brinkmann in retaining the manuscript reading ὅσα and emending ποιεῖσθαι to ποιεῖται because a finite verb is needed. Schmidt (ὁς ἐν... ποιῆται) unnecessarily gives the text an indefinite sense (but strangely
he does not emend the following κινεῖται to κινήται). For the phrasing, cf. X1.8 [40.6].

II.3 [8.4] ἐντορνά τε ἀκριβῶς. Perhaps a dim echo of Arist. Cael. 287b15-16 κατ’ ἀκρίβειαν ἐντορνος [sc. ὁ κόσμος], although the unusual adjective ἐντορνος (ἐν + τόρνος) is used elsewhere to denote round bodies which are turned on the lathe. Pl. Lg. 898a4-5 τῶν ἐντόρνων...κύκλων, 898b2 σφαίρας ἐντόρνου; cf. XXVI.2 [90.19] (πυρηνία), Papp. 1102.13 (τύμπανα) and DGE s.v. 1. The adjective/adverb combination ἐντορνος ἀκριβῶς is found in a theologico-cosmological context at Bas. Caes. Hom. in Hex. 3.4 (argument against the sphericity of the heavens). Given Hero’s insistence throughout the text on the use of the lathe (X1.2 [36.9-10], [36.12-13], XXVI.7 [94.20], [96.2]; cf. XVI.2 [54.16] ἐντετορνεύσθω σωλήν), it is best to retain the original sense of ἐντορνος (‘lathe-turned’): cf. Baldi 17ν (‘tomite’) and Couture 245 (‘tomata’). Schmidt 345 (‘recht rund’) and Murphy 12 (‘perfectly round’) translate more loosely. The adverb ἐντορνως is attested only once (cf. app. crit. to XXIII.3 [76.4]), but, judging from its context, it appears to be a late insertion.

II.3 [8.4] περὶ ἀ κινεῖται. The subject of κινεῖται, which must be supplied, is the preceding ὅσα (thus Couture 245, Schmidt 345, Murphy 12); contra, Baldi 17ν, who unwisely construes περὶ as absolute and ἀ as the subject of the relative clause.

II.3 [8.5-7] οἶν...χαλκάς. Two types of axle configurations, using different bearings: κνώδακες and χοινικίδες (even though the latter configuration is not mentioned anywhere else in the treatise in connection with the figures). Recent investigations by Keenan-Jones–Ruffell–McGookin (2016: 174-79, 181-2) have shed light on the characteristics of these bearings as emerging from a variety of sources. While the κνώδας is a thin, probably pointed pivot (either fixed or rotating within its socket, as in the Automata: Fig. 3), the χοινικίς, cylindrical in shape, generally denotes the hub (as at X1.3 [36.15], XI.4 [36.24], XI.7 [38.15], [38.17], [38.22], in the context of snake-like motion) or the collar of a wheeled axle (but it usually refers to hinge sockets in inscriptions); it, too, can be either fixed (as in the present passage) or rotating (its rotation generally being inde-
dependent of the movement of the axle). The choice of iron over bronze (on which, cf. Orib. 49.3.5-6) and the physical characteristics of the κνόδαξ, provide the former type with high wear resistance and a low coefficient of friction. For Hero’s predilection for κνόδακες over χοινικίδες, cf. XI.8 [40.3-7].

As for ἐπινελίς (‘socket’), the term is not attested outside Hero. It appears to be used quite interchangeably with πελίς (V.3 [20.20]; cf. [ApolloI.] Poliorc. 148.8) and ἐπινελίδιον (X.1 [32.21] and [32.22], XI.9 [40.10], XXVI.2 [90.19]).

II.3 [8.8] συνεσμηρισμένας. In his app. crit. Schmidt notes that the second hand of T corrects σμηρισμένας to συνεσμηρισμένας. I cannot find the presence of two different hands here, even though the first five letters of the word appear to be written in lighter ink. Even assuming that a correction occurred, it is hard to say whether the original reading was σμηρισμένας or, rather, μηρισμένας.

συσμηρίζω is a technical term found only in Hero. It is much more frequent than its un compounded form σμηρίζω (17 occurrences against 2), which is likewise un attested elsewhere. Of uncertain origin (perhaps derived from σμήω/σμάω, ‘rub’, ‘wipe’; cf. Frisk, GEW s.v.), σμηρίζω is explained as meaning ‘to smooth so as to make an air- or watertight joint’ (cf. Spir. 78.2-4). The compound form consistently refers to two tubes (or two cone-shaped containers: Spir. 186.17-18) fitted one inside the other (cf. XIII.3 [46.8]), the whole structure being called σμήρισμα (e.g. Spir. 54.11) or σμηρισμάτιον (e.g. Spir. 54.1); see LSJ s.v. σμήρισμα 1 and Drachmann (1948: 50). It is surely far-fetched to posit a relationship between σμήρισμα and μήριμα, as does Meiser (quoted in Schneider 1801: 120-1); on the latter term, see note on II.11 [14.4].

II.4 [8.9-11] καὶ ἔλαιον... γένηται. On the use of oil as lubricant, cf. Vitr. 10.7.3 supenis in modiolis emboli masculi torno politi et oleo subacti. Unfortunately, neither Vitruvius nor Hero specifies the type of oil to be employed, but we can perhaps rule out olive oil (pace Murpy 40 n. 3) because of its superior quality (see Harris 1974: 33) – unless, of course, the cheapest and lowest grade (ἔλαιον χαλδάιον) was utilised (on qualitative distinctions for oil, see Mayerson 2002: 101-5, 108-9). Note that the term ἔλαιον has a broad semantic spectrum and is best understood in the generic sense of ‘(vegetable) oil’ when occurring unqualified (Mayerson 2001: 115-17, drawing on Sandy 1989: 18-24).
R. Schöne's deletion of the first πάντα (accepted by Schmidt) is unnecessary, since the expression κατὰ πάντα τρόπον makes good sense taken together with the following εὐκύλιστα (‘easy to rotate in every possible way’, i.e. ‘in every possible direction’; cf. ‘in tutto, e per tutto’, Baldi 174). Nor is it necessary to emend τρόπον to τόπον (Brinkmann), as that would imply that the implements could be made to rotate easily either in their entirety (κατὰ πάντα τόπον, cf. Hero, Spir. 12.19) or in part. R. Schöne compared Hero's words with Ph. Parasc. 88.32 and 96.4, where the common phrase κατὰ τρόπον (‘fitly’, ‘duly’, as with LSJ s.v. τρόπος II.4.b) is used. To these Schmidt (app. crit. ad loc.) added Hero, Bel. 73.8 and Dioptr. 290.12 (context corrupt), but he failed to notice that the expression κατὰ πάντα τρόπον occurs elsewhere in the corpus (Bel. 102.5). Perhaps part of the problem perceived by R. Schöne and later by Schmidt has to do with the indeterminate pronoun ταῦτα, but even assuming it does not refer to all of the components mentioned at II.3 [8.5-7], κατὰ τρόπον is not necessarily better than the transmitted text, which, in any case, implies proper rotation. Untroubled by any such concerns, Couture 245 and Murphy 12 omitted translating these words.

Among the main manuscripts, only G, M and T have πάντα between κατὰ and τρόπον. A, instead, has πάντι (written as παντ’, which I have reproduced in my app. crit. ad loc.). The scribe of A commonly employs two vertically aligned dots in combination with τ (‘dotted τ’) to express τα (on this abbreviation, see Allen 1889: 3-4), but in this case he seems to have forgotten to write them down.

II.4 [8.12-15] δεῖ δὲ καὶ... κατεστάθησαν. Because what is sought is non-elasticity (rather than ‘constant tension’, as believed by Murphy 40 n. 4), cords are made of material other than sinew (II.6 [10.4-5]), possibly hemp or flax (for the latter, see already Murphy 40 n. 3). Non-sinew cords need to be pre-treated (or ‘pre-tested’, as at II.5 [8.21]) like sinew spring-cords but, unlike the latter, their pre-stressing greatly reduces, if not removes, springiness (the whole process, which is performed manually, is described at II.5 [8.16-10.1]; cf. Dioptr. 254.13-15 and 262.13-14, passages in which a cord that has been (pre)-tested is defined in terms of its ability to maintain a constant length); on the stretching of spring-cords (with or without the aid of an instrument called ἐντόνιον), cf. Ph. Bel.
61.6-16, Vitr. 10.12.2, Hero, Bel. 98.10-99.1, 107.10-108.7. See also note on II.6 [10.7-8].

There is a logical leap from the considerations of II.3-4 [8.3-12] to the statement that the cords are used εἰς ταῦτα (εἰς clearly expresses purpose since it depends on προσχωμένα and cannot be taken as indicating direction: cf. ‘on these moving parts’, Murphy 12). Even though the function and the positioning of the cords have not yet been discussed at any length (the first discussion of these matters occurs at II.7 [10.11-14]), the reader can easily fill the gap in the argument by taking ταῦτα to refer to the movements effected by means of the bearings.

II.5 [8.16-17] βαλλόντες...εὖ μάλα. If we accept the manuscript reading λαβόντες, we have to construe περὶ with διατείναντες (which is quite uncommon) and delete the comma after πασσαλίσκους. In his app. crit. Schmidt tentatively proposed περὶβαλλόντες on the basis of V.4 [22.10] and VI.2 [24.11], but H. Schöne’s uncompounded form has the advantage of being easier to explain palaeographically, i.e. through simple letter inversion. The verb βάλλω is also used in a comparable way at Mech. Frag. 3.2 = Papp. 1132.8 ὀπλον βάλλοντες περὶ αὐτό [i.e. ξόλον]. It is unnecessary to join the two participial clauses with a coordinating καὶ (Diels) since asyndetic coordination is not unknown to Hero: see, for instance, XI.3 [36.17].

II.5 [8.19] κηρόν μετὰ ἁπτόνης. The same mixture is used for gluing loops of cord onto the axle that imparts movement to the doors of the πίναξ: XXIII.7 [78.13]. Commenting on the latter passage, Prou 224 n. o identified this compound with the so-called ζώπισσα (‘live pitch’, i.e. pitch and wax from the hulls of ships). It is not clear whether Hero’s compound is ζώπισσα or simply pitch and wax (no salt added). Note, however, that Hero is referring to wax mixed with pitch as opposed to pitch mixed with wax (cf. the definitions of zo-pissa/ζώπισσα by Plin. Nat. 16.56 and Dsc. 1.72.5). This could perhaps be taken as an indication that the two substances were mixed together in different proportions. At any rate, the compound clearly serves here as a bonding agent. Similarly, resin (but not wax, as far as evidence goes) was probably used in the pre-
preparation of hair-rope for catapult springs (Marsden 1969: 76 n. 2, on Plb. 5.89.9; cf. also Landels 1978: 111, although the passage is left unspecified).

II.5 [10.1-3] ἕ... ἐγραμμέν. The scribe of Α has corrected ἕ to what seems to me to be one of the abbreviated realisations of καί (something like κῒ), one that is frequently confused with ἑ. Schmidt’s app. crit. does not record Α’s correction, possibly because it closely resembles ἑ. The confusion between the two conjunctions might explain why the corrected reading was not recognised as such by the scribes and, consequently, was not copied in any other manuscript. At any rate, such a correction (already proposed by R. Schöne) does not seem quite right, since Hero is envisaging a scenario in which the procedure he has just described (II.5 [8.16-10.1]) does not yield the most desired results. So, the words ἕ πάλιν correctly introduce an alternative; cf. I.4 [4.8] and Metr. 4.29-6.1.

The manuscripts have ἐξαρτήσαντες in place of ἐξαρτύσαντες (Brinkmann and H. Schöne; also adopted by Schmidt), but this is an error owing to iotaism. The verb ἐξαρτάω (used once at XXVII.6 [94.10]) would require both a direct and an indirect object, and the phrase ἐξαρτήσαντες τὸ αὐτόματον (‘having hung the automaton’) would hardly make sense in the context. Baldi 17 alternatively followed by Couture 245, translated ad sensum (‘dopo averle attaccate [sc. le corde] alla Machina se Movente’) by turning the direct object into the indirect object and by supplying ‘cords’ as the direct object of ἐξαρτήσαντες. In support of his correction, Brinkmann adduced some examples of Philo’s use of the verb ἐξαρτῶ (Bel. 54.24) and its derived nouns ἐξάρτυσις (Bel. 56.29, 57.28, 61.6) and μεταἐξάρτυσις (Bel. 58.2 [hapax]; but LSJ s.v. doubt its authenticity), all referring to the process of readying, that is, stringing a catapult (for ἐξαρτῶ in this sense, cf. also Ph. Bel. 54.19, 61.7, 61.8, 61.20, 66.17). Although the verb ἐξαρτῶ does not appear elsewhere in the Heronian corpus, it accords well with Hero’s tendency to make comparisons with catapult technology (II.6 [10.6-7], XIII.9 [50.11]). On the confusion between ἐξαρτῶ and ἐξαρτύω, cf. also the variant readings at A. Pr. 711.

I adopt Schmidt’s emendation παρεκτεταμένην. The only other plausible reading is G’s παρεντεταμένην, but the verb παρεντετένομαι is never attested in Hero or in other mechanical writers. Schmidt rightly bases his conjecture on II.6 [10.4]. Cf. also Ph. Bel. 65.30 (the stretching of a spring-cord).
II.6 [10.4-8] νευρόφο δὲ δήλον. This passage has attracted interest since the sixteenth century. Baldi 43 nn. 12-13 was the first to discuss the term ὑπελήγξ (or, more commonly, ὑπελήγξ, as in LSJ s.v. ὑπελήγξ 1) within the context of the Automata, albeit without being able to explain the comparison drawn with catapult technology. After enumerating three meanings of the term, that is, ‘whip’ (‘flagello’, ‘sferza’), ‘cord serving as a barrier in footraces’ (‘la corda, che si stende inanzi à chi corre il palio) and ‘ox’ or ‘pig-goat’ (‘pongetto’, ‘stimolo de’ buoi’, ‘sferza da porci’), he observed (n. 12) that the word here means ‘wooden bar’ (‘rightetta di legno’), because this is the sense in which it is employed (mostly in its derived form ὑπελήγγιον) in Hero’s description of the mechanism controlling the movement of the Greek sailors’ arms (cf. esp. XXIV.4 [82.13]; on the mechanism more generally, see XXIV.3-5 [82.7-4.7]; Fig. 29). Baldi’s notes 12-13 have been recently examined by Micheli (2005: 254-7), who, following in the steps of Prou 177-8, has elucidated (if only partially) the mechanism of Hero’s ὑπελήγξ, a mechanism which finds no practical application in the treatise. Micheli (2005: 255-7 with nn. 30, 37, 39) makes the following points: first, ὑπελήγξ and ὑπελήγγιον have different functions, the former being a ‘bar’ powered by twisted sinew (ἵμμιτόνον would denote a single bundle of sinew, as at Hero, Bel. 83.4, and not half of it, as intended by Ph. Bel. 68.24-6; see also Marsden 1969: 17; 1971: 49 n. 18) like the arm (ἄγκυών) of the torsion catapult, the latter an ‘axle’ which is repeatedly set in motion by a wheel (ὑπελήγξ), and hence works in a similar fashion as an escapement (see already Preus 1983: 102); second, the quasi-escapement mechanism of the ὑπελήγγιον suggests that the torsion engine comprising the ὑπελήγξ was attached to a toothed device that served as a flywheel; third, the only other attestation of ὑπελήγξ-powered automata is Arist. MA 701b2-3; fourth, more importantly, Baldi’s notes are misleading or pointless, all the more so since the meanings of ὑπελήγξ listed by the Renaissance scholar are not relevant to the understanding of Hero’s text.

Two interrelated questions arise from these observations: ‘In what sense does Hero use the terms ὑπελήγξ and ὑπελήγγιον?’ and ‘What is the relationship between these two devices?’ Prou 177-8 has to some extent already answered these questions by saying that the original mechanism of the ὑπελήγγιον, involving torsion springs, was replaced by a more effective and safer counter-
weight mechanism, while still retaining its ancient name (there follows a brief
discussion of the term ὑσπληξ employed in the senses of ‘barrier’ and ‘swing
door’, but no source is cited in support of the latter). The hypothesis that a differ-
ent mechanism was used (by Hero?) at an earlier stage, together with the incom-
pletely revised state of the text (on which, see Introduction, pp. cxvii-cxviii),
would in effect explain the reference to a missing passage in the treatise (ὡς ἕξης
ζηται δῆλον), a reference which can hardly point to Hero’s own Belopoeica, as
believed by Schmidt 347 n. 1.

Now, if we look back at the term ὑσπληξ, we see that it may refer, among
other things, to a movable barrier controlling the start of a race (LSJ s.v. ὑσπληξ
3). In the wake of the discovery (1970) of a Panathenaic amphora which dates to
344/343 BCE (stored in Athens, Third Ephoria of Classical Antiquities, inv. no.
A6374) and which shows on its reverse such a starting system, Valavanis (1999:
esp. 35-44) reconstructed a new type of ὑσπληξ (for a detailed analysis of the
reverse of the amphora, see Valavanis 1999: 20-31, with Figs. 19, 20-3, 25), as
compared to the one discovered and reconstructed by Brooner (1973: 49-52) at
Isthmia. Valavanis (1999: 32-41, 51) demonstrated that the newer type of
ὑσπληξ, mainly consisting of two poles with a cord or wooden rod stretched
between them, owed its design and technology to the advent of torsion artillery
machines in the fourth century BCE, a fact which is reflected in the shared ter-
minology used to describe certain elements of these devices (for example, the
poles of the ὑσπληξ are called ἀγκώνες, cf. ID 1400.9 and 1409 Ba col. II 43; a
word of caution against making too much of such terminological overlaps has
been offered by Miller 2001: 53 n. 125). So, Hero’s comparison between the
ὑσπληξ and the catapult arm (ἀξον unmistakably signifies the ἀγκών of a cata-
pult, as is made clear by the variant reading ἀγκὼν [sic] of manuscript Pe, pos-
sibly a supralinear gloss rather than a correction), which has already been high-
lighted by Valavanis (1999: 33 n. 95), indicates that Hero is deliberately using
the term ὑσπληξ to refer to a mechanism operating substantially in the same
way as the torsion system depicted on the Panathenaic amphora. Contrary to
what has been argued by Micheli (2005: 255-6), therefore, what Hero has in
mind is not simply a ‘bar’ but a torsion engine in its entirety (why else, then,
paraphrase ἀγκών as ὃ ἄξων... ἡμιτονίῳ if not to designate the whole arrange-

140
ment?). Furthermore, despite Baldi’s erroneous interpretation, not all of the meanings quoted by him are, in some way or other, irrelevant.

Moving on to consider the relationship between ὑσπληγίς and ὑσπλήγγιον, it seems unquestionable that the latter originally derived its name from the resemblance it bore to the starting barrier rather than from the fact that, as suggested by Preus (1983: 103), a lever such as that may sometimes have been activated by a ‘small pig whip’ (LS) s.v. ὑσπληγίς 6). This last supposition is based on the understanding of the word ὑσπληγίς at II.8 [12.1] and [12.3] as referring to ‘twisted cords’, in accordance with LS) s.v. ὑσπληγίς 2 (so also Schmidt 347; Murphy 40 n. 4, in turn, wrongly regards ὑσπληγίς as a common word for the catapult spring), but it is difficult to see why the term should have a different sense from that in which it is used in all previous occurrences, including II.6 [10.9] (mentioned together with the counterweight, as at II.8 [12.1], where τάσις ὑσπλήγγιος may very well refer to the tension controlling the whole mechanism). The connection between the two devices is brought out most clearly at ΧΧΙV.4 [82.19-20] καταπεσεῖται [sc. τὸ ὑσπλήγγιον] ἐπὶ τὸν ἐπίσωμιν ἐπισωμιμένης τῆς λείας καὶ ψόφον ποιῆσε, because ancient descriptions of the ὑσπληγίς include mention of its (downward) motion (cf. esp. Lucianus, Cal. 12 τῆς ὑσπληγίς... καταπεσούσης) and of the noise produced when its poles were pulled down to the ground (cf. AP 11.86.3 ὃς ψόφος ἐν ὑσπλήγγιος ἐν οὐσίᾳ, also quoted by Plu. Praec. Ger. Rep. 804e); see Valavanis (1999: 5 with nn. 28 and 30), from whom I take the non-Heronian references. However, if Hero’s quasi-escapeament ὑσπλήγγιον maintains some links with the automatic ὑσπληγίς, it does not necessarily follow that the particular type of ὑσπληγίς referred to in our passage should be provided with a flywheel to reduce the speed at which the sinew spring-cords would have been released. What, at least, emerges from Valavanis’ (1999) investigations is that rollers could be used to ease the movement of the cords (starting system of Kos, p. 141), but nothing more than that.

Finally, the more general implication of all this is that Hero’s ὑσπληγίς as reconstructed here cannot be straightforwardly compared with the first of the two mechanisms hinted at by Arist. MA 701b2-10:

ὁσπερ δὲ τὰ αὐτόματα κινεῖται μικρὰς κινήσεως γενομένης,
λιομένοι τῶν στρεβλῶν καὶ κρουόντων ἄλληλα τῶν ξύλων,
καὶ τὸ ἀμάζιον (ὁ γὰρ ὀχούμενος αὐτὸ κινεῖ εἰς εὐθὺ, καὶ πάλιν κύκλῳ κινεῖται τῷ ἀνίσους ἔχειν τοὺς τροχοὺς· ὁ γὰρ ἐλάττων ὡσπερ κέντρον γίνεται, καθάπερ ἐν τοῖς κυλινδροῖς), οὕτω καὶ τὰ ξύλα κινεῖται. ἔχει γὰρ ὅργανα τοιαῦτα τὴν τε τὸν νεύρον φύσιν καὶ τὴν τὸν ὅστὸν, τὰ μὲν ὡς ἐκεῖ τὰ ξύλα καὶ ὃ σίδηρος, τὰ δὲ νεύρα ὡς αἱ στρέβλαι· ὁν λυκο-μένων καὶ ἀνιμένων κινοῦνται.

Just as automatic puppets move as a result of a small movement, when the cords are released and the pegs strike one another, and just as the small cart <moves> (for he who rides <in it> sets it in motion straight ahead, and again it moves in a circle because it has unequal wheels: for the smaller acts as a centre, just like in the cylinders), so too do animals move. For they have organs so constituted, both sinews and bones, the latter <being> like the pegs and the iron therein, the sinews like the cords; when these are released and slackened, <the animals> move.

I follow here the text of Nussbaum (1978) rather than that of Jaeger (1913), except for τροχοὺς (line 5), which Nussbaum (1978: 43) has misprinted as τρόχους (same error in Nussbaum 1976: 146). The textual problems of the passage, which had previously been ignored by Jaeger (1913), have been discussed by the most recent editor in Nussbaum (1976: 150-2), with a review of the solutions proposed and interpretations offered by other scholars. The text adopted by Micheli (2005: 256 n. 34) differs somewhat from Nussbaum’s (1978), but the differences between the two texts do not affect the present line of argument. (It is not clear to me whether Micheli accepts Forster’s addition of τὸ before ὀχούμενον [codd. plerique: ὀχούμενος b] at line 4, because of his inconsistent use of round brackets; cf. already the text cited in Micheli 1998: 458 n. 146.) Textual problems aside, Aristotle’s αὐτόματα (‘automatic puppets’) cannot easily be made to correspond to any of the devices described by Hero. Micheli (1998: 458-9), for example, reads the Aristotelian passage through the lens of Hero’s Automata, but his analogy between the puppets and the apparatuses constituting the Dionysian arrangement lacks stringency (such analogy forms the basis of his more recent argument, as laid out in Micheli 2005: 257). Berryman
(2009: 73), in turn, suggests that the starwheel and ὑσπλήγγιον assembly of XXIV.4-5 (why would the moving arm belong to ‘a figure of Hephaestus’?) fits well with the Aristotelian lines, but unfortunately she does not elaborate further. We can at least infer from her diagram of the Heronian device (Berryman 2009: 74 Fig. 2, based on Schmidt 425 Fig. 103a) that she takes the ξύλα of line 2 to correspond to ‘pegs’ attached to the starwheel (cf. also Berryman 2009: 74 n. 75), but the word used by Hero, ἀστερίσκος, rather leads one to imagine a toothed, gear-like wheel. Moreover, the starwheel’s projections, whether they be pegs or teeth, strike not against one another (as Aristotle’s ‘pegs’ do) but against the ὑσπλήγγιον. From a different perspective, Nussbaum (1976: 149-50) tentatively equates the iron component mentioned at line 8 (ὀ σίδηρος) with the axle connecting the wheels of the mobile automaton, but the wheel axle is nowhere said to be made of iron. On the other hand, she observes (p. 149) that Hero’s figures (which she erroneously considers puppets; cf. also Nussbaum 1978: 347 n. 5), unlike most of the automatic marionettes mentioned in ancient sources, cannot be made to move their limbs by means of a mechanism consisting essentially of interlinking pegs and cables (at least following Nussbaum’s reconstruction, but other reconstructions are possible: see Introduction, p. lxxxv n. 158).

[Arist.] Mu. 398b13-19, one of the passages cited by Nussbaum (1976: 147-8) to support her reconstruction of the puppets’ mechanism, distinguishes between two categories: μηχανοτέχναι (‘machine workers’) and νευροσπάσται (‘puppeteers’); the former initiate automatic sequences of movements using the machine’s single release-mechanism (διὰ μίας ὀργάνου σχαστηρίας), whereas the latter make their puppets move automatically by pulling a single rope (μίαν μύρινθον ἐπιπασάμενοι). Hero’s mobile automaton is activated by pulling a cord (cf. IX.5 [32.10-12]), just like a puppet, but all subsequent movements, including those of the figures, occur through self-triggered activation of regulatory devices (cf. esp. XIII.9 [50.12-14] ὅπως τῆς σχαστηρίας ἀπολυθείσης ἀπὸ τινὸς σπάρτοι τὸ βάρος κατενεχθὲς ἐπιστρέψῃ τὸν τε Διόνυσον καὶ τὴν Νίκην), which are indeed missing in Aristotle’s puppets, as noted by Preus (1983: 100).

Returning to the topic of the ὑσπλήγγες, the term, as pointed out by Michel (2005: 257 n. 35) himself, is absent in the Aristotelian passage, and it is hard to accept his interpretation of the words λυομένων τῶν στρεβλῶν (which he translates as ‘corde attorcigliate che si sciogono’) as a clear reference to this type of
device. When Nussbaum (1976: 150) compares the arrangement of Aristotle’s στρέβλαι (i.e. cords wound around a wheel or roller) with an unspecified Heronian mechanism, she is probably thinking of the ἕξελίκτρα (first mentioned at V.3 [22.2]; see note on V.3 [22.2-3]), the bobbin attached to the wheel axle and around which the cord is wound, certainly not of the ὑσπληγξ, which, as we saw above, she understands as ‘torsion cable’ (the lack of any mention of στρέβλαι in the present context excludes the possibility that Hero’s ὑσπληγξ was connected to some kind of wheel). To this must be added that the purpose of the ὑσπληγξ as defined at II.6 [10.8-9] seems to be to impart motion to the mobile automaton as a whole, not (or not just) to the figures. There seems to be no reason, therefore, to suppose that Arist. MA 701b3 contains a reference to a ὑσπληγξ-type of engine rather than simply to (torsion?) cables (cf. MA 701b9-10). Hero, after all, remains our only written source attesting to a possible use of the so-called ὑσπληγξ (‘trigger board’?) as motive force of automata.

II.6 [10.4] οὐδενὶ δὲν. In his app. crit. Schmidt correctly says that A’s οὐδενὶ seems to be a correction. In the wake of the previous editor, I have reproduced the reading of A as it is found in the manuscript (cf. app. crit. ad loc.). A’s reading before correction is οὐδενὸς δὲν, with -ὸς being written in compendio above the v. It would appear that the o has been neatly inked out, and the termination -i added at a later stage. The scribe did not need to add a grave accent because he had already written one when abbreviating -ὸς. Other manuscripts, such as Gκ and T, have οὐδενὸς ἰδεῖ, probably because the scribe, not recognising οὐδενὶ as a correction, regarded the i as belonging to the following word (wrong word-division). The scribe of G, however, corrects οὐδενὸς ἰδεῖ by replacing the o with ᾖ and deleting i (οὐδενὸς ἰδεῖ). I tentatively take the latter reading to reflect οὐδενὶ δὲν. The scribe might have thought it sufficient to replace the penultimate letter of οὐδενὸς or simply forgotten to underline the ε.

II.6 [10.4-5] παρεκτείνεται ἢ συστέλλεται. Schmidt’s tentative conjecture ἢ is preferable to καὶ. Some manuscripts, including A and M, write καὶ compendiously (on the confusion between ἢ and the καὶ compendium, cf. note on II.5 [10.1-3]), and the disjunctive is what we find in parallel expressions, such as Ph. Bel. 68.11-12 ἐπεκτείνειν ἢ συστέλλειν and Hero, Dioptr. 254.15 ἐπεκτείνεσθαι.
ἡ συστέλλεσθαι. Cf. also Hero, Spir. 90.5-7 τῶν σωρήγων ἦτοι λεπτοτέρων
gινομένων **[>]** ἦτοι καὶ παρεκτεινομένων εἰς μήκος ἢ καὶ συστελλομένων.
Here the repeated καὶ presumably marks an addition to the content of the preceed-
ning context (see generally Denniston, GP 293), which, although lacunose, can
easily be reconstructed: cf. Ps.-Hero, Spir. 90.25-7 τῶν σωρήγων ἦτοι
λεπτοτέρων γινομένων ἢ παρεκτεινομένων εἰς μήκος ἢ
συστελλομένων (note the anteposition of the first καὶ and the suppression of the
second).

II.6[10.7-8] ὁ ἄξον κατατεταμένος ἐν τῷ ἡμιτονίῳ. On the referential meaning
of this phrase, see note on II.6[10.4-8].

The reading κατατεταμένος, which is transmitted by AGT, is surely genu-
ine, because it describes the insertion of the axle (i.e. the arm) through the
bundle of sinew. The reading of M (κατατεταμένος), by contrast, is probably a
mistake owing to the omission of γ. A number of manuscripts (Ab, Ac, Bb, La
Lc, Ld) have ἐντεταμένος. This can possibly be explained as an erroneous cor-
rection of κατατεταμένος made under the influence of the words ἐν τῷ ἡμιτονίῳ.
The verb ἐνταίνω is, in fact, used several times to denote the act of stretching or
stringing catapult springs (Ph. Bel. 61.20; Hero, Bel. 78.4-5, 99.3, 107.10; cf.
Hero, Bel. 101.10, 102.1-2; Ph. Bel. 58.20 reads ἐκτείνεται τὸν τόνον, but Diels
thought fit to emend the infinitive to ἐνταίνει: cf. Ph. Bel. 58.27 Diels-
Schramm), or entire torsion engines (Ph. Bel. 56.12, 56.19 and 67.25); hence the
name of the so-called ἐντόνιον (‘stretcher’), a device used to give tension to the
springs: cf. Vitr. 10.12.1-2 and, especially, Hero, Bel. 107.1-110.3; criticised by
Ph. Bel. 57.32-58.5 (on this device, see Marsden 1969: 30-1, 42; 1971: 59 Fig.
23). On the stringing of a catapult, see also note on II.5[10.1-3].

II.6[10.8-10] πάντα δὲ... μολιβής. Of the two power systems (on the ὑσπληγίς,
see note on II.6[10.4-8]), Hero prefers the latter. What appeals to him is perhaps
the counterweight’s wider applicability. Hero insists (II.8 [12.3-6]) that the
movements other than locomotion, too, take place by means of a (single) coun-
terweight. This is ultimately true, even though a secondary counterweight is used
to rotate the figures of Dionysus and Nike (cf. XIII.8-9 [50.6-14]). Murphy 42 n.
29 has tentatively wondered whether this secondary counterweight is the addi-
tional counterweight introduced in the two-counterweight configuration (XIX.2 [60.18-19]). This seems to me to be utterly implausible not just because, as Murphy points out, these counterweights are activated by different means, but especially because they are positioned in different places (outside and inside the σύριξ, respectively).

Prou 162 observes that ‘[p]our réduire le volume de ce contrepoids, on le fabrique en plomb, d’un poids total calculé sur l’ensemble des résistances à vaincre, quantité facile à déterminer par l’expérience’. Indeed, the density and the workability of lead (on which, see Nriagu 1983: 59, 256-7; Wright 2005: 235) make it a good choice for a small counterweight, which is made to sink in the limited space provided by the σύριξ (II.8 [12.6-7], V.5 [22.15]. That Hero is well aware of the heaviness of lead is clear from IX.4 [32.3] and XXX.3 [108.2]; cf. also XV.4 [54.6-7].

II.7 [10.11-14] κοινῆν δὲ...προσηγκυλομένην. The cord cannot be ‘nailed’ or ‘riveted’ (following the manuscript reading προσηλωμένην) to the element being moved, as this would hinder the transmission of the movement. Baldi 18° had apparently already realised the incorrectness of this reading since he translated it as ‘aviluppato’ [sc. il capo della corda], thus anticipating Brinkmann’s conjecture προσηγκυλομένην. Murphy’s translation (‘one end attached to each’, 12) erroneously conflates the μὲν and δὲ clauses into one expression. Hero, however, is describing two different modes of attachment (‘binding’ and ‘looping’) between the cord and either of the elements. The participle προσηγκυλομένην has been conjectured by Brinkmann, and rightly so, on the basis of two occurrences of προσαγκυλόμαι (II.8 [12.4], II.11 [14.8]) and II.9 [12.14-15] (ἀγκύλη). If we look closer at the context of II.8 [12.4], we find the same distinction as we have here, but expressed in less abstract terms (II.8 [12.4-6]). Also relevant is the definition of τὸ κινούμενον ἃς ἄξον...περὶ ὁν ἧ σπάρτος περιεύληται that immediately follows the present passage.

II.7 [10.15-17] τῷ δὲ ἄξων...τροχὸς. In one of the main manuscripts (M), ἀπειλισσομένην is corrected supra lineam to ἐπειλισσομένην (‘twisting’, ‘being rolled up’), but this correction only indicates that the scribe, perhaps identifiable with the second hand, had a poor understanding of the mechanism whereby mo-
tion is transmitted to the wheel axle (on which, cf. also V.5 [22.15-19], VI.1 [24.4-6], XI.3 [36.15-19]). It is self-evident that, by being pulled by the counter-weight, the cord being wound around the axle, and passing through a pulley at the top of the σφιγξ ([V.5] 22.13-14), was unrolled. Here, however, the reader is first presented with the turning of the axle, and then with the unwinding of the cord (τοῦ ἄξονος στρεφομένου καὶ ἀπειλισσομένης τῆς σπάρτου); such a hyster−

eron proteron focuses attention on how the movement is transmitted from the axle to the wheels, thus letting the reader know immediately how the automaton starts moving.

II.7 [10.18] ἐπὶ τὸ ἔδαφος. ἐπὶ is replaced by κατὰ in M, whereas it is omitted in

T. The former reading has better manuscript support (AG) and also appears

much more frequently in conjunction with ἔδαφος than κατὰ does (both outside

and inside Hero’s works). There is only one instance in Hero (V.5 [22.18-19]) of

κατὰ followed by ἔδαφος, but in that case ἔδαφος appears in the genitive, not in

the accusative: the syntagm κατὰ τὸ ἔδαφος is extremely rare, occurring only in

late sources (Hipp. Air. Berol. 129.39.11, Jos. Genes. 2.8.34, Theoph. Cont. 230.6

and Paraphr. rec. in Lyc. Phr. 625). Similarly, all other Heronian occurrences of

the prepositional phrase ‘on the ground’ (II.2 [6.15], XI.9 [40.14], Bel. 89.3,

Diopt. 202.15-16, 204.12, Mech. Frag. 3.1bis = Papp. 1130.11 and 1130.17)

have ἐπὶ governing the genitive (cf. also Ath. Mech. 30.2, [Apollod.] Poliorc.

162.1, 164.3). The preponderance of the genitive in these phrases suggests that

we emend τὸ ἔδαφος to τοῦ ἔδαφος, but it is difficult to rule out the possibility

that this is merely a semantic equivalence (see generally Bortone 2010: 183-4).

II.7 [10.18-19] τοῖς δὲ...πλαλθοῖν. For a similar expression, cf. XXX.3


The term πλαλθοῖν here, as throughout the rest of the book, denotes the ‘base

unit’ of the mobile automaton (cf. III.1 [14.17] βάσις). Perfectly, or almost per−

fectly, synonymous with πλαλθίον and πλαλθεῖον, it can be used to refer to any

kind of ‘frame’ or, more generally, to any ‘rectangular object’ or ‘figure’ (for a

review of these terms and their relationships, see Saliou 2004: 187-9). Both

Philo (Bel. 60.5) and Hero (Bel. 81.8), for example, adopt the word as a tech−

nical term for the wooden frame of a catapult (see Marsden 1969: 57; 1971: 47-8
n. 16), whereas Bito (Constr. 60.1) speaks of πλατύζων as a box (perhaps a ‘shallow tray’, as conjectured by Marsden 1971: 95 n. 48). The word occurs again in the context of stationary automata, where it most certainly designates the frame of the πίναξ. Thus, there appear to be two main uses of the word πλατύζων in the treatise, both of which are related, though in different ways, to architecture and construction.

According to Baldi 43' n. 14, the term (which he mistakenly accentuated on the antepenultimate syllable) is used in architectural contexts of the ‘lowest square part of the base [sc. of a column], namely the socle’, but his words are more correctly applied to the primitive form πλάνθος (cf. LSJ s.v. II.3; but cf. Didyma 38.10 [277/276 BCE] for the diminutive πλανθίς and its Latin equivalent plinthus (Ionic order: Vitr. 3.5.1-3 and 5.9.4; but cf. Vitr. 3.3.2, where plinth is used twice). What is interesting for present purposes is that this more specialised meaning is thought to have been derived from the meaning of ‘building block’, ‘wall block’ (Hellmann 1992: 342, with ‘pierre d’assise’), a meaning which in epigraphic sources is attached not just to the word πλάνθος (IG 13474 A col. I 10, 474 A col. I 95, 474 A col. I 104 [Erechtheion construction work inventory, 409/408 BCE], CID 2.56 col. II C 82 [337/336 BCE] and 2.62 col. II A 2 [335/334 BCE], Didyma 102.22), as erroneously believed by Hellmann (1992: 342), but also to its derivatives, such as ήμελανθίον (Didyma 99.11-12) and πλανθίς (IG 231668.26, 1668.93 [the so-called Arsenal inscription, 347/346 BCE]). This, together with the alternative designation of πλανθίον (‘case’) as βάσις serving as a support for the whole automaton, suggests that Hero’s usage is influenced, even if only to a limited extent, by the architectural meaning of the word and its close relatives (in other instances, the words πλαίσιον and πλανθείον have been interpreted as meaning ‘stand’ or ‘socle’, but it is more likely that they refer to the frame of a votive offering: see Hellmann 1992: 340 n. 3).

As for the usage of πλανθίον in the second part of the treatise, it somewhat parallels the usage of its associates πλαίσιον and πλανθείον in inscriptions, particularly those from Delos. In addition to the more common meaning of ‘frame [sc. of a votive offering]’ (cf. also ID 1443 B col. II 51 and 1446.24 πινάκιον πεταλαισμομένον), both of these words can also refer to the upper frame of a (painted) ceiling coffer (πλαίσιον: IG 13474 B col. I 240-1 and 474 B col. II 246, ID 504 A 13, 504 A 15, 504 A 16 [279 BCE]; πλανθείον: Didyma 103 a.36,
IG 11²:165.22, 165.32 [Delos, 279 BCE]; Saliou 2004: 188 n. 11 further compares Vitr. 9.8.1 plinthium sive lacunar; for discussion of the link between Hero’s stationary automaton and the tradition of panel painting, cf. note on I.3 [2.17-18]. When Hero instructs the reader to equate the dimensions of the πίναξ and the πλινθίου (XXIII.1 [74.5-7]), therefore, he is talking about the ‘skeletal frame’ of the whole πίναξ, not about an ordinary ‘case’ or ‘box’, as translators have understood the term. This interpretation is further confirmed by another architectural meaning of the term πλινθίου, namely that of ‘(stone) door trim’, as attested by papyrological (PDura 19.10 [88/89 CE]) and epigraphic (Dura⁷-⁸ no. 872 [157/158 CE], YCIS 14.1955.139.6 [169/170 CE]) documents (I take these references from Saliou 1992: 91 n. 95, quoted by Saliou 2004: 188 n. 12); see also LSJ s.v. III. 2 (‘window-frame’) and Hellmann (1992: 340 n. 1).

II.7 [10.19] αὐτομάτου. The correct reading (already conjectured by Schmidt) is transmitted only by manuscript F. All other manuscripts have erroneous readings. Two manuscripts (Ea, Ta) appear to correct αὐτομάτος to αὐτόματος, but the nominative singular masculine form does not fit grammatically into the sentence. It is at any rate noteworthy that in Fabr. 93 the reading αὐτομάτου might have been influenced by the immediately following πλινθίου (in place of πλινθίου). The scribe would seem to have misread the ending of πλινθίου in his exemplar, which would presumably have led him to (mechanically) replace either αὐτομάτος or αὐτόματος with αὐτομάτου.

II.8 [12.1-3] τάσιν δὲ ἀν...πλινθίου. We might suppose that the words τῆς λείας have fallen out between τὸ and βάρος (but cf. I.X.4 [32.3] τὸ βάρος τῆς λείας). These words would complete the somewhat chiastic structure of the passage, although τὸ βάρος can no doubt be understood without further specification (cf. V.5 [22.15], [22.16] and [22.20], XIII.8 [50.9], XIII.9 [50.10] and [50.12-13]).

II.8 [12.3-4] αἱ δὲ ἐκτὸς τῆς πορείας κινήσεις. All manuscripts read ἐκ in place of ἐκτὸς. This emendation has been tentatively proposed by Schmidt (app. crit. ad loc.) on the basis of XII.2 [42.11], which likewise refers to the movements other than locomotion of the case. Similar references are found at XVIII.3 [60.3-4] and XIX.1 [60.11] (supplemented), although in both these passages
ektos is replaced by ezothev. But while these prepositions can be followed by the genitive to express an exceptive meaning ('apart from', 'except'; cf. LSJ s.vv. ekto 3 and ezothev II.c), ek is nowhere else attested in this sense (LSJ s.v. eko 1.5, however, record the earlier spatial meaning of 'outside of', 'beyond'). In a later discussion of the treatise, Schneidt (1903: 275) reconsidered his opinion and regarded ek as equivalent to ekto. The preposition is, by contrast, altogether omitted by Murphy 12 ('Movements in a forward direction').

II.8 [12.5-6] apodeidemewn... leiau. Perhaps we should emend apodeidemewn to apodeidemvnoi. Hero prefers the verb apodiadoi to refer to the attachment of cords (or chains: XIII.8 [50.9]) to the counterweight rather than apodeio, which is used only here in the Automata (and only once elsewhere in the corpus in the same way: Spir. 94.9). There is further support for the proposed emendation in the fact that manuscripts oscillate between apodeidemvoi and apodeidemvnos (XII.2 [42.18], XIII.5 [46.21]), and between apodeidesto and apodeidovnoi (V.5 [22.14], XII.3 [42.21], XIII.7 [48.17], XIII.8 [50.9], XVI.3 [54.21]; cf. Spir. 130.2, 180.3 and 180.5). But cf. II.7 [10.13] (prosidew).

II.8 [12.6] eiv tiin sphiug. On the shape and position of the sphing, see note on V.5 [22.12-13].

II.8 [12.6-7] armostos... eic autin. The adverbial pair armostos/eulotos is quite unique. Cf. also XI.2 [36.11] eulotos kai armostos. While armostos is found nowhere else in Hero (and indeed only twice elsewhere: Papp. in Ptol. 91.4 and Hsch. 767 Latte [paroxytone]), eulotos appears 30 times, nearly one-half of the total occurrences of the adverb in Greek literature. In all but one instance (XIV.1 [50.20]), it occurs with verbs of motion, often describing the ease with which mechanical components (chiefly axles) are made to rotate: see, for instance, XI.2 [36.8] and [36.11] (cited above), XII.2 [42.19-20], XIII.7 [48.16], XVI.3 [56.1-2], XVIII.1 [58.12], Bel. 84.4-5, Mech. Frag. 1.1bis = Dioctr. 308.4 and 310.24-5, Spir. 300.7 and 300.16. The combination of the two adverbs may be a stylistic alternative to a more expanded type of phrase such as that found at XVI.1 [54.13-15] peri de to oton [i.e. ton stulobati] peri auton strefesethai (com-
pare this with Spir. 94.4-6; cf. also Mech. Frag. 1.1 = Diopt. 312.4-5) or Spir. 204.5-6 (downward motion of a piston). This is implied, albeit indirectly, by Prou 163: ‘[I]e contrepoids... s’ajuste à la section du tuyau, de manière à pouvoir y descendre aisément’.

The term ἀρµοστῶς has been corrected in A. The scribe added two letters (in all likelihood οι) above the line. According to Schmidt (app. crit. ad loc.), these letters have been written above ως, but a closer look at the manuscript shows that they have been superscribed between ε (= στ) and ω (the accent appears above the final ς). One cannot therefore be sure whether the scribe intended to correct ἀρµοστῶς to ἀρµοστοι or to ἀρµοστοις. It is worth observing that in A, as in T (ἀρµοστοι ως, with οι above the line), the topmost point of ο is the starting point for a cross-stroke that goes straight through i. This might be interpreted as the horizontal stroke of σ, were it not so long. It is difficult to resist the impression that both the scribe of A and the scribe of T copied the whole digram οι from a text they did not manage to decipher correctly.

II.9 [12.8-10] ἐν δὲ τῇ... ἐμβάλλεται. According to the explanation given by Landels (1978: 204), dry sand is preferred in stationary automata because it flows out more slowly, and thus allows for a longer performance. It would have been superfluous for Hero to spell this out, since emphasis is already placed on the properties of millet and mustard (διὰ τὸ κοῷφα τε ἀµφότερα εἶναι καὶ ὀλισθηρά) as opposed to sand. Unlike other translators, who render ὀλισθηρά literally (‘glissants’, Prou 163; ‘schlüpfrig’, Schmidt 347; ‘slippery’, Murphy 12), Baldi 18 (‘flussible’) and Couture 245 (‘flusca’) have the correct understanding of the term (so also Cambiano 2011: 31 n. 13); cf. the use of the term to refer to foods that pass easily through the digestive system, as, for instance, in Gal. Al. Fac. 6.536, 562, 587, 593, 634 Kühn. The contradiction between the present description and that of IX.4 [32.5-6] (κοὗφον τι καὶ λεπτὸν καὶ γλύσχον, οίον κέγχρον ἢ νάπυ) is only apparent, since there is a difference in emphasis (in the latter case stress is laid on the necessity to prevent abrupt motion of the case, as is made explicit in the immediate context: IX.4 [32.2-4]; cf. IX.6 [32.14-15]). There seems to be a preference for millet over mustard because the former is mentioned far more frequently than the latter (in addition to the passage quoted, cf. IX.5 [32.12], IX.6 [32.16], XVII.2 [56.18] and XIX.2 [60.20]).
II.9 [12.10-13] δὲν ἔκρεόντων... σπάρτον. These lines are complemented by IX.5-6 [32.7-17], even though the focus there is limited to the motion of the case. Schmidt 349 is surely right, therefore, when he keeps the plural τὰς κινήσεις (‘die Bewegungen’). Other translators, on the other hand, are not so scrupulous, since they all render the term as if it was singular (but perhaps we must concede that a certain degree of generalisation is involved).

The adverb ἕρμα is used by Hero on three other occasions, once with reference to the downward flowing of millet (IX.5 [32.13]), and twice to connote the gradual vertical movement of water – either upward (Spir. 238.2) or downward (Spir. 248.14); contrast the use of πράως/πραώς for the gentle stretching of a cord (II.11 [14.6], XXIII.8 [78.18]).

For a modern application of the principle described here (i.e. decentering of arches by the so-called ‘sand box’ method), see Prou 163-5; see also, most recently, Varghese (2007: 79-80 with Fig. 8.4).

II.9 [12.12] τὰς κινήσεις ἀποτελεῖ. Perhaps we should emend ἀποτελεῖ to ἐπιτελεῖ. The verb ἀποτελέω is generally used by Hero to refer to the production of sound (ἦχον: e.g. XIV.2 [52.3] and [52.5], XX.4 [66.18], Spir. 98.2 and 100.14; φωνή: Spir. 316.16 [of a blackbird] and 320.13), whereas ἐπιτελέω is the usual verb for carrying out movements (cf. note on I.1 [2.7-8]). For the scribal confusion between ἐπιτελέω and ἀποτελέω, cf. app. crit. to XIX.4 [62.10].

II.9 [12.13-14] ἄρχῃ δὲ... σπάρτον. I follow Schmidt in adopting the reading τάσις, which appears in the ed. princ. This reading seems to be a correction because the manuscripts used by Thévenot have either the erroneous πάσις (Pe and Pf, like AGT) or σπάσις (Pd, like M). τάσις is preferable to σπάσις (possibly a conjecture based on the preceding ἐπιστομένη) not only because Hero uses the term elsewhere to refer to the stretching of a cord (XI.4 [36.25], XXX.2 [106.16], Bel. 83.6) but also because it forms an antonymic pair with ἀπόλυσις (note parallelism: τάσις σπάρτον... ἀπόλυσις σπάρτον).

The vast majority of manuscripts read the second colon as follows: κινήσεως δὲ στάσις ἀπόλυσις σπάρτου. (Manuscripts Par. gr. 2519 and Leid. Bon. Vulc. 4 replace στάσις, respectively, with στάσις and τάσις, but these readings can be dismissed as mere errors.) The perplexing phrase κινήσεως δὲ στάσις has so far
been understood as referring to the end of motion. In particular, Baldi 18, followed by Couture 245-6, interpreted the term στάσις as denoting both the end-point of motion and the subsequent state of rest: ‘fina e stato del medesimo [i.e. il motto]’ (Baldi’s words ‘stato del medesimo’ are not without ambiguity, as they might also be taken to mean ‘state of motion’). However, there are two arguments against this interpretation. First, στάσις is nowhere attested with the meaning ‘end’ (for a review of the different meanings of the term, see Artés Hernández 2014: 183). Second, it is extremely difficult, if not impossible, to explain why rest should be predicated of its opposite (cf. LS s.v. στάσις II.B.1 and, especially, Pl. Sph. 252d6-11, 255a4-b2). Even admitting that motion indeed partakes of rest (Pl. Sph. 256b6-9; for a detailed discussion of the different interpretations proposed for this problematic passage, including his own, see Movia 1991: 370-3; with a different perspective, see, more recently, Ambrué 2007: 153-4), the term κίνησις, as used by Hero, should not be taken in the Platonic sense as referring to the pure form of motion (as Movia 1991: 372 with n. 128, following Rosen 1983: 279, believes is the case with Pl. Sph. 256b6 ὠτή κίνησις). On these grounds, therefore, I have taken στάσις as an intrusive gloss and emended to τέλος. It is plausible to presume that a scribe glossed the original phrase κινήσεως δὲ τέλος with the term στάσις (cf. the definition of Max. Conf. Amb. 15.7 = PG 91.1217C τῆς δὲ τῶν γεγενημένων ψυχικῆς κινήσεως τέλος ἢ στάσις ἐστίν, cf. also Alex. Aphr. in Top. 361.19-20), and that this gloss was later mistaken for a variant reading. This explanation has the additional advantage of allowing us to restore parallelism to the lexically and conceptually unrelated elements of the chiasmus (ἀρχή/στάσις) through substitution of στάσις with τέλος (ἀρχή δὲ κινήσεως... κινήσεως δὲ τέλος).

II.9 [12.14-15] ἐκπεσοῦσης... ὁργάνω. We need to understand τῆς ἀγκύλης as referring to the loop of cord, as is clear enough from the preceding context; cf. also the use of the verb προσαγκυλόμαι at II.7 [10.13] (conjecture), II.8 [12.4] and II.11 [14.8]. The definition of II.7 [10.14-15] (τὸ δὲ κινοῦμενον ἀξων ἐστί, etc.) does not justify Couture’s inference that the words τῷ κινοῦμενῳ ὄργανῳ must exclusively mean an axle (‘axi’, 246; cf. Prou 162). In addition to being found on axles (wheel axle: cf. esp. V.4 [22.4-5], and XII.3 [44.1-2] τῆς ἀγκύλης ἐκπεσοῦσης ἀπὸ τοῦ τύλου, with note ad loc.; door axle: cf. esp. XXIII.6
[78.3-4]; cf. also XXVIII.7 [104.10], and Orib. 49.4.25 for a definitional approach), a τόλος ('knob') is also found on such devices as pulleys (XXIV.6 [84.8-9], XXVII.4 [98.20-100.1]; for the use of multiple knobs in a different context, cf. XXIX.1 [104.19-20]). Whenever a loop of cord falls off its knob, motion is interrupted, even if imperceptibly (change of direction: VI.1 [24.7-9]; cf. VI.2 [24.11]), or brought to an end (V.5 [22.19-20], given as an alternative to the complete descent of the counterweight, and XXIV.6 [84.9-10] [corrupted]; cf. also the parallel expression quoted above). In order for the loop of cord to fall off, it must not be fixed in any way; cf. Bel. 83.1-2 ἀγκύλα...περόνας ἀπολαβόντες ταῖς ΞΟ, ΠΡ, ὡστε μὴ ἐκπίπτειν τὴν νευράν.

For the use of the term τόλος in a different sense, 'wooden block' engaging the thread of a screw, cf. X.2 [34.8], [34.11] and X.3 [34.13]; on this usage, cf. esp. Mech. Frag. 2.55 = Papp. 1126.3, 1126.9, 1126.10, 1126.15, 1126.17 (Ferriello-Gatto-Gatto 2016: 37 curiously translate the word as 'hinge'; but see Ferriello-Gatto-Gatto 2016: 376); the term has been borrowed into Arb. τύλος (cf. Mech. 2.5 and 2.19, with Drachmann 1963a: 59, 81; see also Laird 2015: 300).

II.10 [12.17] οὐκ...ποιοῦνταί. I prefer the reading ποιοῦνταί (A*GT²) to ἐμποιοῦνται (A*MT²) not only because it receives better manuscript support but also because the verb ἐμποίει is never used in Hero. M's supralinear ἀνίσοταχεῖς is clearly a correction of the corrupt ἀκισοταχεῖς.

II.10 [12.18-19] διὰ τὸ μὴ... ἐλάσσονας. Murphy 40 n. 6 explains Hero’s reference to instruments of different diameter by saying that ‘the different sizes of the axles – like differential gears – allow events in the moving automaton display to occur in sequence’. This misses the point entirely. First, Hero uses the term ὅργανον to refer to any kind of circular component, as the reference to bigger and smaller circles at XVIII.3 [60.2] makes clear. Second, cogwheels are nowhere used in the treatise (Introduction, p. Ixxviii). Third, the possibility of a series of movements depends on the use of slackenings (II.10 [12.19-14.3]) rather than on the different size of the axles. Rather, Hero’s point is that since instruments of different diameter rotate at different speeds, they impart different velocities to the components connected to them. The greater the diameter, the
longer the time required to complete a single rotation, and therefore the slower
the movement.

Here the adjective ὁμοίως denotes geometrical equality rather than geomet-
rical similarity, because, mathematically speaking, all circles are similar (Hero,
Deff. 118; Giardina 2003: 344). For this meaning LSJ s.v. ΠΙ.1 cite only three
passages from Aristotle (Cael. 296b20, 297b19, 311b34) and Thales ap. Procl. in
Euc. 251, all with reference to angles. This use of the term seems to reflect a
naïve usage rather than an archaic (ἀρχαϊκώτερον, Procl. in Euc. 251.1) usage
(Rankin 1960: 75-6).

II.10 [12.19-14.2] δεῖ δὲ τῶν... τετάσθαι. Manuscript Ph reads ἀνατετάσθαι in
place of ἀμα τετάσθαι. This reading does not suit the context, for all the
cords that are attached to the counterweight extend upwards (XVII.2 [56.18-20]). It is
not clear whether Baldi’s exemplar read ἀνατετάσθαι, ἀνατετάσθαι (as in M) or
simply τετάσθαι (‘Bisogna anco, che le corde... non siano tese’). Coutre 246
(‘Observa... funes tensos esse omni ex parte’) is more emphatic.

II.10 [14.2-3] ἀλλὰ... ἔχειν. This is so because, when a cord is slack, it does not
transmit force to the instrument to which it is connected. Hence, if a cord has
some slack to it, it must be made longer (Prou 173). As Baldi 43 rightly pointed
out, the arrangement of the so-called χαλάσματα into hanks (μηρύματα, cf. ΠΙ.11
[14.4-6] with note ad loc.; cf. the use of the verb διαμισθοῦ at X.3 [34.16], XII.11
[42.6], XVI.3 [56.7]) glued onto their respective instruments prevents cords
from tangling (see also Drachmann 1963a: 197). These slackenings are used
either to delay the start of movements (locomotion of the case: Χ.6 [32.14-15],
Χ.6 [38.11-14], Χ.Χ.3 [62.4-9]; all other movements: Χ.Χ.4 [62.12-14]) or to
produce pauses between motions (forward and backward motion: VI.2
[24.12-15], VI.3 [24.19-20]; rectangular motion: IX.4 [32.1-2], X.3 [34.14-17];
nake-like motion: XI.4 [36.21-4], XI.5 [38.1-3] and [38.4-6], XI.7 [38.19-22];
dances of the Bacchantes: XVI.3 [56.6-8]).

II.11 [14.4-6] τὰ δὲ χαλάσματα... τόπον. For the function of such an arrange-
ment, cf. previous note.
Mήρυμα is the term normally employed by Hero to refer to the slack coils of cord (hanks): VI.3 [24.20], XI.5 [38.4], XI.6 [38.7]; cf. VI.2 [24.12] (μηρομάτιον). We also find it in his Belopoeica (81.11, 82.3), where it denotes a hank of spring-cord (Marsden 1971: 23); cf. Ph. Bel. 65.22, 66.1, 67.23-24 (note that these occurrences have been rendered differently by Marsden 1971: 133, 135; cf. also LSJ s.v. μήρυμα). The present occurrence has been translated by LSJ s.v. as ‘kink’ (a translation largely adopted by Murphy; contrast her strange renderings of VI.2 [24.12], ‘stretches’ [15], and of VI.3 [24.20], ‘lengths’ [17]), but this understanding does not accord well with the gloss given by Hsch. μ 1259 Latte μήρυμα· σπέίραμα. ἡ ἐκτεινόμενον (μήρυμα is the reading of the Cyrillian manuscripts, against μήρυγμα, which is transmitted by the Hesychian manuscript: see Latte’s app. crit. ad loc.; for μήρυγμα, cf. also Nic. Th. 160, 265). At XI.4 [36.24] all manuscripts read χάλασμα τοῦ μηρίσματος (μερήσματος Τ<sup>κ</sup>). Likewise, μήρυσμα receives a gloss, albeit interpolated, in Hsch. μ 1263 Latte (μήρυσμα· κάταγμα, ἡ σπέίραμα ἐρίου), although the non-Hesychian branches of the tradition have in its stead μήρυγμα (Cyrillian manuscripts) or μήρυμα (Συναγωγή λέξεων χρησίμων, on which see Cunningham 2003); see Latte’s app. crit. ad loc. Now, we must remember that Salmias thought fit to emend μήρυσμα (almost certainly an error owing to iotadism) to μήρυγμα (see app. crit. to Hsch. μ 1262 Schmidt) and, more importantly, that Schmidt 374, treading in Salmias’ steps, printed μηρύσματος (which I have accepted in my text) in lieu of μηρίσματος (a conjecture anticipated by L. Dindorf ap. TGL s.v. μήρυμα, yet with doubts expressed about the soundness of the reading because of the σ). While they correctly pointed out that both of these instances of μήρυσμα (treated as equivalent to μήρυγμα in LSJ s.v. μήρυσμα) are in fact conjectures, LSJ s.v. μήρυσμα failed to notice that there is some manuscript evidence, however slim, for this form. So, G transmits μηρύσματα instead of μηρύσματα (ΑΤ) in the present passage, and the ed. princ. has μήρυσμα in place of the correct σμήρυσμα at Spir. 252.4. Therefore, notwithstanding Dindorf’s doubts and Lobeck’s (1837: 433) complete rejection of the term, μήρυσμα may well have been regarded, along with μήρυγμα, as an acceptable variant of μήρυμα (a view implicitly embraced by Schneider 1801: 120; Lobeck 1837: 433 n. 1 suspected the term μήρυγμα, too, but did not propose any emendation, as erroneously maintained by Schmidt in his app. crit. to Hsch. μ 1258 μήρυγμα).
For this reason, and in the absence of conclusive grounds for rejecting μήρωσμα, I have treated G’s μηρόσματα as a mere variant reading, relegating it to the app. crit., and accepted Schmidt’s conjecture at XI.4 [36.24].

It remains to consider, however briefly, the reading that we find in M (μὴ ῥόμματα). This seems best explained as due to wrong word-division. Not only is the negative utterly misplaced, but the word ῥόμματα, no matter how we interpret it, does not convey a reasonable sense. Even if we leave aside ῥόμμα (‘stream’), we are left with two omographs, namely ῥόμμα/ῥόμμα: the first (‘bow-shot’, ‘towline’) comes from ἐρώ (‘drag’, ‘draw’), the second (‘defence’, ‘protection’) from ἐρῶμαι (‘protect’, corresponding to LSJ s.v. ἐρώ (D)), and not from the middle of the said ἐρώ, as with LSJ s.v. ῥόμμα (B). Cf. Chantraine, DELG s.vv. ῥομμα and ἐρώ.

II.11 [14.7-10] προσέχειν δὲ δεῖ... λήψεται. Hero’s apparently pedantic insistence on the proper arrangement of cords culminates in a premonition of the automaton’s potential failure; cf. II.4 [8.11-12]. Especially noteworthy is the repetition of the expression ἐπ’ ἄριστερά. Scholars such as Baldi 18’ and Prou 173 interpreted these words as denoting direction. While the latter took them literally (‘à gauche’, cf. Hero, Deff. 8), the former understood them somewhat more loosely (‘al contrario’). The unspoken implication of both these renderings is that the cords should only be wound rightward in order to guarantee smooth functioning of the device, but Hero never gives so many details in connection with the winding or the fastening of cords. So, for example, when a cord must be wound in the opposite direction – τὰ ἐναντία (VI.1 [24.1-2], VI.2 [24.14]; cf. VI.2 [24.12]), not ἐπ’ ἄριστερά – the direction of winding is not specified. Couture 246, in turn, went too far astray with his paraphrase (‘ne circumvectiatur alieno [sc. instrumento]’, which covers the words μὴ... λάβῃ), failing even to notice that the phrase was repeated a second time in the original text. Taking a different perspective, Schmidt 349 (‘verkhert’) and Murphy 13 (‘incorrectly’), with whom I agree, understood the phrase ἐπ’ ἄριστερά in a metaphorically extended sense, thus shifting the focus from the direction of winding to the manner of winding. The interesting point here is that the adjective ἄριστερός is used as an antiphrastic euphemism (see generally Caroli 1999: 52-3 with n. 24, with bibliography) to avert ill luck and ward off a potential breakdown of the auto-
maton (contrast its use at III.3 [16.14], where it simply denotes the left hand of the figure of Dionysus, without bearing any mantic or religious overtones; cf. the passage quoted above from Hero’s Definitions, and XXVI.5 [94.8] ἐν τοῖς εὐωνύμοις μέρεσιν; contra, Chantaine (1955: 376-7; 1956: 64-5), according to whom the euphemistic sense of ἀριστερός faded away after the fifth or fourth century BCE (but see, for instance, Plu. De Iside et Osiride 378b, Didache 12.1, cited in DGE s.v. 2; cf. also LSJ s.v. 4). Further, this apotropaic function is intensified through repetition. One could even go so far as to say that Hero invests mechanics with the supernatural power of prediction and omen reading, because he is employing a term whose origins lie in bird augury and divination (see Caroli 1999: 52). On mechanical foreseeing, cf. also the use of the verb προσηχανόμαι at XXVI.6 [94.17].

II.12 [14.11-12] δεῖ δὲ καὶ... φαίνηται. On the significance of this claim, see my remarks in the Introduction, p. cix. Drachmann (1948: 100) argues rather cryptically that the claim applies not only to the scenic presentation of the automaton (‘the plays of the theatre’) but more generally to Hero’s (technical) ability to innovate, particularly in the Pneumática. He bases his argument on the fact that only a few of the instruments described in the work are connected with Philo’s homonymous treatise (see Introduction, p. cvii). Even if we leave aside the questionable basis of his argument, I still do not understand why the claim should be extended to cover the Pneumática or, indeed, the whole of his work. Hero makes it quite clear that he is referring to the appearance (φαίνηται) of the automaton.

Couture 246 and Murphy 13 take κατασκεύασμα to refer to the scenic presentation tout court. Baldi 18’ (‘opera’) and Schmidt 349 (‘Apparat’), by contrast, translate correctly. The term κατασκεύασμα is used only once elsewhere in Hero: Spir. 238.1 (automatic fountain; Drachmann 1948: 154-6).

II.12 [14.12-14] δύνατόν... ποιεῖσθαι. This clearly refers back to I.8 [6.4-7]. On the significance and implications of this statement, see note on 1.7 [4.20-2].

place of ἀναστρέψει (note that Schmidt's translation presupposes the middle form of the verb: 'grösser wird sein Erfolg sein', 349). According to LSJ s.v. A, the verb ἀναστρέφω, in the active voice, primarily means ‘turn upside down’, ‘turn back’, ‘write with anastrophe’ and secondarily ‘invert’, ‘retire’, ‘deny/refuse’ (occurring only once in this sense, as equivalent to ἀφνέομαι, in S. Fr. 1012) ‘rally’ and ‘convert’, but none of these meanings fits within the context. In the passive voice, by contrast, the verb has, among other meanings, that of ‘conduct oneself’, ‘behave’. Thus used, it is sometimes construed with ἐν + dativ, and can be qualified by an adverb (for examples of this usage, see LSJ s.v. B.II.1). In support of his conjecture, Schmidt (app. crit. ad loc.) cites Spir. 2.11 (ἐν τοῖς μαθήμασιν ἀναστρέφεσθαι), XX.1 [64.3-4] (ἀναστράφθαι ἐν τοῖς προγεγραμμένοις) and Ph. Bel. 59.28-9 (ἐν πάσιν [sc. ὁργάνοις] ἀναστραφῶ). Of these passages, the first two are not close enough to provide support. First, the verb ἀναστρέφομαι is used, respectively, in the senses of ‘to be engaged in’ and ‘dwell upon’ (both meanings are recorded by LSJ s.v. B.II.1). Second, the preposition ἐν, as used in the second passage, has a more concrete sense than it is used here (ἐν τούτοις, sc. ‘automata-making’). On the other hand, the Philonic passage provides a more appropriate comparison, since the passive of ἀναστρέφω is accompanied by the adverbial expression ἐν ἑγώ βούλομαι τρόπον. Here the corruption probably arose from the confusion of the tachygraphic sign for -ται (for which, see Allen 1889: 24 with Pl. VII; Gardthausen 1913: 340) with ἐν.

After giving the dimensions of some of the most important parts of the automaton (III.1), Hero describes its arrangement (III.2-4) and its performance (IV.1-3). The performance consists of three distinct phases: forward motion, apotheosis of Dionysus, and backward motion (Prou 138, 165-6). The main scene involves two almost identical series of movements. There are six different movements, each of which is controlled by a separate cord (Olivieri, 1901: 426; Schmidt 1903: 276). The movements occur one after the other in the following order: (1) lighting of either of the altars (cf. XII); (2) sacrificial libation of wine and milk or water (cf. XIII.1-7); (3) sinking of garlands (cf. XV; occurring only once); (4) dance of the Bacchantes (cf. XVI) and (5) sound of kettledrums and
cymbals (cf. XIV); (6) half rotation of Dionysus and Nike (cf. XIII.7-9). Despite lack of explicit mention, the last of these movements will have been performed twice, too (cf. XIII.8 ὅπως ἀμα ἀποκατασταθήσιν ἢ τε Νίκη καὶ ὁ Διόνυσος). With a renewed attention to the dimensions of the automata, particularly of the mobile type, Hero closes the section (IV.4) by emphasising the apparent absence of human intervention.

**III.1 [14.17-18] <Ἐστω>... τριῶν.** Schmidt’s supplement is necessary because the sentence lacks a main verb. The omission of Ἐστω may have been accidental, owing to its similarity to the preceding ἔστη. For ἔστω βάσις at the beginning of a sentence, cf. Spir. 80.6, 88.3, 224.2, 242.12; cf. also XIII.3 [46.1].

The dimensions given here are only approximate (for the use of ως to denote approximation, cf. LSJ s.v. E; cf. also III.1 [14.21] and [16.4]), as was already recognised by Baldi 19* and Schmidt 353. Couture 246 translated the first ως (‘circiter’), but omitted the last two. Less felicitously, the presence of the adverb (here, as at III.1 [14.21] and [16.4]) has been overlooked altogether by Murphy 13 and McCourt (2012: 196). Based on Hultsch’s (1882: 697) table of correspondences, Schmidt 353 with n. 2 gave the approximate metric equivalents of Hero’s measures (length: 46 cm; width: 31 cm; height: 23 cm). This is remarkable not only for the different degrees of approximation used, but also because the height of the κιόνια (for Schmidt’s misunderstanding of the term, see note on III.1 [16.3-4]), which is given in the text as approximate (62 cm), is elsewhere (Schmidt 353 n. 3) specified as being 61.7 cm. For the sake of consistency and clarity, I prefer to give exact figures rather than approximations (see already Prou 140 n. 55), since the degree of approximation is unknown (I, too, base myself on Hultsch 1882: 697). The base is about 46.24 cm long (one cubit), 30.83 cm wide (four palms) and 23.12 cm high (three palms), which means that we must imagine a very small casing. It thus becomes clearer why the automaton needs to be constructed out of lightweight materials (II.2 [6.17-8.2]). For the dimensions of the column shafts (κιόνια), cf. note on III.1 [14.20-16.1]; the measures of the whole column and of the architrave are discussed in note on III.1 [16.3-4].
III.1 [14.18-19] κυμάτιον ἔχουσα περιτρέχον. The term κυμάτιον is strictly architectural, and denotes any vertical convex moulding (for an analysis of the term, see Hellmann 1992: 245-7). Previous translations are not accurate, since the term has been interpreted as meaning either ‘cornice’ (Baldi 19), ‘curved line’ (‘coronide’, Couture 246), or ‘groove’ (Murphy 13; McCourt 2012: 196). Schmidt 353 has ‘Hohlkehle’. That would be a ‘hollow [sc. concave?] moulding’, whereas κυμάτιον can, at best, refer to the cyma reversa, which is a compound moulding (both convex and concave); see Hellmann (1992: 246).

For the phrasing, cf. Ph. Bel. 66.27 κυμάτιον πῦξιν... κύκλῳ περιτρέχον and 67.1 πῦξιν περιτρέχον κυμάτιον. In these instances, the term points to the moulding that runs on the protective cover of Philo’s wedge-catapult (cf. also Ph. Bel. 62.7-8). It is, in my opinion, overinterpretation to regard Philo’s κυμάτιον as a ‘wave-moulding’ (Marsden 1971: 127 for Ph. Bel. 62.8) or a ‘beading’ (Marsden 1971: 135 for Ph. Bel. 66.27 and 67.1). On Philo’s wedge-catapult, see Marsden (1969: 42).

III.1 [14.20-16.1] κιόνια... δῆ. The column shafts have a height of approximately 61.68 cm (eight palms) and a diameter of 15.41 cm (two palms); compare the figures given by Schmidt 353 with n. 3: 62 cm (or 61.7 cm) and 15.5 cm, respectively; see also note on III.1 [14.17-18]. Manuscript Th reads ἐκοσι (154.2 cm) instead of π, a dimension which would result in a disproportionate height for the columns. This erroneous reading must have arisen from the confusion between minuscule π and κ (κ corresponds to twenty), as confirmed by the fact that the scribe later corrected the mistake by adding π in the margin. For the suggestion that the κιόνια should measure ten palms (77.1 cm) in height, see McCourt (2012: 196); for discussion, cf. note on III.1 [16.3-4].

III.1 [16.2-3] ἐπὶ δὲ τῶν... κύκλῳ. There seems to have been some confusion about the meaning of the term ἐπιστύλιον. Baldi 43 n. 16 was the first to comment on Hero’s usage of the term. According to the Renaissance scholar, the measures of the ἐπιστύλιον (which, as he acknowledged, properly signifies ‘architrave’) given in the following line, III.1 [16.3-4] (for discussion of these, see following note), mean that there is no room for both the frieze and the cornice, and so Hero would be using the term to denote any ornament that is laid upon
the columns. He, therefore, explained his translation (‘cornice’, Baldi 19) by saying that it would have been inconvenient to leave out (what he thought to be) the main element of the entablature rather than the architrave and the frieze (but the opposite is, in fact, the case, with the architrave being the main element, and frieze and cornice the accessory elements: see, for instance, Ginouvès 1992: 110 with n. 440). These observations are especially interesting because they suggest that what is really needed on top of the columns is not an architrave (or something like it; on Schmidt’s addition, see below) but a whole entablature. If we leave aside Couture’s translation (‘coronis’, 246; also used for the κομάτιον: see note on III.1 [14.18-19]), we are left with three major interpretative possibilities: (1) ἐπιστύλιον means ‘architrave’ (Schmidt 353; Murphy 13); (2) ἐπιστύλιον means ‘entablature’ or ‘crown(ing)’ (Prou 229 n. t); (3) ἐπιστύλιον means ‘lintel’ (McCourt 2012: 196). We can dismiss the third possibility right away, since the lintel is commonly found across the top of a door or window, and no such element occurs here. The second possibility is more problematic. First, entablature and crown(ing) do not coincide. The word used by Prou for the latter, ‘couronnement’, can, at best, refer to the upper element of the architrave in the Doric and Ionic orders (Ginouvès 1992: 111-14), but certainly not to the entablature (‘entablement’). Second, the term ἐπιστύλιον can be used to denote both the architrave and the entablature (Ginouvès 1992: 110-11). If we follow Gros (2010: 131) in maintaining that the term has gradually extended its meaning to include the frieze and the cornice since the beginning of the Imperial period, we would be led to think that ἐπιστύλιον here means ‘entablature’. However, the fact that in the immediately following context the dimensions of the ἐπιστύλιον are defined in terms proportional to the height of the whole column suggests otherwise, as this is how, according to Vitruvius (De Arch. 3.5.9), the proportion of the Ionic architraves should be calculated (see Chitham 2005: 22). I have, therefore, translated ἐπιστύλιον as ‘architrave’, in the belief that it still retains its original meaning. All things considered, the first possibility is the likeliest one, and the one that adds to the understanding of Hero’s automaton in relation to ancient architectural practice. What Hero has in mind is, perhaps, the Ionic order.

Now that the meaning of the term is clear, it remains to consider the shape of the architrave. Schmidt 351 Fig. 82 seems to invite us to imagine, and rightly so,
a rectangular (so also Baldi 19) unnumbered Fig.) architrave, since its general shape is made to match that of the case. By contrast, Murphy 13 and 41 n. 9 defines the ἐπιστόλιον, in a rather idiosyncratic way (but see also McCourt 2012: 196), as being circular (as opposed to oval [?]), although this cannot be easily inferred from her graphic representation of the automaton (Murphy 14 Fig. 1). Such a view depends on an erroneous interpretation of the word κύκλῳ (cf. also III.2 [16.6], XXVI.7 [96.2]), which is used adverbially with the sense of ‘in a circle’, ‘(all) around’ (LS s.v. κύκλῳς 2) and cannot refer to the shape of the architrave. Had Hero meant to assign a circular shape to this element, he would have probably said στρογγύλου ἐπιστόλιον (for the adjective στρογγύλος used in this way, cf. III.2 [16.8], XVI.1 [54.10] and [54.11]; cf. also XXVI.2 [92.1]). It may be worth wondering in this context whether the original text would have read κύκλῳ <περιτρέχω>, which seems implied by Baldi’s ‘che corre intorno’ (19) and Couture’s ‘circumducta’ (246). Cf. III.1 [14.18-19] κυμάτων… περιτρέχω, with note ad loc. (especially compare Ph. Bel. 66.27, cited there).

Schmidt’s proposed <τ> is needed because the phrase καθάπερ ἐπιστόλιον cannot serve as the grammatical subject. In his app. crit. Schmidt adduced a parallel passage from Ph. Bel. 62.4 ἐπικείσθαι τι καθάπερ ἐπιστόλιον, said of the protective cover of the frame of Philo’s wedge-catapult; see Marsden (1969: 61), and note on III.1 [14.18-19]. For a similar expression, cf. Gal. San. Tu. 6.344 Kühn (ἐγκείσθαι τι καθάπερ λίθον).

III.1 [16.3-4] ὑψὸς... ἤ. Previous scholars have been misled by these measures. According to Schmidt’s interpretation (353 with n. 4), one-eighth of the height of the whole column corresponds to 7.71 cm, that is, one palm (one-eighth of the height of the κόνια in his understanding: III.1 [14.20-1]), and this does not match the figure given by Hero, five fingers (9.65 cm). He therefore suggested with some hesitation that ἤ should be emended to ὅ (but how would the corruption have occurred?) because four fingers correspond to one palm (see Hultsch 1882: 697). Although not brave enough to adopt his conjecture in the Greek text, in his translation he opted for ‘vier’ rather than ‘fünf’. Schmidt’s conjecture was later endorsed by Murphy 40 n. 9, who, despite everything, preferred to follow the manuscript reading and, hence, to translate ‘five’ (Murphy 13). This, however, is contradicted by the height assigned to the architrave in Murphy 14 Fig. 1...
(one palm). A slightly different stance has more recently been taken by McCourt (2012: 196), who thought that the height of the κίόνια, ‘eight’ (ἴ) palms, should be changed to ‘ten’ palms (77.1 cm), that is to say, in Greek numerical terms, ἵ. This would solve the hypothetical discrepancy between the two different measures of the architrave (one proportional, the other numerical), given that one-eighth of ten palms equals five fingers. This escamotage has the advantage of leaving ἰ unaltered, provided that we are ready to accept ἵ as an error of some sort. I believe that it is possible to account for these measures without having to assume that the text is corrupt. As has become clear, all the scholars mentioned above treat the phrase τοῦ κίονος ἁλου in the same manner as they treat the κίόνια of III.1 [14.20], but Hero’s usage of the adjective ἁλος seems to imply a contrast. So, if Murphy 13 translates κίόνια as ‘little columns’ (see already Baldi 19; Couture 246), Schmidt 353 and McCourt (2012: 196) rather think of them, respectively, as ‘pilasters’ (‘Pilaster’) or ‘small pillars’. What has so far gone unnoticed, though, is that at III.1 [14.20-16.2] the κίόνια are mentioned alongside base-mouldings (σπερία) and capitals (κεφαλαί), which strongly suggests a different meaning for the term κίονιον, that of ‘(column) shaft’ rather than of ‘column’; for a comparable usage of the primitive form κίον, see Hellmann (1992: 217). Thus, when Hero says that the architrave is one-eighth the height of the whole column, he most probably means the column with all its formal elements, namely base, shaft and capital (see, for instance, Ginouvès 1992: 62). We find that there is no discrepancy between the two measures of the architrave, because in the previous lines Hero has not given the dimensions of the whole column, but only those of the column shaft (for these, see note on III.1 [14.20-16.1]). The architrave, therefore, measures approximately 9.65 cm (five fingers) in height, a measure which equates to one-eighth of the height of the whole column. We can easily deduce the height of the whole column, 77.2 cm, a figure which comprises shaft (approximately 61.68 cm), base and capital (these two, taken together, being approximately 15.52 cm).

As for the width of the architrave, Murphy 40-1 n. 9 has drawn attention to the fact that it is not specified in the text, arguing that it has to be at least six palms to match the long side of the case (see also Murphy 14 Fig. 1); but what she has in mind is a circular architrave (cf. previous note). There is no reason to suppose that the long and short sides of the (rectangular) architrave are much
different from those of the case, approximately 46.24 cm and 30.83 cm, respectively.

III.2 [16.5] κατὰ δὲ... σανίδια. The plural τῶν ἐπιστυλίων transmitted by all manuscripts cannot be right because it contradicts the previous mention of only one architrave (III.1 [16.3]). R. Schöne conjectured τὸ ἐπιστύλιον, which would, in effect, agree with Hero’s natural preference for κατὰ + accusative. However, Schmidt’s doubtful suggestion (τὸ ἐπιστύλιον) fits better into the context. The verb καταστόρνυμι (or καταστορέννυμι or καταστρωνυμι) and its uncompounded form are most generally used in conjunction with κατὰ + genitive rather than with κατὰ + accusative: cf. the expressions κατὰ τὸ ἐδάφος καταστρωμένος (Dsc. 2.130.1) and κατὰ γῆς ἐστρωμένος (Dsc. 3.126.1, 4.15.1; cf. Him. Or. 12.116). The corruption probably arose from the occurrence of the plural δακτύλων in the immediate vicinity (III.1 [16.4]). For κατὰ τὸ ἐδάφους, cf. V.5 [22.18-19].

III.2 [16.7-8] νάσκος στρογγύλος περιφανῆς. The manuscripts Pc and Pg both offer the marginal variant reading περιφερῆς for περιφανῆς. The adjective περιφερῆς has several meanings, only one of which would be pertinent here (‘rounded’ or ‘curved’, LSJ s.v. I.2). LSJ s.v. I.2.a-c give two instances of the use of περιφερῆς in combination with στρογγύλος (Hp. VC 11 and, in a metaphorical sense, D.H. Rh. 10.13; for this combination, cf. also Pl. Ep. III 342b8, [Arist.] Mech. 851b15, Corn. ND 56.9 Lang, Plu. Cur. 517e, Gal. UP 3.216 and 658 Kühn, Hsch. δ 1855 Latte), and one instance of the use of the term to mean ‘domed’ (περιφερείς στέγαι, Demetr. Eloc. 13). This reading is therefore either an intrusive gloss that has replaced περιφανῆς or a deliberate conjecture, for it is unlikely that Hero would have laid more emphasis on the shape of the shrine. What matters here is the conspicuous appearance (περιφανῆς) of the shrine (‘riguarda...’, Baldi 19; ‘von allen Seiten sichtbar’, Schmidt; cf. also Prou 140 and 142), situated as it is in the middle of the κατάστρωμα.

Couture 246 (‘aedicula... ad aspectum jucunda’) overemphasises the aesthetic element here, but only at the cost of obscuring the sense. Murphy 13, on the other hand, translates ‘free-standing’, which erroneously implies that the shrine is not attached to the underlying surface. This interpretation seems to de-
pend on the translation given to περισσάς by LS] s.v. 1, who understand the expression περισσά...ζωα (Callix. ap. Ath. 199e = FGrH 627 F 2, further compared to Callix. ap. Ath. 205c = FGrH 627 F 1) as indicating ‘figures standing and unattached’, in contrast to figures in relief (πρόστυμα). But in fact Callixenus contrasts figures ‘in high relief’ with figures ‘in low relief’ (Olson 2007: 463).

III.2 [16.8-10] ἀλὰ δὲ... ἔφησενα. This passage presents two difficulties. The first has to do with what is meant by ‘stretched surface’ (ἐντεταμένη... ἐπιφάνεια). The second concerns the fact that the manuscripts have ἔφησαν in place of the conjectured ἔφησεν (R. Schöne). Baldi 43' n. 17 was the first to realise that the transmitted words καθάρεν ἔφησαν are out of context, noticing that Hero has so far never mentioned either the πυρίον (which he translated as ‘cupola’ [19’]; see also Schmidt 1899a: 353, with ‘Kuppel’) or its surface. After recording R. Schöne’s conjecture, Schmidt in his app. crit. made reference to XIII.3 [46.4-5], because, as he explained elsewhere (L1), Hero there talks about the roof of the shrine (see also Murphy 41 n. 10). In truth, what Hero says in that passage is that ‘ὁ λόγῳ should be a knob (πυρίον) placed on top of the shrine’, which certainly implies, but does not directly state, that the knob rests on the summit of the roof (for more on this, see note on on XIII.3 [46.4-6]). While not dismissing R. Schöne’s conjecture as unlikely, Schmidt L1 tentatively suggested that ἔφησαν is a corruption of ἐφήσαν, a verb which he found at Spir. 250.2 (erroneously cited as 250.3). It is not clear, however, how ἐφήσαν was intended to improve the sense of the passage, all the more so since the expression ἐντεταμένη... ἐπιφάνεια had not been properly understood. If we look closer at this expression, we find that Baldi 19’ was, as I will explain below, the only one to offer the correct interpretation of it (‘superficie distesa’). Couture 246 would seem to have rendered the participle ἐντεταμένη as ‘arcuatum’, but it is difficult to see how the surface of a conical turret can be said to be ‘bent like a bow’. Taking a more serious approach, Schmidt L1 showed his approval of Brinkmann’s interpretation of the expression (‘eine anstrebbende Oberflache’, namely ‘a surface that extends upwards’), an interpretation arrived at by comparing Hero’s words with Marc. Dic. Vit. Porph. 75.15-16 ἀνατεταμένον εἰς ὅψιν (of a conical turret). In Schmidt’s opinion, this interpretation would have the
advantage of allowing us to avoid assuming a lacuna in the text (more precisely, the lacuna which he suspected after I.2 [2.14] τόπον: the reference made by Schmidt L1 to a suspected lacuna occurring here in the text must be corrected), but the words καθάπερ εἴρηται (which, in this case, should be understood as ‘as has just been said’, following Schmidt L1) would be redundant and pointless. Schmidt 353 himself, though, must not have been entirely convinced by Brinkmann’s comparison (indeed, the verb ἔντεινο cannot bear the sense of ‘stretching up’; cf. LSj s.v.), as he mysteriously glossed his translation of ἄντεταμένην (‘überspannt’) with the term ‘überdacht’ (‘roofed’). The same caution has not been observed by Murphy 41 n. 40, who accepted what she erroneously believed to be a conjecture of Schmidt (ἀνατεταμένην, translated as ‘raised’ [13]), claiming that the word ἄντεταμένη does not make any sense at all. The verb ἔντεινο is used elsewhere by Hero with reference either to the stretching of the string of a bow (Spir. 186.21) or to the stretching or stringing of the spring of a catapult (for references, cf. note on II.6 [10.7-8]), but nonetheless it is in a different context – Hero’s Definitions – that we find the closest parallel to its usage here. Hero, Deff. 9 augments Euclid’s definition of a plane surface (El. 1 Def. 7 Ἐπάπεδος ἐπιφάνεια ἔστιν, ἓτε εἰς ἱσοῦ ταῖς ἐπφ ἕασεν εὐθείας κεῖται) by adding the words ὀρθή οὖσα ἀποτεταμένη (as noted by Heath 1956: 171), and then goes on to explain that, if a straight line joins two points on this surface, the surface adapts itself completely to the said straight line, that is to say, it is uniformly stretched to match the entire line (see Giardina 2003: 281). In this way, Hero explains the Euclidean definition in similar terms to those he uses (Deff. 4) to explain Euclid’s definition of a straight line (El. 1 Def. 4, on which Euc. 1 Def. 7 is based), a line that lies evenly with respect to its points and which is, therefore, ὀρθή... καὶ... ἐπ’ ἄκρον τεταμένη ἐπὶ τὰ πέρατα (for the expression ἐπ’ ἄκρον τεταμένη said of a plane surface, cf. Procl. in Euc. 117.7-8; see Giardina 2003: 272-3). In the light of these definitions, particularly the first, there is little doubt that Hero simply meant to describe the cupola as having a plane surface and that, in order to do so, he used the middle of the verb ἔντεινο as a synonym for ἀποτεταμένη or τεταμένη. Thus, the meaning of the term is exactly the opposite of ‘bent’ or ‘raised’, and has also nothing to do with the function of the turret as the roof of the shrine. While we cannot determine whether Baldi in
some way understood Hero’s terminology, we can conclude that he was right in retaining the original sense of ἐντεταμένη.

At this point, we can consider the words καθάπερ ἐφηται more carefully. The perfect ἐφηται cannot be right, because, as has been said, no previous reference has been made to the cupola. Schmidt did not give an explanation for his conjecture ἐφηται, but reading καθάπερ ἐφηται (‘as is customary’) would presuppose common knowledge of what ‘stretched surface’ refers to. At Spir. 250.2-3, the passage cited by Schmidt in support of his conjecture, Hero begins his description of the construction of a cupping glass (σικώα) by saying that the instrument should be οία ἐφηται γίνεσθαι τῷ σχήματι, but in this case the reader is invited to draw on general rather than specialised knowledge. Even without knowing the technical application of the term (LS s.v. σικώα II; Bliquez-Rodgers 1998: 238 with nn. 11 and 13), any reader would have been able to imagine the shape of an instrument bearing the same name as a fruit (‘[bottle] gourd’). This is to say that Schmidt’s conjecture does not seem to me well supported. The alternative envisaged by Schmidt in his app. crit. to 338.15 consists of assuming a lacuna after 1.2 [2.14] τόπον. This possibility largely depends on his (mis)understanding of the previous lines as a precise reference to Hero’s own mobile automaton rather than as a broad reference to various types of mobile automata (see further note on 1.2 [2.9-10]). It is extremely unlikely, therefore, that a lacuna occurred there, even more so because it would unnecessarily interrupt the flow of the narrative. Following R. Schöne, I deem it more likely that the future εφητείται corrupted into ἐφηται. This corruption is easy to explain palaeographically both in absolute and relative terms (when compared to ἐφηται). The difficulty remains that Hero makes no further mention of the cupola’s surface. He was probably planning to return to the subject, but forgot to do so.

III.3 [16.11-12] Νίκη ἐκπεπτακοῦσα τὰς πτέρυγας. The use of the verb ἐκπεπτάναι with the accusative of respect is unparalleled in Greek literature. A cultivated reader of Hero’s time would have been reminded of the Meleagrean image of Eros spreading his wings: AP 5.179.10 = HE 4037 ἐκπέπτασον ταχίνας... πτέρυγας. As noted by Floridi (2007: 318), this imagery seems to have
been picked up and adapted by Strato of Sardis in AP 12.221.2 τὰς διφυεῖς ἐκπετάσας πτέρυγας (said of an eagle).

III.4 [16.18-20] ζύσματα... εἶναι. I accept Schmidt’s suggested deletion of τῶν σανίδων. In his app. crit. Schmidt rightly pointed to XII.4 [44.7] (τὰ τεκτονικὰ ζύσματα) and XXVIII.5 [102.17-18] (ζύσματα τεκτονικὰ ξηρότατα). Neither the expression ζύσμα(τα) τῶν σανίδων nor the variant ζύσμα(τα) τῶν σανίδων, for instance, is found in any ancient source. When we find similar expressions elsewhere (ζύσματα ξύλων or ζύσματα ξύλων ξηρά: Apollod. Poliorc. 145.13 [where <ξηρά> is doubtfully suggested by Whitehead 2010: 88], Hero Byz. 217.1; ζύσματα τῶν ξύλων καὶ καλάμων vel sim: Schol. anon. rec. Ar. Nub. 130c beta, Schol. rec. Ar. Nub. 130a, Schol. Tzetz. Ar. Nub. 129a), the term ζύσμα is never qualified by the adjective τεκτονικός. This speaks in favour of the assumption that τῶν σανίδων is a later insertion, intended to explain the words ζύσματα τεκτονικά. On two other occasions, XXVIII.5 [102.19-20] and [102.20], the term ζύσμα appears unqualified, but this seems to be due to the fact that these occurrences are preceded by XXVIII.5 [102.17-18].

On the efficacy of woodwork shavings over other (unspecified) combustibles, cf. XII.4 [44.7].

III.4 [16.20] κατὰ δὲ κίόνα. The preposition κατὰ is here distributive, denoting spatial proximity: cf. Lyr. Alex. Adesp. 37.13 = Powell, Coll. Alex. 199 παῖδα κατὰ κρίνην (cited by LS ἀν. B.II.1). There is no need, therefore, to add <ζκαστὸν> after κίόνα (R. Schöne). Nothing in the text warrants Murphy’s interpretation that the Bacchantes are ‘in line with’ (13) each column.

III.4 [16.21-2] Βάρχη διασκευασμένη ὡς ἐν τὶς προακρήται. Prou 141 with n. 56 expressed his amazement at the sober decency of Hero’s language here, but the verb διασκευάζω, in Heronian usage, has generally more to do with function than with appearance. In addition to I.3 [2.19-20] and XXII.1 [70.8-9], compare Spir. 86.5, 118.6, 116.3-4, 246.13-14, 304.2, where pneumatic components are cast into a particular form; for other, more aesthetically oriented expressions, cf. Spir. 126.2 and 280.5. As indirectly acknowledged by previous translators (see, in particular, Schmidt 353 and Murphy 13, both referring to the Bacchantes’
posture), a veiled reference to the demeanour of the Bacchantes as known from mythological accounts would have been out of context.

IV.1 [18.1-2] Τούτων δὲ... <ἡμῶν>. Schmidt is right in suggesting, however hesitantly, that the text should be supplemented with <ἡμῶν>. It seems apt to compare, as does Schmidt in his app. crit., the present passage with XIX.3 [62.7-8] ἀποστάντων ἡμῶν. ἀποστάντων can, indeed, be regarded as qualifying an unexpressed ἡμῶν, but the subject cannot be easily supplied from the context (see generally KG 2.81). Note the accumulation of genitive absolutes, each with a different subject. Examples of genitive absolute with unexpressed subject are frequent in Book Two (πίναξ: XXI.1 [68.11-12], XXII.5 [72.14-15], XXII.6 [72.18-19] and [74.3], XXV.1 [84.12-13] [perhaps to be supplemented]; θύραι: XXII.4 [72.7]). Cf. also XIX.4 [62.13].

IV.1 [18.3] ἐπάξει. The scribe of A appears to have corrected ἐπάξει (also transmitted by GM) to ἐπάξει, a reading conjectured by Schmidt. A’s reading was recorded by Schmidt in his app. crit. as ἐπάξει, but the Teubner editor failed to notice that ἐ (in ἐπάξει) was originally written detached from the rest of the word. When making the correction, the scribe did not limit himself to changing the smooth breathing into the rough, but he conjoined the first two letters in one stroke, starting at the top of ἐ rather than at its bottom. Since normally initial epsilon in A are not conjoined with the letter that follows, this stroke seems to me to have been intended to correct ἐ to ν. Scribes copying from this manuscript could be easily deceived into writing ἐπάξει, as in T.

IV.1 [18.6] ἐκπνοιοθήσεται. The reading ἐκπνοιοθήσεται is inserted above the line by the second hand of M as a correction of ἐκπνοιοθήσεται, the latter also transmitted by A, G* and T. Three other manuscripts (Aa, Bc, O) have ἐκπνοιοθήσεται. A similar kind of variation is found at IV.3 [18.17] ἀναπνοιομός/ἀναπνυμός (M/AG) and at XIII.1 [44.15] ἀναπνοιοθήναι/ἀναπνυσθήναι (M/AGT). The Teubner editor preferred to print the reading with better manuscript support in each of these places, and indeed we find separate entries in LSJ for the forms ἀναπνυσθώ/ἀναπνυσθῆ, ἀναπνυσθήναι/ἀναπνυσθήσεται, and ἐκπνοιοθήσεται. In addition to comparing the
hapax legomenon ἀναπιτυσμός with ἀναπιτύξω (why not ἀναπιτύξω?), LSJ s.v.v. assign different meanings to the verbs ἀναπιτύξω/ἀναπιτύξω (‘cause to spirt out’/‘spit out’, ‘spout up’) on the one hand, and to the verbs ἐκπιτύξω/ἐκπιτύξω (‘eject’/‘spit out’) on the other. What is interesting is that the verbs ἀναπιτύξω and ἐκπιτύξω are not attested outside the Heronian corpus. What is more, they are used in exactly the same way as ἀναπιτύξω and ἐκπιτύξω, namely, to describe a spurt of liquid (usually water). ἐκπιτύξω occurs only once more at Spir. 134.19, whereas ἀναπιτύξω appears in no other place than XIII.1 [44.15]. At all other times, we find forms of ἀναπιτύξω (Spir. 134.1 [J. G. Schneider: ἀναπιτυξόντι AG : ἀναπιτυξόντι Τ], 212.18), ἀναπτύξω (Spir. 76.10-11) and ἐκπιτύξω (Spir. 242.10, 242.11, 242.20, 246.1). The compound verbs ἀναπιτύξω and ἐκπιτύξω are formed, respectively, by the prepositions ἄν and ἐκ and the verb πιτύξω. One fragment attributed by Theodoridis (1976: 351) to the first-century BCE grammarian Philoxenus of Alexandria gives us information on the verb πιτύξω (fr. *587 = Orion, Etymologicum s.v. πιτύξιν [134.20-1 Sturz] + Et. Gen. s.v. πιτύξω [= EM 697.57]; cf. Ps.-Zonar. Lex. s.v. πιτύξιν): πιτύξιν· παρὰ τὸ πτῶ πιτύξιν ἐστίν παράγωγον καὶ ἀποβολή τοῦ τ πιτύξω, etc. The text goes on to compare the derivation of πιτύξω from πτῶ with that of πᾶς from πτῶσσο (πτῶσσο — πτύξιν — πτύξιν — πτύξω), but this portion is taken from the Etymologicum Genuinum, more precisely from the text of the tenth/eleventh-century CE manuscripts Vaticanus gr. 1818 (A) and Laurentianus S. Marci 304 (B). Similarly, the lemma πιτύξιν and the word πιτύξω are transmitted by either or both of AB (πιτύξιν B : πιτύξω A), while Orion’s text (Par. gr. 2653, sixteenth century CE) gives, in their stead, πιτύξιν and πιτύξω. These forms do not seem right in the context of the etymological explanation, because the term πιτύξω appears in Orion, too. One may suggest emending πιτύξω to πιτύξηω, but in that case the origin of the term would not be clear. Nor does it seem necessary to think, with Sturz (1820: 134 n. 50), that the whole of Orion’s entry should be replaced by an etymological gloss on the verb πιτύξιν (‘practise regular swinging of the arms’, according to LSJ s.v. 1), for this has a quite different meaning from πιτύξω/πιτύξω. All of this suggests that the forms ἀναπιτύξω and ἐκπιτύξω (and hence also ἀναπιτυσμός and ἐκπιτυσμός, the latter occurring once at Spir. 134.14) originated as scribal errors owing to iotaism no later than the thirteenth century CE, when the scribe of A copied the forms
The same mistake appears to have taken place in the transmission of the text of Philoxenus of Alexandria. I have, therefore, adopted the readings which are found in M (ἀναπτυσσόμενος is a hapax legomenon, too), thinking that each pair of LSJ entries should be merged into a single entry: ἀναπτύσσον, ἀναπτυσσόμενος and ἀναπτύσσον. Likewise, Spir. 134.14 (ἐκπτυσσόμενον) and 134.19 (ἐκπτυσσότατοι) should be corrected.

IV.2 [18.9-10] αἰ δὲ περικύκλῳ... ναίςκον. I follow Schmidt in adopting Diels’ correction περικύκλῳ (against the manuscript reading περὶ κύκλῳ), since the adverb is generally written as one word in non-classical authors (cf. LSJ s.v. περίκυκλός). Baldi 20' and Schmidt 355 correctly bring out the attributive position of the adverb. Couture 247 (‘in gyrum circuientur’) and Murphy 13 (‘will dance in a circle’), on the other hand, treat περικύκλῳ as an adverb modifying the main verb (their translations omit, respectively, χορεύονται and περιέλυονται).

IV.2 [18.11-12] καὶ μετὰ... ζόδιον. The words σταθέντων τῶν ᾗχων have been variously emended and/or supplemented, mainly because of the strange use of the verb ἴστημι to refer to the noise of kettledrums and cymbals coming to an end. R. Schöne wondered whether the word ᾗχων should be replaced by the word ἠχων, but the term commonly used by Hero to denote any kind of noise is ἠχος, not ἱχή (never found in Hero): see, for instance, IV.2 [18.10], XIX.2 [52.2], XX.3 [66.4], XX.4 [66.14], [66.15] and [66.18]; for further references, see Schmidt, Supplementum 160 s.v. ἠχος. A lacuna was suspected by H. Schöne and Brinkmann, who proposed similar conjectures: σταθέντων <τῶν ζώδιον καὶ παυσόθεντον> τῶν ᾗχων (H. Schöne) and σταθ<εις>ν τῶν βακχῶν καὶ παυ<θε>ντον τῶν ᾗχων (Brinkmann). H. Schöne’s solution has the merit of being less invasive than Brinkmann’s, even though the Bacchantes are never explicitly called ζώδια in the treatise. The verb παύω, indeed, occurs twice in Hero in connection with sounds (Spir. 198.4, 200.18) and other six times to describe the interruption of a liquid flow (Spir. 42.6, 82.3 [libation], 182.11-12, 232.5, 258.14, 268.17), albeit never used in the aorist passive form. In the wake of Brinkmann’s proposal, Schmidt tentatively suggested emending σταθέντων τῶν ᾗχων to σταθεισῶν τῶν βακχῶν, citing in support IV.3 [18.20] σταθεισῶν.
αὐτῶν [i.e. τῶν βακχῶν]. There are, however, two objections to this and other emendations. First, μετὰ ταῦτα already refers to the movements that have taken place up to this point, including the dance of the Bacchantes. Second, throughout IV.3 [18.16-20] there is stylistic variation: note, especially, the use of the nouns ἀναπτυσμός and ἐκχυσίς in place of the verbs ἐκπυτίζω and ἐκχέω (cf. IV.1 [18.6-7]), the inversion of the syntactic roles of the verbs περιέρχομαι and χορεύω (cf. IV.2 [18.9-10]), and the prepositional phrase μετὰ ψόφου τιμήτων καὶ κυμβάλλων replacing the main clause of IV.2 [18.10-11]. There is therefore nothing to suggest that the text should contain the same (type of) reference as that of IV.3 [18.20], and one may even wonder why scholars did not feel the urge to supplement the latter passage on the basis of the words σταθέντων τῶν ἒχων. Perhaps we should content ourselves with emending σταθέντων to παυσθέντων. We may suppose that the first syllable of παυσθέντων had been omitted and that the resulting reading στάντων was later corrected to σταθέντων through addition of τα. As much as I am tempted to print παυσθέντων, I prefer to keep open the possibility that Hero used the passive of ἔστημι in an unusual way.

IV.3 [18.15-16] ὁ ἐμπροσθὲν... ἀνακαυθήσεται. The apparent change of the altar’s position clearly depends on the fact that Dionysus has rotated. Neither of the altars moves around the figure of the god, contrary to what Murphy 14 believes: ‘the altar that started behind Dionysus arrives in front of him’. M replaces ἀνακαυθήσεται (AGT) with ἀνακαυτήθησεται (‘will bend back’), a similar misunderstanding. Cf. also IV.1 [18.4] and XII.1-4 [42.11-4.14].

Schmidt’s proposed correction of the manuscript reading τῷ διονύσῳ is necessary, since ἐμπροσθὲν governs the genitive only (LSJ s.v. II).

IV.3 [18.18] αἱ Βάκχαι χορεύουσι. Manuscript La alone transmits the reading χορεύουσι (already conjectured by Schmidt) against all the other manuscripts, which have χορεύοσου. The future tense agrees better with the context than the present (cf. the consistent use of the future throughout IV.1-4 [18.3-20.1]). On Schmidt’s suggested χορεύουσι at XVI.1 [54.9], see note on XVI.1 [54.8-9].

IV.3 [18.20-1] καὶ πάλιν... τόπον. I take πάλιν to refer to the genitive absolute σταθεσίων αὐτῶν (‘Wenn sie dann zum zweiten Male stehen bleiben’, Schmidt
355) rather than to the main verb ἀναχωρήσει (‘e di nuovo... ritomerassi la machina’, Baldi 20). The automaton has not come back before, whereas the Bacchantes have already danced once (IV.2 [18.9-10]). The adverb has been omitted in Couture 247 (‘Quibus omnibus perfectis... machina sponte reverteretur’, my emphasis) and Murphy 14 (‘when they stop the automaton will return’).

M’s reading ἀναχωρήσει is replaced in AGT by ἀναχωρίσει (which Prou 166 apparently corrected). The verb ἀναχωρίζω has the causative meaning of ‘make to go back’ (LSJ s.v.), whereas here we need the corresponding non-causative meaning of ἀναχωρέω (LSJ s.v. 1.2). Reading ἀναχωρίσει would presumably mean taking τὸ αὐτόματον as the direct object rather than the subject and assuming that the subject is missing. But the whole point is that the automaton moves back on its own. The reading ἀναχωρήσει can be easily explained as having been caused by iotaism.

IV.4 [20.1] ἐπίδειξις. The term, as Cambiano (1994: 614) rightly pointed out, refers to the performance (‘esibizione’) of the automaton. For the same sense, cf. XXI.1 [68.6] and Spir. 174.8 (automatic fountain). Commenting on Heron’s use of the term, Tybjerg (2003: 455) has drawn attention to its rhetorical meaning (‘display speech’; cf. LSJ s.v. 3). Note, however, that during the Hellenistic and Imperial periods the word is used to refer not only to the exhibition of oratorical skills, but also to any kind of artistic performance (Pepe 2013: 272-3; cf. Van Liefferinge 2000: 150-1 with n. 10 [Delphic decrees]).

On the theatrical presentation (διάθεσις) as encompassing the ἐπίδειξις, see note on 1.3 [2.19].

IV.4 [20.1-6] τοῖς δὲ εἰρημένοις... ὑπόνοιαν. This passage seems to serve a double purpose: to emphasise the sense of wonder inspired in the viewer by creating the illusion of self-motion, and to assert the identity of the automaton as a wholly mechanically operated device. Roby (2016: 146) has recently compared Hero’s words μειζόνοιν... δημιουργοῦντος with Ph. Bel. 78.11-12, where great importance is attached to the appearance of Ctesibius’ catapult as a means of achieving mechanical credibility (see Roby 2016: 144-5 with n. 118, drawing on Meissner 1999: 92): οὐ μόνον τῆς ἰσχύος, ἀλλὰ καὶ τῆς ὄψεως στοχαζόμενος
[sc. Κτησίβιος], ὡς ὀργανικὴ φαύνηται. Hero’s insistence on the need to follow specific measurements (and hence, more generally, to avoid too big dimensions in both types of automata) can, therefore, be read as setting out one of the preliminary conditions for the proper functioning of the device (contra, Cambiano 2011: 32; but see Cambiano 1994: 623). Needless to say, the dimensions given by Hero at III.1 (on which, cf. notes on III.1 [14.17-18], [14.20-16.1] and [16.3-4]) could easily forestall suspicion of a human operator inside the automaton (Murphy 41 n. 11).

Baldi 20’, partly followed by Couture 247, took the words δεῖ φυλάσσονται... ὑπόνοιαν to mean ‘one must follow the mentioned dimensions to avoid the suspicion that might arise’ (‘bisogna serbare le dette grandezze per fuggir’il sospetto, ch’intendo potrebbe nascere’), but the verb φυλάσσω is here in the middle voice (cf. LSJ s.v. C.11.1 for its use with the accusative) and cannot mean ‘preserve’, ‘maintain’ (a metaphorical meaning attested in the active LSJ s.v. B.3; cf. B.6). Moreover, the term μέγεθος does not seem to refer to size in general (LSJ s.v. I.1), but to great size (‘grosen Dimensionen’, Schmidt 355), as implied by the concurrent use of μέτρον a few lines earlier and by μειζόναν... δημιουργοῦντος.

IV.4 [20.2] γὰρ γενηθέντων. The reading of G, M and T is to be preferred to that of A (γὰρ γε γενηθέντων), since the combination γὰρ γε is entirely, or almost entirely, avoided (Denniston, GP liii with n. 3). After γε two letters (perhaps νν) have been deleted. The scribe might have begun writing γενηθέντων, but made a mistake and repeated the ν (γενν-). He would thus have corrected his error and written the word γενηθέντων over again, albeit without deleting the remaining letters γε.

V-VI [20.8-26.5] Forms of motion. Straight-line motion

Hero introduces the main types of motion: straight-line, circular and rectangular (V.1-2). While the mechanism for straight-line motion is clearly presented as an improvement on the method (ὁδός, V.1) of the author’s predecessors, circular motion (VII-VIII) and rectangular motion (IX-X) represent brand-new contributions to the field. Hero then proceeds to detail the configuration for forward motion (V.3-5), while also providing general information about the drive mechan-
ism of the automaton. There follows a description of backward motion (VI.1-2), including a mechanism for producing a pause between outbound and inbound journeys (VI.2). After suggesting a configuration for making the automaton travel forth and back many times (VI.3), Hero closes the section with a reference to a side view of the case (VI.4).

**VI.1** [20.9-10] καὶ ἔπικινδυνον. The καὶ is concessive and is used to emphasise the dangerousness and impracticality of the ancient system (Murphy 15, unlike other translators, omits it).

The combination κακοπαθής τε καὶ ἔπικινδυνος is not found elsewhere. LSJ s.v. κακοπαθής II cite only this instance of the adjective in the sense of ‘troublesome’, ‘difficult’.

**VI.1** [20.11-12] ὡς ἔστι... αὐτῶν. Cf. XX.1 [64.6-7]. On the importance of practical testing (πείρα), cf. note on XI.6 [38.7-8].

**VI.2** [20.13-14] ἡμεῖς δὲ... ἀκινδύνως. In advocating the feasibility of achieving straight-line motion, Hero sets himself apart from and above his predecessors. The adverbial pair εὐκόπως/ἀκινδύνως (later expanded by the addition of the adverb ἔνως, XX.1 [64.4-5]), emphasises the success of the method Hero is going to describe, in sharp contrast (δὲ) with the terms κακοπαθή τε καὶ ἔπικινδυνον. Perhaps the adverb ἀκινδύνως, with its privative alpha, implies that the locomotion of the automaton still involves some element of risk. McCourt (2012: 188) is clearly wrong to say that all other mechanisms of movement have no ‘guarantee’ attached. In addition to the passage cited above, cf. Hero’s remarks on rectangular (X.4 [34.23-4]) and snake-like (XI.11 [42.6-8]) motions.

**VI.2** [20.14-16] ἐτι δὲ καὶ... φέρεσθαι. The combination ἐτι τε καὶ is never found in Hero, unlike ἐτι δὲ καὶ, which occurs a total of 11 times. On these grounds, I have corrected the τε of the manuscripts to δὲ: cf. esp. XI.1 [36.3] and XX.3 [66.3] (both at the beginning of the sentence) and, after τε-καὶ coordination (as here), Mech. Frag. 2.1 = Papp. 1116.9 (τε... καὶ), Metr. 132.7-8 (τε καὶ... καὶ) and Bel. 74.1-3 (τε καὶ... καὶ... καὶ... καὶ). As far as the syntax is concerned, I have preferred to follow Schmidt in supplementing <ἔστι> after ὡς.
Hildebrandt’s deletion of ὑς, on the other hand, does not seem quite right to me, because it presupposes a long-distance dependency between the ἔστι at the beginning of the previous subordinate clause and the infinitive φέρεσθαι (occurring twice, once here and once at the end of the sentence). It is helpful to compare the present passage with XI.1 [36.3-4] (ἐπὶ δὲ καὶ... δυνατὸν ἔστι), where the main verb is repeated from the previous sentence.

In his app. crit. Schmidt suggested, somewhat hesitantly, that the article before πληθιῶν should be emended to τι and that the words ἦ τοῦ ζῷόν should be deleted. In support of his conjecture he cited V.3 [20.18-19] (ἐπὶ πόρτα τι πληθιῶν, etc.), but there the use of the indefinite pronoun is best explained by the geometric style of the description (see further note ad loc.). The proposed deletion of ἦ τοῦ ζῷόν is more tempting. The main problem lies in the fact that no figure is said to move in a rectangular pattern (the verb περιάγω at XXIX.2 [104.24] suggests that the figure of Athena, just like the Bacchantes, could be made to move in a circular fashion), but perhaps we have to assume that the alternative was not intended to apply to the following clause. To further complicate matters, Schmidt 357 with n. 1, followed by Murphy 15, translated ‘ein Kasten oder eine Figur’ (my emphasis). The presence of the second definite article does not seem to be too problematic, if we concede that Hero was following his own train of thought.

V.2 [20.16-17] ὀν μὴν ἀλλὰ... φέρεσθαι. Or, more simply put, along a given rectangle. Curiously, Couture 247 took these words to mean that motion can be effected along an octagonal path (‘per latera parallelogrammi octogoni’). This is even more surprising when we realise that at XI.1 [36.2] he understood the adjective ὑρθογώνιος correctly. For Hero’s definition of rectangular parallelograms (based on Euc. 2 Def. 1, as implied by Giardina 2003: 199 n. 25), cf. Def. 56. Τῶν δὲ παραλληλογράμμων ὃσα μὲν ὑρθογώνια ἔστιν, περιέχεσθαι λέγεται ὑπὸ τῶν ὑρθῶν γωνίαν περιεχουσῶν εὐθεῖων, etc.

V.3 [20.18-19] ἔστω γάρ... ἀβεβήσαι. Hero begins his description of the configuration for forward motion in standard geometrical style. All manuscripts, except La, have the indefinite pronoun τι. Manuscript La has τὸ in its stead. One might be tempted to accept τὸ, since the case (πληθιῶν) is by now well-known to the
reader. This, however, is the first of a series of similar geometric-like descriptions in which the definite article is generally omitted, as required by the formulaic nature of the geometrical language (see Schironi 2010: 349); but cf. XI.2 [36.6] ἔστω γὰρ τὸ πλευθόν, ἐν δὲ εἰσιν οἱ τροχοὶ, τὸ ἀβγό, etc. This is the only case in the treatise where the indefinite pronoun accompanies the first mention of either a geometrical or geometrised object; but similar examples are frequent in the Pneumatica (for instance, ἔστω τι ἄγγελον: e.g. Spir. 44.13, 112.16, 136.15; ἔστω σμηνισμάτων τι: Spir. 54.1; Drachmann 1948: 82).

V.3 [20.21-22.1] δύο τροχοὶ... φακοειδεῖς. Various interpretations have been given to the words τὰς περιφερείας εἰργασμένοι φακοειδεῖς. Baldi 434-44ψ n. 19, who was the first to acknowledge the proper meaning of the term φακοειδής ('lentil-shaped'; cf. Schmidt 357), brought to the reader’s attention the distinction made by Pappus (more correctly, by Hero ap. Papp. 1126.21-1128.2 [= Mech. Frag. 2.5]) between two types of screw-thread: square (τετράγωνος) and lentil-shaped (φακοειδής or φακωτός, the latter being a more technical designation, according to Drachmann 1963a: 59). If we follow Pappus’ account (cf. also Mech. 2.5, with Drachmann 1963a: 58-9), the square screw-thread is the one with perpendicular indentations, while the lentil-shaped screw-thread is the one with oblique indentations that converge to a single line. This equates to saying that the lentil-shaped screw-thread is much Sharper than the square screw-thread (see Schmidt 1900: 287 with Figs. 71a-b). Thus, based on these features, Baldi concluded that what Hero had in mind were toothed wheels, and this because, as Hero himself pointed out (?), wheels of this kind had a better grip on the ground. Slightly more than a century later, Couture 247 ('orbes acute dentati') accepted this interpretation without any hesitation. In a more original way, Prou 160 thought of the physical properties of lentils and so provided the rim of wheels πῆ and κλ. with a 'surface rugaeuse' ('rough surface'), despite what is said at II.13 [8.3-5]. Hero’s primary goal would, once again, be a firm grip on the ground. Another, more eclectic approach has been taken by recent translators. Murphy 15 came up with ‘wheels... with bevelled edges’ (my emphasis), whereas McCourt (2012: 188) assigned a ‘convex... shape’ to the entire wheels. Given all this confusion over what the expression τὰς περιφερείας εἰργασμένοι φακοειδεῖς refers to, I would like to pay more attention to the distinction between the two
types of screw-threads. In order to obtain a clearer picture of what a lentil-shaped screw-thread should have once looked like, we need to turn to another source. After briefly dismissing the square screw-thread, Oribasius (Coll. Med. 49.4.56) explains that lentil-shaped (φακωτοῦ) screws (that is, screws with a lentil-shaped thread) ‘are those that have the roots (τὰς μὲν κούλας ἐλικας) narrow at the bottom but wide at the top, and the crests (τὰς δὲ ὑπερεχοῦσας) broad at their base but tapered at the top, resembling a lentil cut in half (ημιτόμω φακῶ)’. Therefore, the crests have the same shape as the roots but inverted, the inversion being explained by the very alternation between roots and crests. Oribasius’ explanation is interesting because it accords with some technical applications of the term φακοειδής. As noted by LSJ s.v., Ruf. Onom. 153.12 uses the adjective to refer to the lens capsule of the eye (which has the appearance of a convex disc), and Galen (Meth. Med. 10.448 Kühn) speaks of a knife with a ‘blunt and smooth lentil-shaped guard that projects at the margin’ (see Johnston-Horsley 2011: 217 Fig. 7 no. 4). In yet another context, Plu. Aet. Rom. 288b8-11 = VS 21 A 60.20-22 reports Empedocles’ view that the shape of the half-moon coincides with that of the lentil and the disc. This short survey allows us to make three observations about the meaning of the expression τὰς περιφερείας εἵργασμένοι φακοειδές. First, the wheels cannot be toothed, since the adjectives φακοειδής and φακωτός denote not the alternation between roots and crests in a lentil-shaped screw-thread but their form: concave in one case, convex in the other. Second, there is no indication in our sources that the adjective φακοειδής ever meant ‘rough’ or ‘bevelled’. Three, McCourt (2012: 188) was right to think of a convex shape, given what we know about wheel-making in antiquity (see Wehler 1999; Stieber 2006: 585, 587-8, on E. Ba. 1066-7). This, however, does not characterise the wheels as a whole, but only their circumferences or rims. What Hero almost certainly meant was that the outer surface of the wheel rim should be worked so as to be convex.

V.3 [22.2-3] καὶ ἔστω... ἐπεισιθήσεται. I deem it necessary to supplement the text with Schmidt’s proposed ἔστω, since the main verb is missing. Previous translations, including McCourt’s (2012: 188), appear to supply the third-person singular imperative form from the ἔστωσαν of the preceding sentence, but the presence of coordination (καὶ αὐτῇ συμφωνήσας, etc.) suggests that a verb is needed.
Moreover, it is extremely rare, if not impossible, at least in the Automata, to find omission of third-person imperatives, especially when they are used to introduce the description of an object.

Hero's ἐξελίκτρα (literally ‘unwinder’, following Keenan-Jones-Ruffell-McGookin 2016: 167) has first attracted the attention of Prou 161 with n. 143. Unlike most scholars, who understood the term as referring simply to a ‘cylinder’, Prou 161 n. 143 acknowledged that the ἐξελίκτρα is in fact a ‘spool’ (see also Drachmann 1948: 145-6, on Spir. 298.7-302.3, where the term occurs thrice) or ‘bobbin’ (‘un dévidoir, une bobine’). Rather than being derived from the noun ἔλεξ (as maintained by Prou), the term (which is never attested outside Hero) is, more correctly, derived from the verb ἐξελίσσω (see already Keenan-Jones-Ruffell-McGookin 2016: 173). Prou observed that the ending -τρα indicates that the object has a rectilinear shape. This is a very curious remark, given that the feminine suffix -τρα, and the corresponding neuter form -τρον, can be used to denote all sorts of instruments (Chantraine, Form. 330-3), regardless of their shape. Add to this that Hero’s ἐξελίκτρα is probably cylindrical (in addition to the translations, see Baldi 20’ unnumbered Fig.; Fig. 5, the ἐξελίκτρα cannot be distinguished from the axle in Schmidt 356-7 Figs. 83ab and Murphy 16 Fig. 2), as it is used to ‘unwind’ the cord from the wheel axle. More recent attention has been drawn to the origin and function of the ἐξελίκτρα. Keenan-Jones-Ruffell-McGookin (2016: 172-4) have shown how Hero’s ἐξελίκτρα, which can, perhaps, be traced back to Philo (also compare Philo’s mention of a wooden ἐξελίκτρον for storing, or assisting with reinstallation of, catapult spring-cords: Ph. Bel. 67.22-5), functions as an inverted windlass (‘un-windlass’, in their terminology). While the windlass, as described by Hero, Mech. Frag. 21 = Papp. 1118.2-10 (ἵ... ἐξον τον... Αλτσαρ), lifts heavy weights using a smaller force, the axle and ἐξελίκτρα assembly is made to rotate by a cord being unwound under the impulse of a light weight. As stressed by Keenan-Jones-Ruffell-McGookin (2016: 174), the most probable function of the ἐξελίκτρα, with its position at the centre of the axle (κατὰ μέσον τὸν ἐξονα), was to reduce the inclination angle of the cord and, therefore, to minimise the resulting loss of force. If Hero did derive the term ἐξελίκτρα from Philo, as might well be the case, the employment of the feminine rather than neuter suffix need not be overemphasised (Keenan-Jones-Ruffell-McGookin 2016: 173), all
the more so when we consider the overlap of meaning between -τρον and -τρα (Chantraine, Form. 333). The term ἔξελικτρα also occurs in Book Two, where it refers to the bobbin used to unwind a scroll of papyrus (seafaring scene): 

XXVI.7 [94.20], XXVI.8 [96.6], XXVIII.2 [100.13-14], XXVIII.3 [102.2]. The etymology of the term is clearly brought out by XXVI.8 [96.5-7] περιελήσας οὖν σπάρτον περι τὴν ης ἔξελικτραν, ὅπως μέλλει ἔξελισσεν τὸν χάρτην, etc.

V.4 [22.4] τύλος ὁ ξ. Schmidt was no doubt right in correcting the manuscript reading νε to ξ (not just here but also at [V.4] 22.10 and [VI.1] 24.1), since ν already denotes one extremity of the ἔξελικτρα. Furthermore, a knob is never designated by more than one letter. The reading of M before correction (στύλος) is obviously a mistake, for it makes no sense to have a ‘pillar’ attached to the ἔξελικτρα.

V.4 [22.5-7] τροχός... σφόδρα. This is clearly a non-driving wheel in that there is no cord connecting its axle to the counterweight. It is labelled ρε in the manuscripts, but ρ is already used for one of the points of the wheel’s frame (ρστυ). It is, once again, necessary to accept Schmidt’s correction (see previous note). The reading πίγματι, which is transmitted by G and MP, is surely right as against πίγματα (Aρ), because ἐν requires the dative. Manuscript PG bears in the margin the plural πίγμασι, which does not make sense in the context. The wheel is, in fact, set within its own frame, as illustrated by the manuscript diagrams (see Fig. 4a). The plural also does not agree with the following τὸ ρστυ. Πολευόμενος (AGT) fits better here than πορευόμενος (M). The middle-passive voice of the verb πορεύο (‘to be driven’, ‘go’) never refers to the automaton’s wheels, only to the πλυνθίον as a whole. By contrast, the verb πολεύω is used elsewhere in the middle-passive voice with regard to a screw (or its extremities) turning on dowels (X.2 [34.10]) or within διαπίγματα (Mech. Frag. 2.6 = Papp. 112.8.20-3).

V.4 [22.7-9] οὖτως δὲ... μέρος. The same emphasis on balance and equilibrium appears at VII.3 [26.18-19] οὖτως οὖν τετάχθωσαν οἱ τροχοὶ τῇ θέσει, ὡστε ἔστος ἐπ᾿ αὐτῶν τὸ πλυνθίον ἰσορροπεῖν. Cf. also VIII.2 [28.12-13].
V.5 [22.12-13] σῴρηγος... πλυνθόν. As correctly pointed out by Murphy 41 n. 12, the tube is placed at the centre of the case (between the four columns) for the sake of balance and to facilitate attachment of the cords to the counterweight. Its designation as τετράγωνος (‘viereckige’, Schmidt 359) probably refers to a rectangular shape (so Murphy 15) rather than to a square shape (so Baldi 20'; Couture 248; Prou 162). When referring to a square, Hero sometimes uses the adjective together with ισόπλευρος (Defn. 51 and 100; cf. XXVI.2 [90.15]). The rectangular shape here has the advantage of allowing maximisation of the space between the four columns. In any case, it is clear that the tube is not conceived as cylindrical, as supposed by Landels (1978: 203). It is not until IX.5 [32.7-8] that the reader is informed of the hole at the bottom of the tube, but the missing information can easily be reconstructed from II.9 [12.10-11].

V.3 [22.13-14] τροχίλον. Hero’s τροχίλος is a single-sheaved pulley, which is used exclusively to change the direction of the force (Keenan-Jones-Ruffell-McGookin 2016: 173). On the term, see especially Rambaldi (1999: 77 with n. 51), with further bibliography.

V.5 [22.16-17] ἐάν... σπάρτον. I adopt Schmidt’s suggested emendations of κάτω φέρεσθαι το καταφέρεσθαι and of τείνει το τενεί. In support of the first emendation, Schmidt (app. crit. ad loc.) cited five occurrences of the verb καταφέρομαι (II.9 [12.12], VI.1 [24.4], IX.4 [32.3], XV.3 [52.17], XV.4 [54.7]): of these, the first three refer to the fall of the counterweight, and the other two to the fall of the wreath. Indeed, the usual verb for the descent of the counterweight is καταφέρομαι (in addition to the passages cited, cf. XI.3 [36.17] and XIII.9 [50.13]). The adverb κάτω occurs elsewhere in Hero only once modifying φέρομαι (Spir. 122.9), but the resulting expression refers to a pipe bearing downwards, not to a body falling down. The second emendation (anticipated by Baldi 20') is necessary too, as Hero shows a strong tendency to prefer future forms in the apodosis of conditional clauses of this type (for two exceptions, cf. Stereom. 1.43.2a and 2.3.1).

I take the subject of the apodosis to be the same as the subject of the protasis (cf. XIII.8 [50.1], XXIII.3 [74.18-19]), rather than assuming an unexpressed
‘counterweight’ (so Coutu 248; Schmidt 359). I do not understand why Murphy 15 and McCourt (2012: 188) translate ἐὰν τις as ‘if anything’.

VI.1 [22.22-24.3] ἐπειλείσθης... ἡξελίκτραν. As reiterated at VI.2 [24.10-15], it is by changing the direction of winding of the cord that the automaton can travel forth and back (see also Keean-Jones-Ruffell-McGookin 2016: 173). Prou 166-8 devised a system whereby forward and backward motion would be brought about by the winding and unwinding of two distinct cords, each looped around the knob ε. During the time when the first cord would unwind from the ἡξελίκτρα and thus cause the automaton to move forward, the second cord would instead wind in the opposite direction. This would then be followed by the unwinding of the second cord and, consequently, by the backward motion of the automaton. Prou 168 even specified that the second cord should be longer than the first, arguing that this is what Hero warns his readers about at VI.2 [24.9-14]. What Hero says there, however, is only that a pause can be effected between the forward and backward motions by forming a slack hank of cord to be glued on the ἡξελίκτρα. This does not represent a warning (‘précaution indispensable’, in Prou’s words) but an alternative or additional configuration to that illustrated here (as also signalled by OPENING E, ἐὰν δὲ βουλώμεθα). It is all the more significant that only one cord is mentioned in that context too. Schmidt, Supplementum 139 was therefore right in condemning Prou’s addition ὢλη> after περιλείσθη, for having two cords does not accord with the author’s intentions.

The reading transmitted by M (ἐπικείσθω) in place of ἐπειλείσθω (AGT) makes little or no sense, even assuming that Schmidt’s suggested ἔπειλήσει should be replaced by something else (but what?). From what follows (see above), it is clear that the cord has to be alternately wound and cannot be ‘placed contrariwise in/on the preceding winding’ (taking ἐπίκειμαι with the following dative, cf. LSJ s.v. esp. 1.2 and 1.1). Schmidt rightly based his proposed addition ἔπειλήσει on VI.1 [24.5] τὴν πρῶτην ἐπειλήσιν. The reading was probably omitted owing to its proximity to ἐπειλείσθω. In his app. crit. Schmidt added ‘minus placet ἡ pro τῇ’, but it is not immediately obvious whether he meant ἡ πρῶτην ἔπειλήσει (which does not sound right to me) or simply ἡ πρῶτην (occurring only once in Hero: Spir. 38.1 πληρέστεροι ἡ πρῶτην). Translators such as Baldei 21’, Coutu 248 and McCourt (2012: 189) must have
felt some difficulty here, since they omitted translating τῇ πρῶτῃ. Despite not printing his own addition in the Greek text, Schmidt 359 (‘Umwicklung’) adopted it in his translation.

VI.1 [24.3-4] κρίκος συνεχομένου αὐτή. In his app. crit. Schmidt proposed emending συνεχομένου to συγκεκοινωμένου (‘firmly fastened’) on the basis of XIII.9 [50.10] ὁ δὲ συγκεκοινωμένος τῷ βάρει κρίκος. The verb συνέχω is generally used by Hero in its primary meaning of ‘hold together’, ‘confine’ (XV.3 [52.20], XXV.6 [88.8], Bel. 83.3, 107.4, Dioptr. 196.18, 196.28, Spir. 310.10), but can also refer to liquids being held back (Spir. 58.14, 202.3, 274.12). On three other occasions (Bel. 99.6, 99.8, 100.7), it is found in the passive voice in connection with the joining or fitting of components together. Schmidt’s proposed συγκεκοινωμένου is therefore unnecessary. Cf. also Spir. 326.9-10 συνέχεσθαι δὲ τὴν κεφαλὴν τῷ σώματι.

VI.2 [24.10-11] ἐπειλήσαντες...τῷν. The aorist participle περιβαλόντες is preferable to the present περιβάλλοντες (Pa and Pf) because, just like ἐπειλήσαντες, it serves to indicate anteriority to the future action of the main verb ἐπειλήσομεν (on Brinkmann’s conjecture, see following note).

VI.2 [24.12-15] οὐκ εὐθέως...λέαν. Unlike the Teubner editor, I have adopted Brinkmann’s conjectured ἐπειλήσομεν in place of ἐπειλησόμεθα. The verb ἐπειλέω is never used by Hero in the middle voice, which strongly argues for ἐπειλησόμεθα being a mistake. Presumably this reading arose under the influence of the preceding ουλόμεθα. As recorded in Schmidt’s app. crit., Brinkmann deleted the following ἐπειλήσομεν as a corrective gloss on ἐπειλησόμεθα. This must be right, because the (deleted) ἐπειλήσομεν appears out of context. The participle ἐπειλήσαντες and the main verb ἀποδόσομεν presuppose an unexpressed object such as τὴν σπάρτον (cf. also VI.1 [24.1-3]), whereas ποιήσαντες and προσκόλλησαντες are clearly construed with the direct object μηρυμάτων. Accepting ἐπειλήσομεν would thus imply that the hank is wound on the ἐξελίκτρα, which is not consistent with the purpose of the cord slackenings (see note on II.10 [14.2-3]). Prou 168 with n. 156 quoted the Greek text from the ed. princ., but instead of writing the erroneous προσκολλάσαντες (in lieu of
προσκολλήσαντες), he wrote the equally erroneous προσκολλήσαντες (from *προσκολλώ?) and curiously translated it as 'appliqué'. I was unable to find such reading in any of the manuscripts consulted by Prou, which means that it is either an unhappy conjecture or a trivial mistake.

As for Schmidt's tentatively suggested μηρυμάτια, it has been conjectured on the grounds that the plural of the primitive form μήρυμα occurs at II.11 [14.4] and VI.3 [24.20]. However, I would like to raise two objections. First, the use of the plural in the first passage can be explained by the fact that Hero there is making a general observation. Second, the context of the second passage is quite different from the present one. There Hero mentions the possibility of performing repeated forward and backward motion (which entails the occurrence of several pauses), whereas the current configuration is for the automaton to move, stop and come back. Unlike with the configuration for repeated motion, there is no need to form multiple hanks here, because the automaton is configured to make only one pause.

**VI.2** [24.15] καὶ ἔσται τὸ προκείμενον. Perhaps we should write καὶ <ὁστος> ἔσται τὸ προκείμενον, as at Spir. 128.2-3. Cf. VI.2 [24.8] καὶ οὕτως ἔσται ἡ ἀποφορεία, picked up and varied by VI.2 [24.10]; but cf. Metr. 148.2 and 184.10. For the phrasing, cf. XI.5 [38.6].

**VI.3** [24.16-20] ἡδὲ καὶ... προαιρόμεθα. This passage has been suspected of being an interpolation by Schmidt LII. The main reason which Schmidt implicitly adduced in support of his opinion is that in ch. XIX, the only other place in the text where Hero speaks of outbound and inbound journeys, there is no hint as to how to repeat the movements. The aim of ch. XIX, however, is to illustrate the use of two counterweights and two tubes as an improved alternative to the more traditional and perhaps safer single-counterweight system (Introduction, p. cxiv). A further point made by the previous editor is that the configuration for repeated forward and backward motion requires the placement of multiple knobs on the ἡξελίκτρα. This is not necessarily true. A configuration with only one knob is still possible, provided that the latter is sized to receive multiple cord loops. To this must be added that the section begins with a variation of Opening E (ἥδὲ καὶ... βουλόμεθα), a fact that strongly speaks against interpolation. As
already suggested by Olivier (1901: 432), Hero is simply elaborating upon the configuration of VI.2 [24.9-15], albeit without giving full practical details.

More problematic are the concluding lines of the passage. The text, as it stands in the manuscripts, reads τοὺς τῶν δαίμων χρόνους ποιήσομεν διὰ τῶν μηρυμάτων, etc. The reference to certain δαίμονες is problematic because Hero does not use the term anywhere else. Three different interpretations have been proposed, none of them convincing. The first, and oldest (Baldi 44’ n. 20), is that Hero might have meant to refer to Greek planetary gods (or, presumably, figures thereof) who, introducing themselves into the automaton, would have mimicked the motion of the planets. While such an interpretation is clearly absurd, it demonstrates that despite his apparent mistranslation of the term (‘Tempi’ [21] instead of ‘Temple’, Couture 249), Baldi understood the text correctly. The second interpretation (Schmidt 361-3 n. 2) relies upon the editor’s choice to translate his tentative conjecture χοροῦς for χρόνους. Schmidt seems to think that δαίμονες refers to the Bacchantes, insofar as they are the only dancing figures in the automaton. As he points out, the dances take place while the automaton is not moving and the cord slackenings are being taken up. This is no doubt true, but it is not clear how such a reference would fit within the context. Schmidt’s interpretation is, moreover, made less plausible by the fact that the female followers of Dionysus are designated as δαίμονες only twice and in late sources (Bas. Caes. Epist. 74.1.21 and Ps.-Nonnus, Comm. in Greg. Naz. Serm. 39.4 = 223.21-3 Nimm. Smith). The third interpretation (Murphy 41 n. 13) seems to take ‘deities’ to mean Dionysus. That the term refers to the god, and perhaps also to the Nike, is a possibility, but a slack hank of cord has just been mentioned in connection with the pause of the automaton (VI.2 [24.12]). Perhaps the best way to make sense of the transmitted text is to suppose that the phrase τοὺς τῶν δαίμων χρόνους originated in a separate source. The term δαίμον could thus refer to such figurines as might have been described in Hero’s now lost Ζύγια (Introduction, pp. lxxvi-lxviii with n. 108). However, the fact that the term never occurs in Hero (or in other mechanical writers) seems to suggest otherwise. This naturally leads to the assumption that the text was corrupted and that δαιμόνες should read δὲ μονόν (Brinkmann). This conjecture gives excellent sense and is palaeographically plausible (δὲ μονόν > δαίμον > δαίμονες), although it produces an awkward word order (contra, Brinkmann ap.
Schmidt’s app. crit. to δαιμόνων). Denniston, GP 186 records only one instance of δὲ immediately following two definite articles (E. Tr. 848 τὸ τὰς δὲ [Murray: τὰσδὲ codd.] λευκοτέρου), but this is clearly treated as an exception. The most likely scenario is that δὲ was interpolated into the text. Perhaps a scribe, thinking of the halt state of the automaton (VI.2 [24.9-10]), corrected τὸν to τὸνδὲ (but in fact he should have more correctly written τὸνδὲ τὸν μονῶν). The demonstrative pronoun was probably later misread as τὸν δὲ (incorrect word-division), which subsequently led to the corruption of δὲ μονῶν. On these grounds, I have deleted δὲ. The resulting phrase (τοὺς τὸν μονῆν χρόνους) has a parallel in Gal. Nat. Fac. 3.7 = 220.5 Helmreich τῆς μονῆς ὁ χρόνος (of food remaining in the stomach).

VI.4 [26.1-5] νοεσθε... ε. Hero does not merely assign a different set of points to his configuration, as he does later on in the case of rectangular motion (VI.4 [32.19-20]). Rather, he also gives a side elevation of the case, as can be seen in the accompanying diagram (Fig. 6a). Contrast VI.4 [20.18-22.2], with Fig. 4a (plan view). As pointed out by Drachmann (1972: 489), nowhere else does Hero give two elevations of the same device.

Schmidt was right to delete δὲ after τροχίλον, both because it repeats the preceding δὲ, and because of its odd position. All manuscripts except F have the participle περικειμένην. F has περικείμενον, which probably arose under the influence of the preceding τροχίλον. This reading cannot be right, since it is the cord that is wound around the pulley. I have therefore corrected περικειμένη to περικειμένη to make the participle agree with the subject σπάρτος.

VII-VIII [26.6-30.2] Circular motion

Hero’s treatment of circular motion shows a high degree of geometrisation. As Roby (2017: 533) acutely notes, the automaton is reduced to ‘an imaginary mathematical “skeleton” of itself’. Ch. VII describes the configuration for circular motion, whereas ch. VIII lays the mathematical principles of motion itself. The configuration consists of three wheels mounted on two axles which are set at an angle. From VIII.1 'o ὅδε δὲ, ὅκ, ἀρ τροχοί ἐν κάνον ς ἐς ς ὡς, ὅν βάσεις μὲν ὅδε, ἀρ κύκλοι, it is clear that the outer wheel ὅδε ought to be made bigger than the inner wheel ὅκ (see also Murphy 41 n. 15). This results in a fixed turn-
ing radius, no matter how large the latter is (VII.1 τις ηὶ ἄδ). For more on this configuration, see McCourt (2012: 190-2).

**VII.1** [26.7-8] ἔστω γὰρ... ἀβῦ. Schmidt’s proposed emendation for τὸ must be accepted because the article before ἀβῦ has to agree with κύκλος (see generally Schironi 2010: 347). Schmidt in his app. crit. correctly cited XII.2 [42.15] ὅ ἀβυδ [sc. βωμός]; but cf. also, for instance, Metr. 54.9-10, Spir. 158.8-9.

**VII.1** [26.8-9] <πρὸς> ταυτην... ἁκ. When the adjective ὀρθὸς is used to express a relation of perpendicularity, it is followed by πρὸς + accusative (LS) s.v. ὀρθὸς I.b.; cf. also Mugler, Dictionnaire s.v. ὀρθὸς 2-3), not by the dative (ταυτη, following the manuscripts): see, with reference to a straight line, Defn. 115.2, Dioptr. 232.22, 290.17-18, 292.3-4, 292.4-5 and Metr. 96.2-3; for further references in Hero’s Definitions and Stereometrica, see Heiberg (1914: 259) s.v. ὀρθὸς. I have therefore emended ταυτη to ταυτην and added <πρὸς> in front of it. In his app. crit. Schmidt hesitantly suggested replacing ὀρθὴ with the prepositional phrase πρὸς ὀρθὸς [sc. γονίας], but this is clearly a more invasive emendation. For πρὸς ὀρθὸς + dative (very frequent in Hero), see, for example, VII.2 [26.15] and XXVII.4 [100.3], already cited by Schmidt in support of his suggestion; cf. also XXVII.4 [100.4].

**VII.2** [26.12] τὸ δὲ μεγέθει... ἁη. Line ἁη, as has been correctly noted by Murphy 41 n. 14, corresponds to the portion of the axle contained between wheels ἁζ and ὄκ. The whole axle, in fact, appears to be τὸ (VII.2 [26.16-17]). This distinction is also shown in some diagrams, such as that of A (Fig. 7a). For ἁζεν as denoting the ‘axle shaft’, cf. XIII.8 [50.4].

**VII.2** [26.13] ἳ ὅκ. In his app. crit. Schmidt proposed emending ὅκ to ὅκ, certainly because ἰ represents the midpoint of the line. The suggestion makes good sense in terms of its consistency with the preceding ἁκ (VII.1 [26.9]). I have, however, preferred to retain the best attested reading, since its letters are arranged in alphabetical order (on this tendency, see Roby 2017: 523). M and manuscripts Ld and Ph (in margine) have, respectively, ὅκ, ἀτη and ὅκο. The first two readings are clearly errors: ὅκ arises from haplographic omission of ἰ,
whereas $\eta \theta \eta$ from confusion between minuscule $\eta$ and $\kappa$. The reading $\eta \kappa \theta$ probably represents a failed attempt to correct $\eta \theta \kappa$.

**VII.2** [26.13-14] τὸ δὲ πλανθῶν... ὄ. It is probably unnecessary to add
<πλανθῶν> after $\nu\zeta$, as doubtfully suggested by Schmidt in his app. crit (but see
already Baldi 22'; Couture 249). $\tau \nu \nu \zeta$ can simply be understood as referring to
the line $\nu\zeta$ in the accompanying diagram.

**VII.2** [26.15] ἦ πρ... ὄ. Both Murphy 17 and McCourt (2012: 190) have interpreted
the phrase to mean that $\pi\rho$ bisects $\delta \delta$ below ($\nu\pi\delta$) the point $\delta$. But the
participle τεμνομένη must be understood as passive (so Baldi 22'; Couture 249;
Schmidt 363) rather than middle. Moreover, it would be pointless to say that a
bisection occurs below a point denoting the extremity of a line. Murphy 17 Fig.
3 shows $\pi\rho$ bisecting $\delta \delta$ into two unequal parts, but δύχα τεμνεῖν signifies geo-
metrical bisection (for instances, see Mugler, Dictionnaire s.v. τεμνεῖν; cf. VIII.2
[28.13-15]). McCourt (2012: 191 Fig. 2), on the other hand, has no point $\delta$.

Schmidt’s tentative emendation τῆς $\delta \delta$ (anticipated by Baldi 22') for τοῦ $\delta$ is
tempting but perhaps unnecessary. The line $\pi\rho$ is in fact bisected by the line $\delta \delta$.
Taking $\delta$ as the point of bisection (διχοτομία, cf. VII.1 [26.10]) implies that one
of the extremities of the axe of $\pi\rho$ coincides with the centre of the wheel ($\pi\rho$
being the wheel, $\sigma\chi$ its axe; VII.2 [26.16-17]), which is clearly absurd. How-
ever, some manuscripts diagrams, including that of A (Fig. 7a), show the point $\delta$
(not the ‘line’ $\delta$, as Couture 249 has it) a little further away from $\pi\rho$, but still
inside the circumference passing through $\delta$ (which, indeed, is not one of the
extremities of the axe of $\sigma\chi$). This might be taken to reflect the original arrange-
ment for two main reasons. First, the cones within which are inscribed $\sigma\chi$ and $\pi\rho$
are said to describe more than one circle (VIII.2 [28.7-11]). If $\pi\rho$ were as distant
from the centre as $\sigma\chi$ (as illustrated in Baldi 22’ unnumbered Fig. and McCourt
2012: 191 Fig. 2), the wheels would describe the same circle. Second, placing $\delta$
on or outside the circumference (see, respectively, Murphy 17 Fig. 3 and Baldi
22’ unnumbered Fig.) would probably result in the point itself, and hence the
pivot (VII.3 [26.19-20]), being too distant from the wheel. Speculatively speak-
ing, if Hero was describing the diagram as we find it in A, he might have been

189
influenced by the proximity of ὀ to πρ. The text could therefore be not corrupt, but simply inaccurate.

**VII.3** [26.19-20] οἱ ἀρα κνόδακες... σημείοι. The term κνόδακες has been repeated and then corrected in the margin of manuscript Par. suppl. gr. 11, where we read κνόδακες πυελίδες. These words have been written in a different ink, perhaps by a later hand. There seems to be no reason to adopt the reading πυελίδες instead of κνόδακες. The points ῥ, υ, ὀ and χ represent the extremities of the axles of the wheels ἐκ, ὅκ and πρ (VII.2 [26.17]), and are therefore correctly identified with the pivots of the axles. Furthermore, saying πυελίδες τῶν ἀξόνων would probably entail that the sockets are part of the axles, which is not true.

It is worth wondering whether the word σημείοι is a later addition. It could have been added by a scribe seeking to elucidate the reference to the said points. In fact, similar references largely take the form of elliptical phrases in the treatise. cf. esp. οἱ πρὸς τοὺς ὀ, ὅ κνόδακες (Χ.1 [32.20-1], Χ.3 [34.18-19]); but cf. VIII.1 [28.9] (τὸ ὄ σημειον).

**VII.3** [28.1-2] καὶ... εἰρημένοις. Presumably, a reference to the drive mechanism as described at V.4-5 [22.9-20].

**VIII.1** [28.4-6] Ἐὰν γάρ... ἀκόνητος. If we accept the reading γράφει supported by the best manuscripts, it seems better to accept also Schmidt's proposed emendation of μένει to μενεῖ, with only a slight change of accent. It is curious that the Teubner editor preferred γράφει over γράφει, not least because in his app. crit. he made reference to VIII.2 [28.11] (γράφουσι).

H. Schöne inserted <ἰσοσκελῆς> after κόνος. This is unnecessary, as Hero's words seem intended to apply generally. It is not entirely clear why H. Schöne did not also suggest supplementing the text at VIII.1 [28.7-8] (οἱ δὲ ἐκ, ὅκ, πρ τροχοὶ ἐν κόνωι εἴσι). He perhaps realised that the cones are specified as being isosceles at VIII.2 [28.10] (οἱ κόνωι ἡ ἱσοσκελεῖς).

For the use of the term πλευρά to denote the generatrix of a cone (or cylinder), that is, any line extending from its vertex to its base, cf. LSJ s.v. III.d (Archimedes); Mugler, Dictionnaire s.v.
VIII.2 [28.12] κείμενος... ἐπιπέδῳ. It seems necessary to add <κόνος> here (cf. VIII.1 [28.4]), since the subject changes from plural to singular; cf. also VIII.2 [28.16] (αὐτοῦ). In his app. crit. Schmidt suggested doubtfully that the text should read either ἐν τῷ <παρὰ τὸν ὁρίζοντα> ἐπιπέδῳ or ἐν τῷ ἐπιπέδῳ <παράλληλω τῷ ὁρίζοντι>, adducing in support of his proposal several passages from Hero’s Dioptra and Pappus’ Mathematical Collection (τὸ παρὰ τὸν ὁρίζοντα ἐπίπεδον: Hero, Dioptr. 232.15-16, Papp. 1028.12 and 1054.5; ἐπίπεδον παράλληλον τῷ ὁρίζοντι: Hero, Dioptr. 204.28, 226.20-228.1, 228.12, 230.14, 230.22-3 and 232.2-3). These expressions merely serve to indicate that the plane in question, being parallel to the horizon, is horizontal (contrast ἐπίπεδος ὀρθός πρὸς τὸν ὁρίζοντα, denoting verticality, as in the following sentence). Such specification would be superfluous in the present context, given that Hero has already provided details on the inclination of the ground at ΙΙ.1 [6.9].

VIII.2 [28.12-13] βεβηκός... πλευράν. The perfect participle of βαίνω is used in a strictly geometrical sense to mean ‘stand’ (LSJ s.v. A.1.2.b; Mugler, Dictionnaire s.v.). In this sense the verb is more commonly followed by ἐπὶ + genitive or πρὸς + dative, but for comparable examples with κατά, cf. Bito 50.10 and Ptol. Alm. 1.8 = 30.11-12 Heiberg. Murphy’s ‘moving along’ (18) and McCourt’s (2012: 191) ‘moving upon’ are clearly inappropriate; cf. also LSJ s.v. A.1.2.a.

VIII.2 [28.13-15] τέμνεται... δήχα. This simply means that the cone is notionally divided into two equal parts by a vertical plane passing through one of the sides of the cone, presumably along its axis. There was no need for Hero to specify which side he referred to, because in an isosceles cone (following Archimedes’ terminology) all sides are equal (Heath 1897: clxv; Netz 2004b: 60 n. 63, on Archim. Sph. Cyl. 1.8 = 23.13-24.2 Mugler). The implication here seems to be that the weight is equally distributed between the two parts, and hence the cone remains in equilibrium. McCourt (2012: 191) understood Hero’s words in a rather idiosyncratic way: ‘for it is cut through by a plane perpendicular to the line produced by the side, dividing [the cone] in two’. The first observation to make is that ‘the line’ is nowhere to be found in the Greek text. The term πλευρά already denotes the generating line (or generatrix) of the cone (cf. note on VIII.1.
[28.4-6]). Therefore, it does not make sense to say that a line is produced by the side. A second point is that ὧρθον cannot govern the participle ἐκβαλλομένου. The plane resulting from the imaginary extension of the side of the cone is perpendicular to (πρὸς) the underlying surface (thus Schmidt 365, followed by Murphy 18), insofar as the latter is parallel to the horizon (cf. note on VIII.2 [28.12]). Finally, τὸν ὧρθονα is a substantive participle, and should not be taken with the following adverb (note the hyperbaton between τέμνεται and δίχα).

ἐκβαλλομένου is replaced by ἐμβαλλομένου in M. The latter reading (‘put in[to]’) does not make sense in the context of the geometrical abstraction. For ἐκβαλλομένου... ὧρθονα, cf. Dioctr. 232.12-13.

VIII.2 [28.16-18] ἔκαστον... ἕμικουλλον. I find Schmidt’s tentative suggestion that ἔκαστον should be emended to κινοῦσῃ somewhat peculiar. The emphasis is correctly placed on the uniform transmission of the force, which results in smooth, uninterrupted motion. δύναμις can be nothing else than the ‘motive force’.

VIII.3 [28.20-1] ἐπινοομένων... κορυφῆς. Brinkmann was right in suspecting the second τῶν. If we were to retain the article, we would translate thus: ‘If the semicircles which <reach> up to the vertex are conceived [sc. as existing], etc.’. The main objection to the transmitted text is that the semicircles have already been imagined into existence, albeit implicitly, at VIII.2 [28.16-18]. What matters here, instead, is that the semicircles are visualised (ἐπινοομένων) up to the vertex of the cone, and this is possible only if we delete τῶν. The presence of the article has been strangely overlooked by previous translators.

VIII.3 [28.21-2] οὗ λείπεται... διαστάτων. Because the vertex of the cone is a point (VIII.1 [28.9]; cf. Deff. 85), and this is, by definition, πέρας ἀδιαστάτων... ἀμερές τε καὶ ἀμέγετες τυχάνον (Deff. 1). For the Neopythagorean and Neoplatonic influences on Hero’s conception of geometric point, see Giardina (2003: 255-64).

VIII.3 [28.23] τοῦ... μέρη. Technically, nothing lies on the opposite side, given the adimensionality of the vertex. But Hero probably thinks about the cone in
more concrete and physical terms. \textit{G} transmits \textit{κινούμενον} instead of \textit{κειμένον}. Such a reading may easily be dismissed as erroneous, because no movement at all is produced in the vertex (VIII.1 [28.6]).

\textbf{VIII.3} [30.1-2] εἰ μὴ ὃρα... γίνεται. The term \textit{προωθήσα}, formed from the verb \textit{προωθέω} ('push forward'), is a hapax legomenon. Manuscripts such as \textit{G} and \textit{M} have in its stead the meaningless reading \textit{προωρισμόν}, (mis)corrected by the second hand of \textit{M} supra lineam to \textit{προωρισμόν} ('early determination', LS\textsuperscript{S} s.v.). Baldi 22\textsuperscript{v} gave a curious paraphrase of these words: ‘se non forse se [sc. la forza movente] Io [i.e il vertice] spingesse in qualche luogo stabilito’. This cannot be right, because it contradicts what has just been said. What is especially noteworthy, however, is that Baldi translated the reading in his exemplar (presumably \textit{προωρισμόν}) as ‘qualche luogo stabilito’. He would seem to have corrected \textit{προωρισμόν} to \textit{προωρισμένον} ('predetermined') and to have understood his correction as referring to an unexpressed \textit{τόπον} (which is strange enough), perhaps influenced by the use of the perfect participle of \textit{ὁρίζω} at I.2 [2.11] (κατά τινας ὁρισμένους... τόπους) and IV.1 [18.3-4] (ἐπὶ τινα ὁρισμένον τόπον). This, together with the fact that he took \textit{οὐτῆς} as a subjective rather than as an objective genitive, meant that he had to supply ‘Io’ as a direct object.

\textbf{IX-X} [30.3-34.24] Rectangular motion

Hero introduces a mechanism comprising two sets of three wheels, one of which is alternately raised and lowered (IX.1-3). He interrupts his description to give a fuller account of how the automaton initiates its motion (IX.4-6; cf. II.9). He then returns to the original topic to consider more closely the mechanism for raising and lowering the additional set of wheels (X, with a reconfiguration). In order to produce a rectangular pattern, the two sets of wheels will have been mounted at right angles to each other, as shown in \textit{Figs. 8a-b} (see also Olivieri 1901: 427; McCourt 2012: 193). There is, however, at least one significant problem with this configuration: the force caused by the counterweight (no matter how heavy) would not have been enough to lower the second set of wheels and to lift the automaton (McCourt 2012: 193).
IX.1 [30.7-8] δὲ δὲν ... προγέγραπται. Heron’s point is not that the automaton can be carried both forward and backward along a rectangular path, but rather that the wheels ἵθος, καλὸς and μὲν correspond to those appearing in the mechanism for forward and backward motion. Having the automaton travel backwards along a rectangle would have required programming both sets of wheels.

IX.1 [30.8-9] ἔστω δὲ καὶ ... ϕ. A few words must have dropped out between ὀμοίως and τὸν ϕ., because the wheel ϕ (cf. IX.2 [30.13]) cannot be fitted to the same axle as the wheels ἵθος and καλὸς. All manuscript diagrams agree in showing the wheel ϕ as being mounted on its axle within a frame that is attached to the middle of the side ἀρχαίος, as shown by the example of A (Fig. 8a). Furthermore, at X.2 [34.6-7] the wheel ἱθος (corresponding to ϕ here) is said to be provided with its own axle ἀρχαίος (not to be confused with the current axle ἀρχαίος). It is curious that modern scholars such as Schmidt 366-7, Murphy 18 and McCourt (2012: 193), while acknowledging that the setting of ϕ should be independent of the setting of ἵθος and καλὸς (Schmidt 366 Fig. 88; Murphy 18 Fig. 4 and 41 n. 16; McCourt 2012: 194 Fig. 4), accepted the transmitted text. McCourt (2012: 193) went even as far as to say that both the axle of ἵθος and καλὸς and the wheel ϕ were intended to be set within their own ‘frames’ (the κανόνια of X.1 [34.1]? On this term, see note on X.1 [32.22-34.1]), a fact that is not reflected in his Fig. 4 (where only the wheels δέν and ϕ are correctly shown enclosed in separate casings). No less ambiguous is Schmidt, who (app. crit. ad loc.), although somewhat anticipated by Baldi 23r (‘Siavi anco la ruota u, x’), tentatively proposed reading ὀμοίως <τρίτος τροχὸς> ὅ ϕ. This proposal seems to be based on a comparison with IX.1 [30.6-7] ὅ δὲ τρίτος τροχὸς ἔστω ὅ μὲν. However, the presence of the words καὶ ὀμοίως, along with the accusative article before ϕ, suggests to me that the lacuna should contain a reference to the wheel’s axle (cf. ἀρχαίος...καλὸς). Since the axle of ϕ is not mentioned in the rest of the chapter, and indeed it is assigned its own label at X.2 [34.7], we would expect only a generic mention of it. I therefore believe that the text should be supplemented by something like <ἀρχαίος συμφωνή ἐκόν τροχὸν> or <ἀρχαίος ἐκόν συμφωνή τροχὸν>. The overall distribution of the adjective συμφωνή (in the accusative case, serving as the predicate of an object) and the participle of ἐκόν in the Heronian corpus shows a preference for the sequence ‘participle + adjective’ over the sequence
'adjective + participle': 10 instances as against 4 instances. If we confine our attention to contiguous or nearly contiguous sequences (i.e. with or without one intervening word), we find that this preference becomes less marked, with the former sequence occurring 5 times (XI.2 [36.8], Dioftr. 294.17, 294.22, 310.2-3, Spir. 164.4), and the latter 4 times (here, as well as at IX.1 [30.5-6], XI.9 [40.12], Dioftr. 294.1). Given that almost all (quasi-)contiguous sequences of the type 'participle + adjective' have the singular form of the adjective (the opposite being true of the sequence 'adjective + participle'), the missing words are perhaps more likely to be <ἀξίων ἔχων συμφών τροχών> (cf. esp. XI.2 [36.7-8] ὁ μὲν ηῆ [sc. ἄξων]... ἔχων συμφών τροχών τὸν ἔλθα). Yet the context suggests otherwise. In the absence of firmer evidence, it seems more prudent to place an unfilled lacuna in the text, leaving it to the reader to decide which, if any, of these suggestions would fit best.


IX.3 [30.17-20] καὶ ἀνασαποθέντος... πλυνθὸν. At some point in the transmission of the text the main clause δί αὐτῶν... πλυνθὸν was quite certainly understood as a continuation of the consecutive clause ἄστε... ἐδάφει. This meant that an early scribe added καὶ (deleted by Brinkmann) at the beginning of the main clause and altered ποιεθήσεται (restituted by Schmidt) into the infinitive ποιεθήναι. Schmidt in his app. crit. correctly cited in support of his correction VI.1 [24.5-6] (τὸ πλυνθὸν ποιεθήσεται) and IX.3 [30.22] (ἐνεκχήσεται τὸ πλυνθὸν); but, more generally, note that the future tense is used consistently throughout IX.2-5 [30.15-2.12].

IX.3 [30.23-4] ἔλεοςτε... πλυνθὸν. It is unnecessary to emend τὸ παραλληλώγραμμον το τὰ παραλληλωγράμματον, as doubtfully suggested by Schmidt in his app. crit. Despite the fact that ἐπὶ + genitive is found in a similar context (VII.1 [26.6] ἐπὶ κύκλων πορεία γίνεται, adduced by Schmidt to support his suggestion), the accusative may have been selected to convey a spatial sense of direction (LS) s.v. ἐπὶ C.13; cf. Netz 2004a: 101 [geometrical usage]). We cannot exclude the possibility that the two constructions are used interchange-
ably: compare the occurrence of the accusative in place of the genitive at II.7 [10.18] ἐπὶ τὸ ἔδαφος (see note ad loc.).

**IX.4** [32.1-2] πορείας δὲ... χαλασμάτων. Vindob. suppl. gr. 21 is the only manuscript to transmit the reading μονᾶς, already conjectured by Haase and also presupposed by Baldi 23 (‘II fermarsi’). Several other manuscripts, including א, have μόνας (for the confusion between the feminine form of μόνος and the term μονή, see Kroll’s app. crit. to Procl. in R. II 188.23), which appears to have been corrupted into μόνον in some witnesses (Ab, Bb, La, Lc, Ld). If we were to follow Thévenot 251 and Murphy 19 in adopting the best attested reading, we would have to take πορείας as accusative plural rather than as genitive singular. This would appear somewhat strange, since Hero never uses the term πορεία in the plural. It is also not clear what purpose the cord slackenings would serve. Similar problems would arise if we tried to make sense of the variant reading μόνον: ‘It [i.e. the case] will only make journeys however we choose, etc.’.

Brinkmann believed that the words τέ... καῦ should be deleted, probably on the grounds that absence of motion is generally linked directly with the slackenings of the cord (cf. note on II.10 [12.19-14.3]), and not with its windings. This is true as far as it goes, but it fails to take into account the observation (XI.6 [38.8-12]; cf. XI.6 [38.12-14]) that, in order to determine the length both of the windings and of the slack hanks of cord, the automata-maker drives the case backwards by hand and starts making the windings from the point where he wants it to stop. The reason for this is that the automaton ceases to move as soon as the winding of the cord is completely unrolled, at which point the slackening starts being taken up. There is nothing suspicious, therefore, in the fact that the slackenings are mentioned alongside the windings (cf. also X.3 [34.15-16] and XI.5 [38.4-5]).

**IX.5** [32.8-9] ἀ κλειθρῷ... σπάρτῳ. Before the word σπάρτῳ the manuscripts have either ἐκδιθέν (as in AGT) or ἐνδεθέν (as in M). Schmidt (quite unnecessarily, in my view) obelised the oldest attested reading, relegating his own suggestions (ἐκδιθέντι and ἐνδεθέντι, the former being substantially anticipated by Brinkmann’s ἐκδιθέντι <ἐν>), to the app. crit. Although syntactically possible, a neuter participle agreeing with the subject (ὁ) poses problems, because it is not
the hole, but the lock that is connected to the cord (cf. IX.5 [32.11-12]; cf. also XIX.4 [62.11-12]). In their translations, Baldi 23 and Schmidt 369 included the last two words in a new sentence, which rather suggests that the main verb is missing and that the neuter nominative singular participle agrees with an unexpressed κλειθρίον: ‘detto serraglio sarà raccomandato ad una corda’ (Baldi), ‘[d]ieser [sc. Schieber] ist an eine Schnur geknüpft’ (Schmidt). This, however, entails punctuating heavily after κλειθήσεται and, possibly, assuming a lacuna between either of the participles and σπάρτο. I prefer to adopt Schmidt’s doubt-ful emendation ἐνδεθέντι (apparently also adopted by Murphy 19), which makes the participle agree with κλειθρίῳ and avoids the need for further emendation. To support his conjecture, Schmidt cited Spir. 188.6 (τὸ ἀλοσέιδον τὸ ἐνδεδεμένον), but there the verb is followed by εἰς + accusative. This is the only occurrence of ἐνδεδω in Hero (unless one follows Schmidt 1900: 258 and accepts the manuscript reading ἐκδεδεμένα of Diopt. 308.12-13 [ἐκδεδεμένα H. Schöne, also tentatively favoured by Schmidt; but without attribution: see his app. crit. to Mech. Frag. 1.1 = 258.13]), although the verb is commonly attested with the dative (LSJ s.v.; cf. also, for instance, [Apollod.] Poliorc. 164.2-3, 173.3-4, Bito 50.6-7, 50.10-11). By contrast, the verb ἐκδεδω (which occurs more frequently in Hero, especially in reference to cords) is normally construed with the genitive (with or without ἐκ, cf. LSJ s.v.;) Hero uses it not only with ἐκ + genitive (e.g. XVIII.1 [58.15], XIX.4 [62.14], XXIII.8 [78.17-18]) but also with εἰς + accusative (e.g. XXIV.4 [82.13-14], XXVIII.7 [104.7-8]). Schmidt’s suggested alternative (ἐκδεθέντι) would therefore require further emendation, perhaps something along the lines of ἐκδεθέντι ἐκ τινος σπάρτον or ἐκδεθέντι εἰς τινα σπάρτον (Brinkmann’s conjecture can be easily dismissed because ἐκδεδω is never followed by ὑπ’ + dative).

The term κλειθρίον occurs only in the Automata and nowhere else. The term is mainly used to refer to the lock mechanism of the συργύς (or to either of the two mechanisms in the context of the two-counterweight configuration: XIX.3 [62.3-4], XIX.4 [62.12] and [62.15], XIX.5 [62.18-19]), but it also refers to the mechanism whereby the balls producing the sound of kettledrums and cymbals are released (XIV.1 [50.21], XIV.2 [52.6]). An entirely similar mechanism is presumably alluded to at XX.4 [66.10-13] (cf. XX.4 [66.15-16]), where Hero sets out to illustrate the device for generating the sound of thunder. In its most
basic form, the mechanism appears to consist of a slide (Prou 163; Schmidt 369 and passim) that is pulled back (either manually or automatically; cf. the use of the verb ἐπιστάω at XIX.4 [62.11], [62.15] and XIX.5 [62.18]; cf. also XIX.2 [62.2] and XIX.3 [62.3]) by means of a cord. In one case, there is reason to believe that the slide was closed automatically (cf. XIX.4 [62.14-15] with note ad loc.). The closest parallel to the usage of κλειθρίων is found in Str. 17.1.37, where the plural form κλείθρα denotes the locks used to regulate the inflow and outflow of water in a canal (i.e. a locking system consisting essentially of a key and a horizontally sliding wooden bar: see Bonneau 1993: 74-5 with n. 620, cited by Laudenbach 2015: 213); this use is not recorded by LSJ s.v., but see Hellmann (1992: 221 n. 18), where Strabo’s passage is erroneously cited as 17.4.35. Another related meaning of κλειθρον is ‘boom (harbour barrier)’: cf. LSJ s.v. I.2 and, most recently, Whitehead (2016: 313), on Ph. Parasce. 94.40-2.

IX.5 [32.11-12] ἐπλαμβανόμενοι... κλειθρίων. The negative οὐ is clearly a later addition, since Hero’s audience is not supposed to know how the automaton is activated (in his app. crit. Schmidt misreported that manuscripts Lb and Pc omit οὐ, and therefore left it out from the text: see Schmidt, Supplementum 114 and 115 n. 1). The reading might have arisen from a copyist repeating the ending of the preceding σπάρτου.

IX.5 [32.12-13] καὶ οὖτος... πλινθίων. The passive form κινεῖται (La<sup>n</sup>; cf. ‘si faccia il moto’, Baldi 23°) is to be preferred to the active form κινεῖ (transmitted by all other manuscripts, including Leid. Bon. Vulc. 4 in textu) because τὸ πλινθίων is best understood as subject (Baldi 23°; Couture 251; Murphy 19) rather than as object (‘setzt die Schnur den Radkasten in Bewegung’, Schmidt 369). The reading κινεῖ would necessitate a pronominal subject referring to the pouring out of millet (e.g. <σωτό>κινεῖ τὸ πλινθίων). Contrast IX.6 [32.15-17] ἢ σπάρτος... ταξιέα κινήσει τὸ πλινθίων. Schmidt expressed his tentative approval of κινεῖται by citing X.3 [34.17] (κινεῖται τὸ πλινθίων); for the passive of κινέω, cf. also I.2 [2.12], II.3 [8.4] and VIII.2 [28.19].

Murphy 19 seems to have understood the term βάσις here as referring to a catch basin placed somewhere inside the base of the automaton. I fail to understand why the term should denote anything different from the base containing
the wheels (cf. note on II.7 [10.18-19]), primarily because it has been used consistently up to this point. It is not difficult to imagine the millet pouring out on the ground, if we suppose that the base was bottomless. The bottom of the case had to be at least partially hollow to allow the wheels to rest on the ground.

On Hero’s use of ἀρέμα, see note on II.9 [12.10-13].

IX.6 [32.15-17] ἔξει... πλινθόν. It is tempting to emend κινήσει to κινήσῃ, since Hero almost always uses the subjunctive after ὅπως. Cf. esp. IX.5 [32.9-12] and, for a similarly constructed passage, XVI.3 [56.6-8]. There are, however, at least two other instances of ὅπως with future indicative: XXVI.8 [96.3-5] περιτίθημι ἀξονα... ὅπως... στραφήσεται, Geom. 414.28-416.1 Εὑρεῖν δύο χορία... ὅπως τὸ τοῦ πρώτου ἐμβαδὸν... ἔσται τριπλάσιον (with a seemingly paratactic construction used imperatively; on this usage, cf. Cooper 1998: 720-22).

X.1 [32.19-20] Ἐστωσαν... ἡθ. The wheels ἀβ, γδ and εξ correspond, respectively, to πρ, στ and υφ, as illustrated in Fig. 8a. The axle ἡθ corresponds instead to εξ (cf. IX.1 [30.8-9] and Schmidt 369 n. 1). The manuscript diagram accompanying this (re-)configuration lacks any letter labels, but these were first supplied by Thévenot 252 unnumbered Fig.; see also Baldi 24r unnumbered Fig., but with partial lettering.

X.1 [32.22-34.1] τὰ ὄν... κανόνια. No explanation is given of what these κανόνια are. Baldi 23r (‘rigoli’) and Couture 251 (‘normulis’) strangely understood the term as indicating ‘rulers’ or ‘measuring-rods’ (LSJ, Supplement s.v. κανόνιον); similarly, but more generally, Schmidt 371 (‘Latten’). The term is used elsewhere in the treatise in its general sense (X.2 [34.9], on which see more below; ὑπελήγησιν: XXIV.3 [82.8], [82.10], [82.11] and XXIV.4 [82.13]), but here it seems to have a more specific meaning. The observation that the wheel εξ is placed ἐν τινι κανονιῷ (X.2 [34.3]; on such arrangement, cf. note on X.2 [34.3-5]), in fact, points to some kind of frame. This is not entirely surprising, considering that the semantically related diminutive κανονίς is attested in the meaning of ‘door-frame’ (Hellmann 1992: 187 with n. 7): IG 2.1672.155 (Eleusis, 329/328 BCE; but LSJ, Supplement s.v. II doubtfully suggest ‘upright of a door-frame’), ID 1403 Bb col. I 48 (165-157/156 BCE). Add to this that Hero,
Bel. 100.8-9 uses the base noun κανόνιον to refer to the beams constituting the stock of a stone-throwing engine, the so-called κλιμακίς (‘ladder’; on this, see Marsden 1969: 23-4 with Fig. 13): διάπηγμα κατασκευάζεται ἐκ τεσσάρων κανόνων συνεστικός. For a similar use of the derivative κανόνιον, cf. Ph. Bel. 74.7-8.

Murphy 19 first adopted the term ‘bar-frame’ (which I also adopt in my translation) to refer to the κανόνιον of wheel ἡς (in addition to the above-cited occurrence, cf. X.2 [34.5], [34.7] and X.3 [34.13]; cf. also Murphy 41.1 n. 17), but rendered the other occurrences of the word by either ‘bars’ (here and X.1 [34.1]) or ‘guide-bars’ (X.2 [34.9]). Although the wheels ἄβ and γῶ (unlike ἡς) are not each encased by their own κανόνιον (they are in fact on the same axle, an arrangement similar to that of ἡς would have required ἄβ and γῶ to be mounted on separate axles), there seems to be no reason why the term should be taken as denoting a different structure. The three κανόνια are all attached to the sides of the case with dovetails (cf. X.1-2 [34.1-4], and following note), their purpose being to permit simultaneous lifting and lowering of the wheels (cf. X.3-4 [34.17-23]). The case is different with regard to X.2 [34.9], where the term seems merely intended to specify the shape of the γόμφοι, ‘dowels’ (see further note on X.2 [34.9]). I cannot understand why the γόμφοι should serve as ‘guide-bars’ (my emphasis). They appear to be used only to hold the screw ἐν τῇ in place, allowing it to rotate but not to slide back and forth: cf. X.2 [34.10-11].

Schmidt tentatively suggested adding either ἐνερησομένα or ἐμβεβηκότα between ἐστω and ἡς. Neither of these supplements accords with the nature of the ἐμπελείδια. The constructions ἐναρμόζει + εἰς and ἐμβαίνει + εἰς, as used by Hero, refer to components fitting one into the other: for example, pivots into sockets (ἐμβαίνει: II.3 [8.6]; ἐναρμόζει: X.1 [32.21], adduced by Schmidt in support of ἐνερησομένα). The sockets, which are made to receive the pivots, are to be fitted on(to) the κανόνια, not ‘into’ them (as with Murphy 19), just as at XI.9 [40.9-10] other ἐμπελείδια are on ἐν either side of a διάπηγμα (cf. also V.3 [20.20-1] πελείδας... ἐν τοῖς... τοῖς, with Keenan-Jones-Ruffell-McGookin 2016: 176). The preposition εἰς is here clearly used instead of ἐν, a late usage (LS s.v. ἐις 1.2; cf. XXVII.2 [98.11] and Spir. 16.4 and 274.4, with Hammer-Jensen 1910: 502).
X.1 [34.1-2] τὰ δὲ κανόνια... τοῖχος. Sliding dovetail joints are probably used here because the κανόνια are joined perpendicularly (ἀρθά, cf. X.2 [34.3]) to the sides of the case. In order for the κανόνια to be able to move up and down (X.3 [34.12-13]), the joints will not have been made too tight. The term πελεκένως in its technical sense of ‘dovetail’ (LS) s.v. III) has been convincingly explained by Orlandos (1968: 102) as referring to the double-axe shape of the joint (cf. Lat. securicula, OLD s.v. 2); see also Baldi 44' n. 21 and, more recently, Ginouvès-Martin (1985: 109).

X.2 [34.3-5] τὸ ἔξ... πλευσθ. The details of this arrangement have been discussed by Murphy 41 n. 17, who envisaged three possibilities: (1) the wheel is set so as to protrude through the side of the case; (2) the κανόνιον has a width greater than the radius of the wheel, and hence it serves as a frame for the wheel; (3) the κανόνιον holds the wheel by means of a projecting bracket (as shown in Schmidt: 371 Fig. 90a). The idea that the wheel is entirely or partly encased by the κανόνιον as if by a frame (cf. note on X.1 [32.22-34.1]) must be closer to the truth than the other two possibilities, as also suggested by the manuscript diagrams. As can be seen in Fig. 9, the wheel on the right-hand side, unlike the remaining wheels, is placed into what appears to be its κανόνιον (compare with Fig. 8a, see note on IX.1 [30.8-9]). This very arrangement is also reproduced in perspective in Baldi 24' unnumbered Fig. As for the first possibility, it is not clear to me why the wheel should stick out through the side. This, or a similar arrangement, would involve dislocating the wheel, which is neither described nor implied anywhere in the text. There is, in any case, an inconsistency between Murphy’s claim (41 n. 17) that the κανόνιον moves in a dovetail on the side of the case (as illustrated in Murphy 20 Fig. 5) and her interpretation of the words τὸν πρῶς τὸ ἐξ τοῖχον τὸν πλευσθ. (‘the side of the base facing EZ’ [19], my emphasis; same understanding at X.2 [34.8-9]). Πρῶς is here followed by the dative, not by the accusative, and clearly indicates proximity (LS) s.v. B.1, as at VII.3 [26.20] (mathematical usage: Mugler 1958: 26); cf. also X.1 [32.22].

Schmidt’s καταβιβαζόμενο (καταβιβαζόμενο codd.) is no doubt correct. Cf. X.1 [34.1-2] τὰ δὲ κανόνια διὰ πελεκένων καταβιβάντω. Note the variation between the verbs καταβαίνω and καταβιβάζω.
X.2 [34.5-6] ἔστω... κλίμαν. Schmidt's correction of the manuscript reading ηθο (cf. also X.3 [34.13]) is not trivial because ηθο already denotes the axle of the main wheels (Schmidt 371 n. 1): X.1 [32.19-20]. Manuscript Ad alone transmits the nonsensical κθο (an error owing to confusion between η and κ). The letter κ designates one corner of the mortise κλίμαν and cannot be conjoined with θ.

X.2 [34.8] ἐνειλεόθω. LS] s.v. ἐνειλέῳ do not record this sense of ‘screw on’, ‘joint’, attested only here and at X.2 [34.9]; cf. DGE s.v. A.11.2. This specialised meaning presumably developed from the basic passive meaning of ‘to be enwrapped’ (LS] s.v. 1; cf. also DGE s.v. A.1.1).

Pα transmits ἐνείσθω. This erroneous reading must have arisen from the omission of the penultimate syllable of ἐνειλεόθω. The verb ἐνίημι (which, in its basic sense, means ‘send into’, LS] s.v. 1) does not fit well within the context of the sentence. The only occurrence of the form ἐνείσθω in Greek literature is Hp. Aff. Int. 48 = 7.288.9 Littre ζαθήτα δε ἐνείσθω [sc. ὁ νοσέων], but there the verb is used in a middle rather than a passive sense.

X.2 [34.9] δύο γόμφοι καθάπερ κανόνια. This comparison comes as a surprise, because the term κανόνιον occurs throughout the chapter in reference to the bar-frames which make it possible to raise and lower the wheels. It seems to me, though, that κανόνια here should be understood in a more general sense as ‘bars’ - Murphy 19 goes astray in her rendering ‘guide-bars’; cf. note on X.1 [32.22-34.1]. The reason for this is that the noun γόμφος can indicate any small object used to fasten components together, as transpires from a Cyrillian gloss in Hesychius: Hsch. γ 805 Latte γόμφοι: μύλοι. σφήνες. δεσμά. ἄρθρα. σύνδεσμοι. καὶ ὀδόντες γόμφοι. The Hesychian gloss on the term is even more vague, although it only concerns woodwork (Hellmann 1992: 85 n. 4): Hsch. γ 806 Latte γόμφους: ταῖς τῶν ζύλων ἀρμογαίς. Such terminological polyvalence led to different translations: ‘chiodi’ (Baldi 23°), ‘cuneoli’ (Couture 252), ‘Bolzen’ (Schmidt 373). Among these, the most curious is that of Baldi. The term, in fact, does not ever seem to refer to a nail (cf. LS] s.v. and Hellmann 1992: 84-6), despite Hsch. γ 808 Latte γομφοτήρια: ἥλιοι (for γομφοτήριον in the sense of ‘tenon’, cf. XXVII.1 [98.5]). The Renaissance scholar, however, apparently understood that Hero adduced the comparison to clarify his reference to the two
γόμφοι - a procedure followed elsewhere in the text: II.6 [10.6-8], XII.2 [42.16-17], XXVII.1 [98.5], XXVIII.3 [100.18-19]; cf. XIII.9 [50.10-11] and XX.4 [66.17-18]; XXVIII.4 [102.10-11] (ὅπῃ διαφαίνουσα ὀσεὶ θυρίς) almost certainly represents a stylistic mannerism. Baldi’s understanding of the comparison (later endorsed by Couture and Schmidt) largely hinged on his understanding of the word κανόνιον (cf. note on X.1 [32.22-34.1]): ‘chiiodi piani come rigoli’ (my emphasis). This interpretation has two disadvantages. First, it does not take into account the γόμφοι’s function as supports for the screw (cf. X.2 [34.10]). If they were used to hold the screw, they were probably not too flat. Second, it rests on an erroneous interpretation of the word κανόνιον, which often denotes simply anything bar-shaped (in Hero, too: LSJ s.v. I; for further references in Hero’s Belopoeica, see, for example, Bel. 77.3, 77.5, 78.2). Given the semantic indeterminacy of the term γόμφος, the most natural assumption is that Hero adduced the comparison καθάπερ κανόνια to specify the shape of the fastening elements rather than their thickness. If this is the case, then we have to understand γόμφοι as ‘dowels’ or ‘pins’ (Ginouvès-Martin 1985: 112), dismissing other possible shapes such as wedges (σφήνες/cuneoli) or tenons.

X.3 [34.16] διαμημητημένα. LSJ s.v. διαμηρόω cite the present occurrence as the only attestation of the verb διαμηρόμαι (erroneously recorded as active). The verb occurs three more times (XI.11 [42.6], XVI.3 [56.7], Bel. 108.9), or five more times if one counts the two occurrences in the fragments preserved by Pappus: Mech. Frag. 2.1 and 3.1=Papp. 1118.8-9 (deleted by Hultsch) and 1132.9 (middle). In most instances, the verb refers to the act of winding a cord (or its slackenings) into hanks. On one occasion (Bel. 108.9), Hero uses the verb to describe the process of threading the spring-cord through holes in the frame of a catapult.

X.3 [34.16-17] ἀρμοστὰ...πλευθὸν. Note the variation with XI.5 [38.5-6].

For the technical use of ἀρμοστός, cf. DGE s.v. I.1, citing the present passage and XVI.1 [54.14] among others.
X.4 [34.20-2] δεύ δε τολκ... δημούς. A rare piece of advice intended for the expert builder. For a statement of (allegedly) exact proportionality, cf. XXIII.1 [74.7-9].

XI [36.1-42.8] Other forms of motion

Hero now discusses three different configurations for snake-like motion, with only passing mention of the possibility of making the automaton travel along non-rectangular polygonal paths (XI.1). At their basic level, all three mechanisms share the idea of a differential drive to produce changes in direction. The first mechanism (XI.2-5) has the two front wheels independently mounted on hubs, and the rear (non-driving) wheel turning on pivots. The second mechanism (XI.7) is a modified - but probably unsuccessful - version of the previous configuration, featuring the addition of a third hub but with the rear axle now attached to the case and a cord connecting the hub to the counterweight. The third and last mechanism (XI.9-10), explicitly favoured for technical reasons (αἱ... εἰς τῇ κινήσει δυσχερῶς ἐπιστρέφονται, XI.8), replaces the χωνικής type of bearing with the κνόδαξ, and the single front axle with two independent axles. Both XI.7 and XI.10 have been condemned by the previous editor as interpolations (Schmidt LIII-IV). The incipit βελτίων δὲ καὶ, etc. (XI.7) alone argues against interpolation, for it occurs, in a slightly modified form, in at least two other places (II.5 and Spir. 202.9-10). The addition of the third hub does not contradict XI.8, because Hero does not express his preference for the second configuration. As regards XI.10, the idea that each axle receives two cords is clearly wrong. That Hero is employing single cords is suggested not by XI.11 (as argued by Schmidt), but by his actual use of δυλός (cf. note on XI.10 αἰ δὲ περὶ... στρέψει). For further arguments against interpolation, see notes ad locc. Nor does it make sense to propose, as Murphy 42 n. 22 does, that, taken together, XI.7 and XI.10 describe an alternative to the first configuration. They indeed describe two different configurations with different bearings. The flow of the narrative is once again interrupted (XI.6; cf. IX.4-6) to incorporate more general information on the (empirical) measurement of cords.

XI.1 [36.1-3] Δυνατον δὲ... σχήματι. Hero does not elaborate, but the incipit, a variation of OPENING E, makes it clear that he refers to an improvement of his
own devising, quite possibly one that he did not finalise. In modern terminology, a ‘rectilinear figure’ is simply a polygon: cf. Euc. 1 Def. 19 Σχήματα εὐθύγραμμα ἕστι τὰ ὑπὸ εὐθείῶν περιεχόμενα, etc. Cf. also Hero, Def. 39, with Giardina (2003: 299-300).

**XI.2** [36.7-10] ἀξονες... εἰργασμένος. Manuscript diagrams show both these axles fixed to the case (see Fig. 11a), even though Hero’s counterposition (ὅ μὲν ἐστι... ὁ δὲ εἰς συναρμόδες ἕστι τῷ πλευρίῳ) suggests that ηθος was, in fact, intended to be detached from it. Were it not so, we could not understand the proposed change of XI.7 [38.15-17], which, indeed, must have led to modifications of the original diagram. Previous editors and translators, notably Baldi 25’ unnumbered Fig., Schmidt 374 Fig. 91a and Murphy 21 Fig. 6, have placed wheel κάλι within a frame in the middle of side γδ, probably influenced by the wheel configuration for straight-line (Figs. 4a-b) and rectangular (Figs. 8a-b) motions; see also my modern reconstruction (Fig. 11b) and note on XI.10 [40.18-19]. Hero’s silence in this respect is not surprising, for only once does he mention the peculiar arrangement of the third, non-driving wheel: V.4 [22.5-7]; but cf. IX.1 [30.7-8] with note ad loc.

Murphy 41 n. 18 took the words ἀπὸ τορνου ἰσοταχῆς εἰργασμένος to mean that the axle εε should be made as thick as the other axle. This, however, is not implied by the Greek text. The significance of Hero’s words has to do with the necessity to reduce friction and to ensure smooth turning of the χονικίδες around the fixed axle εε (see generally Keenan-Jones-Ruffell-McGookin 2016: 177), as becomes apparent from the immediately following lines: XI.2 [36.10-13]. On Hero’s recurring insistence on the use of the lathe, cf. note on II.3 [8.4] ἐντορνά τε ἀκριβῶς.

**XI.2** [36.11] εὐλότας καὶ ἀρμοστάς. On the pairing of these adverbs, see note on II.8 [12.6-7].

**XI.2** [36.12] καὶ αὐταί. I prefer the reading of Ld αὐταί, already conjectured by Schmidt on the basis of V.3 [22.2-3] καὶ αὐτή to that of M αὐταί). Schmidt printed the latter reading, although it is not clear whether he took it from M or corrected it from AGT αὐταί).
XI.3 [36.17-18] καταφερομένης... τροχοῦ. These lines recall Hero’s first description of the axle-wheel arrangement (II.7 [10.16-17]), but here the asyndeton between the two genitive absolutes shifts the focus from the mechanism by which motion is transmitted to the rapidity with which the individual movements succeed one another; for a similar use of asyndeton, cf. XI.7 [38.24-40.1]; see also, for instance, E. Andr: 1154 βάλλων ἀφάσσων, with Allan (2009: 197). Murphy 20 rendered the second genitive absolute as a subordinate clause (as the strings are unwound), thus obscuring the causal relationship between the fall of the counterweight and the unwinding of the cords. Other translators, such as Baldi 24', Couture 253 and McCourt (2012: 195), correctly understood the syntax, but they all replaced the ‘cords’ with a single cord. Not only does this violate grammar, but it also contradicts XI.3 [36.15].

XI.5 [38.1-3] δεήσει... ἐνεχάθηνα. In other words, the size of the slackening is determined based on the desired length of the trajectory of the automaton. There is no mention of how the turning angle could be regulated, but that must have depended mainly, but not only, on the wheel arrangement. For a description of the method used to measure lengths of cord, cf. XI.6 [38.7-12] with note ad loc.

XI.6 [38.7-12] δεήσει... δόσομεν. For the rationale behind this process, cf. note on IX.4 [32.1-2].

Berryman (2009: 142 n. 165) sees a contrast here (albeit without giving the precise reference), as elsewhere (?), between what happens automatically (τὸ αὐτόματον) and what happens by trial (ἐκ πείρας). I cannot find such a contrast anywhere in Hero’s corpus. What I do find is a contrast (either explicitly or implicitly articulated) between automatic processes and manually induced (ταῖς χερσίν or τῇ χειρὶ) movements: in addition to the present passage, cf. XXIII.3 [74.18-76.1], XXVII.3-4 [98.16-20], XXX.4 [108.3-4], Spir. 186.9-12 and 198.12-200.1; cf. also XIV.1 [82.5-8] (τοῖς δακτύλοις vs αὐτόματον). In fact, the phrase ἐκ πείρας or, more correctly, ἐξ αὐτῆς τῆς πείρας is not used to describe the manual steps involved in the measuring process, as argued by Berryman, but, rather, to describe a systematic testing procedure. This emerges from a comparison between Hero, Bel. 112.8-113.4 (εἰδέναι δὲ δεῖ ὅτι ἡ τῶν μέτρων [sc. τῶν εὐθυτόνων καὶ παλιντόνων] ἀναγραφῇ ἐξ αὐτῆς τῆς πείρας ἔλθῃ,
etc.) and Ph. Bel. 50.14-29, where Philo gives an account of the discovery of the
diameter of the hole that receives the spring of the catapult as the guiding prin-
ciple in artillery construction. The emphasis placed there on the importance of
πείρα serves to indicate that the discovery would not have been made without
systematic empirical testing (Schiefsky 2015: 628-31; cf. also Ferrari 1985:
256). Hero likewise assigns an important role to practical testing. Repeated test-
ing enables the practitioner to determine specific measurements (here, as at Spir.
288.2-3 πείρα οὖν εὑρόντες τὰ μέτρα, etc.); it promotes understanding of how
components fit together (Spir. 320.13-14 πείρα οὖν σκεψάμεθα πότε μὲν
catάλληλον τὸ τρήμα τῷ ΜΟ σωλήνι, etc.); it assists in calculating the speed
ratio between a screw and a cogwheel (Diopt. 298.6-9). Hero, however, goes
further than assigning a heuristic status to πείρα. Just as importantly, testing
serves as a basis for comparing the poor performance of earlier automat with
the superior performance of Hero’s own models: XX.1 [64.4-7] καὶ γὰρ εὐκόπως
καὶ ἀκινδύνως καὶ ἔνως παρὰ τὰ πρὸ ἡμῶν ἁναγραμμένα καταχειρίκαμεν,
ὡς ἔστι δὴλον τοῖς πεπεραμένοις τῶν πρότερον ἁναγραμμένοις; cf. V.1
[20.10-12]. That is to say, it provides the ultimate guarantee of the safety and
effectiveness of the devices. It is in this light, too, that one should read Hero’s
concern about the potential failure of the mobile automaton: cf. II.4 [8.11-12]
and, more ominously, II.11 [14.7-10].

XI.7 [38.15-19] βέλτιον δὲ καὶ... ἀποδοθῆναι. This configuration seems to re-
fect a failed attempt to improve the simpler arrangement of XI.2-5 [36.7-8.4].
While the addition of the third hub, as well as of the third cord (both deemed
pointless by Schmidt LIII; cf. note on XI.10 [42.2-3]), might be explained on the
basis of the designer’s desire to obtain more control over the third wheel
(Murphy 41 n. 20), the slackenings of the cord have no purpose (Schmidt LIII).
In fact, as noted by the Teubner editor, the wheel ἔκαστος has been presented as con-
tinuously rotating (XI.3 [36.19-20], XI.4 [36.22-3]; cf. XI.5 [38.3-4]), which is
also consistent with XI.7 [38.22-40.2]. Assuming that ἔκαστος could be forced to stop
turning because of the slackening of its cord, it would still have been dragged by
either or both of the two other wheels. The words καὶ τὰ χαλάσματα ἔχουσαν
(see app. crit. ad loc.) seem therefore to have been interpolated in order to make
the arrangement of ἃλιπον match exactly the arrangement of the main wheels προπτερέσσαι and ὅτε.

There is no reason to emend ὅταν to σὺν, as hesitantly proposed by Schmidt in his app. crit. Schmidt did not adduce any evidence in support of his conjecture, although he probably thought of XI.3 [36.18] (ἐπιστρέψατοι σὺν ταῖς χοινικίσι). The verb used here, however, is not ἐπιστρέφω but περίκειμαι, which refers to the mounting of the wheel. Cf. XI.9 [40.12-14] ἐκάτερος [sc. τῶν τροχῶν] κείσθω... ὅταν κυνόδαιv.

**XI.7** [38.19-23] τέπος... τροχόν. I agree with Schmidt LIII that ὅπως poses a serious linguistic problem, but disagree that it constitutes a strong argument for interpolation. He put a crux in front of it, but deemed it ‘spurium’ in his app. crit. This is somewhat curious, since he had already deleted the whole of XI.7 (see also my app. crit. to καὶ τὰ χαλάσματα ἔχουσαν). None of the proposed emendations is entirely convincing. Brinkmann suggested adding either <συμβή> or <ποιήσωμεν> after ὅπως, but neither of these verbs is ever found as the main verb of a final ὅπως clause in Hero. Schmidt proposed doubtfully ὅς (= ὅταν) in place of ὅπως, but Hero typically uses a consecutive ὅς to introduce shorter, syntactically less convoluted clauses; for instances of this usage, see Schmidt (1899b: 180-1) s.v. ὅς (but I.1 [2.6] should be regarded as limitative) and Heiberg (1914: 273) s.v. ὅς. The presence of accusative and infinitive constructions (ἐνα... ἔστάναι and τὸν δὲ ἃλιπον... στρέφσθαι) suggests that we need a ὅταν, but it is difficult to see how that would have been corrupted into ὅπως. I have placed ὅπως between cruces and translated ad sensum (as previous translators did), taking the infinitives ἔσταναι and στρέφσθαι as the main verbs of the final clause.

**XI.7** [38.24-40.1] πάλιν... τροχόν. Manuscripts read the words ἄμα... τροχόν in the sequence ἄμα τῶν τριών κινουμένων τροχῶν (‘along with the three moving wheels’), which does not make sense in the context. More importantly, the use of the genitive with ἄμα is quite rare (cf. LSJ s.v. ἄμα B.11). When Hero uses ἄμα prepositionally, he always employs the usual construction with the dative: see, for example, IV.2 [18.13] and IX.6 [32.14]. Previous translators misinterpreted the transmitted sequence as a genitive absolute, without paying attention
both to the prepositional value of ἄμα and to the position of the participle κινουμένων. The transmitted text is best explained by supposing that κινουμένων has at some point been misplaced. I have therefore transposed κινουμένων and placed it after ἄμα. Because of the transposition, ἄμα now serves as an adverb modifying the genitive absolute κινουμένων... τροχῶν, and the two genitive absolutes are asyndetically connected. Cf. XI.3 [36.16-18] with note ad loc. For the sequence of movements, cf. also XI.4 [36.25-6].

XI.7 [40.2] τὴν ἔπε εὐθείᾳ ὡδὲν φέρηται τὸ πλινθόν. The subjunctive φέρηται depends on the preceding ἀχρις. Baldi 252 and Couture 254 treated it as a main verb, but probably only because of the complexity and length of the sentence. Brinkmann, conversely, construed it as dependent on the preceding ὡποις, with the effect of straining the syntax (even assuming that ὡποῖς should govern another verb that is now missing; cf. note on XI.7 [38.19-23]).


XI.8 [40.3-4] περικείμεναι τοῖς ἀξιοῖοιν. These words were unnecessarily regarded by Schmidt LIII as an interpolation resulting from XI.7.

XI.8 [40.4-5] ἐν τῇ κινήσει... ἐπικείσθαι. For problems associated with the load-bearing capacity of the χοινικίδως, see Keenan-Jones-Ruffell-McGookin (2016: 179).

Schmidt's addition of <ὁ> is necessary, because the infinitive of ἐπικείμαι is used substantively (ὁϊς <ὁ>... ἐπικείσθαι). Its omission in the manuscripts can be easily explained by haplography.

XI.8 [40.6] ἄφάσκει. An idiom not used elsewhere in the text (see Introduction, pp. cxi-cxiii with n. 245).

XI.8 [40.6-7] ἐν τοῖς... στρέφεσθαι. Hero's preference for the κνόδαξ type of bearing seems to be dictated by concerns over friction (Keenan-Jones-Ruffell-McGookin 2016: 177).
XI.9 [40.8-9] γεγονέτω... ἄφαρκς. Instead of τόπον (a doubtful conjecture of Schmidt, anticipated by Baldi 25'), the manuscripts have τρόπον (adopted by Schmidt 378 and Murphy 22; see below), which does not make sense (‘in the same way as the axle, etc.’?). Other supplements and emendations have been proposed. Brinkmann emended τὸ πλανθίον to τῷ πλανθίῳ (made to depend on ἄφαρκς, which is harsh), but γεγονέτω γὰρ demands the presence of a subject in close proximity: cf. Spir. 32.7 γεγονέτω γὰρ σίφων ἕχον, etc. Cf. also XI.10 [40.18-19] and XIII.6 [48.3-4]. Schmidt put a crux before τὸ πλανθίον, while tentatively suggesting (app. crit. ad loc.), on the basis of XXIV.5 [82.21-2] (ἐν τῷ ἐξαπληθεῖν μέρει τοῦ πίνακος), ἐν τῷ ἐξαπληθεῖν μέρει τοῦ πλανθίου. He also wanted either to delete καθ’ ὑν τρόπον... ἐξον or to transpose it (reading τόπον for τρόπον) after XI.9 [40.11] γεγονέτωσαν (an option partly adopted in his translation, albeit with persistent doubts [379 with n. 1]: ‘Man mache aber (in der Weise wie die Achse mit den zwei Rädern) zwei Achsen’). These changes seem unwarranted. First, XXIV.5 [82.21-2] provides a weak basis for emendation. Second, if we emend τρόπον to τόπον (a common enough scribal error), the words καθ’ ὑν... ἐξον, although incomplete, no longer appear misplaced. Later in the text (XI.9 [40.12-14]), the two axles, such as can be seen in Figs. 14a-b, are described as being set between the διάπηγμα and the sides of the case. A transposition would therefore be pointless. Third, without the words καθ’ ὑν... ἐξον, we would have no indication whatsoever of the position of the διάπηγμα, and it is not clear why an interpolator, and not Hero, would have thought fit to include the information. I adopt Hildebrandt’s ἐξον, anticipated by Baldi 25' (‘habbia’). This supplement, which has been adopted by Schmidt 379 in his translation (‘Es habe nämlich der Kasten, etc.’), has two advantages: it gives a typically Heronian construction, and it is easy to explain palaeographically (τὸ πλανθίον ἐξον... ἐξον). However, it still requires (as do all the other proposed emendations) the addition of a main verb within the relative clause καθ’ ὑν... ἐξον. I have added ἔγνω after ἐξον, partly on the basis of a comparison with Ph. Bel. 75.6-7 συνέχετο δὲ [sc. ἡ σύριγγα] πρὸς τὴν κάτω σύριγγα... καθ’ ὑν τόπον ὁ ὄνισκος ἔγνω. The past tense of the verb ‘to be’ (already supplied by Baldi 25') is needed, because the single axle which appears in the previous two configurations has now been replaced by two distinct axles. This verb form probably dropped out by partial homeoteleuton (ἐξον ἐξον <ἔγνω> ὀδήγησεν). I do not under-
stand why the variant reading γενέσθω (A·P·G) for γεγονέτω should be ‘more logical’ (Murphy 41 n. 21). The form γενέσθω is found elsewhere in Hero only once (Geom. 250.20), whereas γεγονέτω occurs several times: for occurrences in the Automata, cf. VII.3 [28.1], X.3 [34.17], XI.10 [40.18], XIII.6 [48.3] and XIX.2 [62.1]; cf. also XI.9 [40.11], quoted above. Murphy 22 mistranslates here: ‘Let a right-angled partition be attached in the same manner as the base to the axle holding the two wheels’.

XI.9 [40.14-16] ἄστε... κνώδαξιν. These lines have been suspected by Schmidt LIII of being an interpolation. He claimed that ἐκαστον... κνώδαξιν repeats something that has already been said (he did not cite a specific passage, but he presumably had in mind XI.8 [40.6-7] ἀρέσκει... στρέφεσθαι) and that βεβηκέναι... τροχοὺς expresses something obvious. Schmidt’s doubts seem excessive. In truth, the words ἐκαστον... κνώδαξιν do not repeat XI.8 [40.6-7], because, in the latter case, Hero’s remark is intended to have wider applicability.

Compare βεβηκέναι... τροχοὺς with II.7 [10.17-18].

XI.10 [40.17-18] αἰ δὲ περὶ... στρέφειν. Schmidt LIII-LIV, followed by Olivieri (1901: 433) and Murphy 41 n. 22, understood the reference to ‘double cords’ (cf. also XI.10 [42.2-3]) to mean that each axle has two cords wound around it. In his opinion, this would contradict the Heronian principle that forward and backward motion is controlled by a single cord: cf. VI.1 [22.22-24.3] with note ad loc. Another implication would be that since both front wheels are in the centre of their respective axle (μεσολαβεῖν τὸν τροχὸν; on Schmidt’s doubtful μεσολαβεῖν, see below), they become closer to each other (compare Fig. 14a with Fig. 11a, although in the former they appear disproportionately large) and so increase the chances of the automaton tipping over (Schmidt 381 n. 2). This may be true, but it overlooks the fact that this particular arrangement is described as favouring the even rotation of the wheels (ἐξ ἵσου στρέφειν). Unlike previous scholars, I do not think that the use of the adjective διπλός (here, as at XI.10 [42.2]) refers to the presence of two cords. LSJ s.v. I.1 give as basic meanings of διπλός ‘twofold’, ‘double’, being properly used of ‘cloaks and articles of dress’ (hence ‘double-folded’). The only examples given of the proper sense of the word are from Homer (II. 4.133, 10.134, Od. 19.226) and Apollodoros of
Carystus (fr. 4), but this use is found as late as the Imperial period (Plu. Mar. 17.4; cf. Sor. Gyn. 4.8.14 and 4.12.3, of the posture of the foetus); cf. DGE s.v. A.1-2. That Hero (and not an interpolator) is using the adjective in a similar way is shown by XXIII.4 [76.5-7], where a single cord is said to have been double-wound (λαβών σπάρτον ἐπεξήγοις δυσλήν καὶ ἐνέβαλον τήνδε ἀπλήν εἰς τὸ τρόπτημα). If the cords are double-wound, they each have three ends, two of which in the form of a loop. The axles can then each be inserted through these looped ends, each wheel being contained in the middle of the axle between the said ends. It is thus clear that Hero did not intend to double the number of cords.

I have accepted Schmidt’s suggestion to read μεσολαβεῖν instead of μέσον λαβεῖν. In his app. crit. Schmidt rightly pointed to XI.10 [42.3] μεσολαβοῦσα τὸν τροχὸν. The verb μεσολαβεῖν properly means ‘take in the middle’ (not recorded as such in LJS); but cf. TGL s.v.), but it also means, according to LJS s.v. I, ‘seize’, ‘nip’, ‘interrupt’, ‘intercept’. Murphy 41 n. 22 equates μέσον λαβεῖν to μεσολαβοῦσα, arguing that Hero uses these words to mean that the wheel is in the middle of the axle. However, if we were to accept the manuscript reading, we should render μέσον λαβεῖν τὸν τροχὸν (μέσον being in predicative position) as ‘take the middle of the wheel’; but the cords are wrapped around the axles, not the wheels: II.7 [10.14-15]. The expression μεσολαβοῦσα τὸν τροχὸν, by contrast, can be understood to mean ‘containing the wheel in the middle’. The closest parallel to this technical use of μεσολαβεῖν is the use of expressions denoting a premature death, such as μεσολαβηθεὶς τὸν βίον ὑπὸ τῆς πεπρωμένης (D.S. 11.26.8; cf. 1.3.3 ['having one’s life cut short in the midst', LJS s.v. I]) or simply μεσολαβηθεὶς... ὑπὸ τῆς πεπρωμένης (D.S. 16.1.5 and Plb. Fr. 184.2). The latter expression is aptly glossed by Suda μ 667 as ἐν τῷ μεταξῷ [sc. βίῳ] συσχετικός. So, μεσολαβεῖν τὸν τροχὸν seems to mean συσχεῖν τὸν τροχὸν ἐν τῷ μεταξῷ [sc. ἄξονι].

XI.10 [40.18-19] γεγονέτω δὲ... κινοῦμενος. Schmidt is right to prefer G’s reading ἐτέρος. Hero never uses the combination ἐτέρος τρίτος (as in AMT) to introduce the third item in a series of three. This may be qualified either as ἐτέρος (e.g. V.4 [22.5]) or as τρίτος (e.g. IX.1 [30.6]).

Manuscript diagrams show this axle attached to the case (see Fig. 14a). However, the words τούτοις ὁμοίως κινοῦμενος only indicate that, just like the
two front axles, the rear axle is made to turn on pivots. Following in the foot-
skets of Baldi 251 unnumbered Fig. and Schmidt 378 Fig. 92a, and in analogy
with the configurations for straight-line and rectangular motions, I have placed
the rear axle and wheel assembly within a frame (Fig. 14b). It is quite possible
that the original diagram has at some point been modified under the influence of
the diagram for the first configuration, which in turn had been modified under
the influence of the second configuration (see note on XI.2 [36.7-10]). (Note that
the diagram for the second configuration is apparently now lost, and that the
other two diagrams pertaining to snake-like motion are positioned next to each
other in a number of manuscripts, including A.)

XI.10 [40.19-42.1] ἐμπροσθεν τοῦ πλινθίου}. These words have been previ-
ously mistranslated as ‘at the front of the case’. In fact, when used preposition-
ally, ἐμπροσθεν means ‘in front of’ rather than ‘at the front of’ (LSJ s.v. II). Al-
though he did not make a clear distinction between these two meanings (‘in dem
vorderen... Teile des Kastens’/’vor dem Kasten’), Schmidt 381 with n. 1 did
realise that these words are inappropriate in the context. In his app. crit. he tent-
atively suggested emending the text and reading <ἐν τῷ> ὀπισθεν τοῦ πλινθίου,
which correctly places the axle ‘at the back of the case’. However, there are at
least two reasons for rejecting Schmidt’s solution. First, Hero’s use of the ad-
verbial pair ἐμπροσθεν/ὀπισθεν would require us to write <ἐν τῷ> ὀπισθεν
<μέρει> τοῦ πλινθίου (cf. esp. XXIV.5 [82.21-2] ἐν τῷ ἐμπροσθεν μέρει τοῦ
πίνακος). In this case, it would be more difficult to explain the combined ommi-
sion of ἐν τῷ and μέρει. Second, while scribal confusion between ἐμπροσθεν and
ὀπισθεν is not uncommon (see, for instance, my app. crit. to XXIII.2 [74.12]),
the exact position of the axles is always left unspecified in the treatise (Intro-
duction, p. ciii). It is, therefore, more likely that the words ἐμπροσθεν τοῦ πλινθίου
were interpolated at a later stage. We can easily imagine a rather incompetent
scribe trying to describe the diagram in front of him, where the third axle would
presumably have been located on the right-hand side of the case (see Fig. 14a).

XI.10 [42.1-2] ὄστε... πλινθίον. Schmidt 381 n. 2 found it strange that, with the
addition of another axle (‘Einrichtung der zweiten Achse’ [my emphasis], no
doubt referring to either of the front axles: XI.9 [40.11]), the automaton travels
on three wheels (instead of four?). I do not see how the front axles could be
made to carry more than two wheels, especially considering that the wheels are
now closer to each other than they were in the previous two configurations: cf.
note on XI.10 [40.17-18]. Perhaps he meant to say that the rear axle should like-
wise carry two wheels (despite XI.10 [42.3]?), but this remains on the level of
speculation.

XI.10 [42.2-3] περ... σπάτος. The presence of a third cord was looked upon
with suspicion by Schmidt LIV, because, with the exception of XI.7 [38.17-19],
the third wheel is always dragged along by either or both of the front wheels: cf.
XI.3 [36.19-20] and XI.4 [36.23]. This cord, however, presumably serves the
purpose of giving more control over the rear wheel: cf. note on XI.7 [38.15-19].
On the doubling of the cord, cf. note on XI.10 [40.17-18].

XI.10 [42.3] μεσολαβοῦσα τὸν τροχὸν. On the meaning of this phrase, cf. note
on XI.10 [40.17-18].

A few manuscripts (Aa, Bc, O, Pb, Vd) have the corrupt μεσοσυλλαβοῦσα
instead of μεσολαβοῦσα. LSJ s.v. give as meanings of μεσοσυλλαβέω ‘use one
remedy alternately with another’ (I) and ‘to be intercepted’ (II, passive voice),
citing, respectively, Aët. 7.45 = 108.1 Hirschberg and Alex. Aphr. Pr. 2.14 =
58.12-13 Ideler. As regards the first example (μεσοσυλλαβεῖν τί ἐπερον), which
Hirschberg (1899: 107) translates as ‘etwas Fremdartiges einschieben’,
μεσοσυλλαβεῖν is a variant reading for the better attested μεσολαβεῖν (printed by
Olivieri 1950: 297; see app. crit. ad loc.). In any case, the sense demanded by
the context seems to be that of ‘interpose’, ‘interject’. The earliest and most
common use of μεσοσυλλαβέω is in grammar, where it denotes ‘intervening’ parts of
speech: see, for instance, Hdn. Gr. GG 3.1 (484.6, 484.11, 484.13) and 3.2
(161.32), Ps.-Theodos. Gr. 97.19, 109.7 and 109.19 Göttling; for later refer-
ences, see Bécares Botas s.v.
XII [42.9-44.14] Other movements. Lighting of the altar(s)

At this point, the discussion turns to movements that do not concern the locomotion of the automaton (XII-XVI), first among which is the lighting of the fire on either of the altars (XII.1). The device described (XII.2-4), consisting of a hearth over a sliding plate placed over a fire-grate, is strikingly similar to that used to light Nauplius’ torch in the stationary automaton (XXVIII.3-7). Silences surround the ignition of the fire, but comparison with XXVIII.4 (ὅταν λύχνος καιόμενος τεθή εἰς τὸ κιβωτάριον, etc.) suggests that it was performed manually during the initial setup of the automaton (Murphy 42 n. 24).

XII.1 [42.11-13] ἡ πρώτη κίνησις... βαμφ. Brinkmann cast doubt on the authenticity of the term κίνησις, but he did not venture to emend it. In his app. crit. Schmidt hesitantly suggested emending to μήνυσις (‘revelation’), citing as support Dioptr. 288.22 τὰ... συμβαίνοντα μηνύσαι. Indeed, the construction with περί is strange, but not strange enough to prompt emendation. Hero uses the verb μηνύω (‘reveal’, ‘indicate’) only once more (Dioptr. 298.16), but he never uses its corresponding noun. I have here followed Schmidt’s translation of περί (‘betrifft’ [381]).

XII.2 [42.17-18] παρακάτω... τρόπημα. The comparison serves to illustrate the sliding of the plate, as already implied by Baldi 44 n. 22. A γλωσσόκομον (also γλωσσόκομος) – or, less frequently, γλωσσοκομεῖον or γλωσσοκόμον – is a ‘case’ or ‘chest’, which may be employed for different purposes; see Colace et al. (2001: 106-9). In his description of the water organ, Hero uses the term in a technical sense with reference to a series of ‘compartments’ (Spir. 196.5, 198.5, 198.13-14, 200.2, 200.5, 200.14); see LSJ s.v. γλωσσοκομεῖον. Interestingly, the apertures of these compartments have sliding lids to close them (cf. Spir. 196.7-11). For a related use of the term, we must turn to medicine, where γλωσσόκομον – and not γλωσσόκομος, as with LSJ s.v. 2 – refers to a machine for setting broken bones (Gal. Meth. Med. 10.442 Kühn, Orib. 49.7, 49.21 [chest of Nymphodorus]); see DGE s.v. γλωσσόκομον and Drachmann (1963: 172-3, 176-8). The chest of Nymphodorus is described as having πόματα... χάριν τοῦ κρύπτεσθαι τὰ ἐν αὐτῷ μηχανήματα (Orib. 49.21.7; cf. 49.23.25 [trispaston of
Apellis or Archimedes); on surgical traction machines more generally, see Wilson (2008: 345-6).

The verbal adjective παρακτός is not recorded by LSJ, but seems to be attested only here. Both Baldi 26' and Coutre 255 omitted translating it, whereas Schmidt 381 rendered it correctly (‘das sich... verschieben lässt’); Murphy 22, less correctly, has ‘which can slide’ (my emphasis). For the formation of verbal adjectives in -τος, cf. KB 2.288-9. The verb παράγω, from which παρακτός is formed regularly, occurs in the Automata at XIX.2 [62.2] (passive) and XIX.3 [62.3], both referring to the act of sliding the κλειδρίον (on which, see note on IX.5 [32.8-9]). Cf. XII.3 [44.1] (παράλλασσω). This use of the verb is consistent with the way it is used in the Pneumatica with respect to a weight that is shifted along a rod: Spir. 288.6, 294.13, 294.14, 294.20, 296.5. Cf. also the corresponding noun at XXVI.16 [94.16] (παραγωγή).

XII.2 [42.19] ἁζόνιον ἐντὸς τοῦ βωμοῦ καιμενον. Hero does not specify whether the axle is vertical or horizontal. Schmidt LIV argued that a vertical ἁζόνιον, such as is found in the manuscript diagrams (see Fig. 15), would entail a considerably smaller altar (a vertical axle should be an ἁζόνιον, according to his line of argument), and so made it horizontal (Schmidt Fig. 93b). This openly contradicts his claim that Hero most likely intended to describe the device for kindling the fire on the altar in a similar way to the mechanism of Nauplius’ torch (XXVIII.3-7 [102.3-104.10]; Fig. 32), where, apparently, the axle is vertical. It seems to me that he has attached too much importance to the diminutive value of the term ἁζόνιον (‘kleine Achse’, Schmidt 383). The size of the (vertical) axle will rather depend on the size of the altar. Murphy 42 n. 23 wanted the altar to be square (and not rectangular, as in Fig. 15), with sides measuring one-half to one palm (3.85-7.71 cm).

XII.3 [42.21-2] ἐκ δὲ τοῦ... <***>. I accept Schmidt’s doubtful suggestion to read ἐκ... τοῦ ἁζόνιον instead of ἐν... τῷ ἁζόνιῳ (‘on the axle’; thus Murphy 22, who mistakenly construes ἀποδεδόσθω with ἐν + dative). Cf. XII.2 [42.18] ἐκ δὲ τοῦτον [i.e. ἔποιήσαν] ἁλασέαυν... ἀποδεδομένου, etc. As an alternative, Schmidt (app. crit. ad loc.) suggested a lacuna after ἁζόνιῳ, albeit without indicating its size. He seems to have thought that the lacuna should have contained
information on the winding of both the chain and the cord around the axle and, possibly, on the attachment between the two (Schmidt LIV). The chain and the cord, however, need not be connected to each other (see further note on XII.4 [44.8-9]). The most important piece of information missing, it seems to me, is the presence of some slack in the cord (cf. XII.4 [44.13]). It is thus necessary to posit a lacuna somewhere in the sentence, but the word order suggests that something dropped out after σπάρτος – perhaps ἄγκυλης ἄξονας? Cf. esp. XI.4 [36.21-2] and XIII.5 [46.20-1]. Positing a lacuna after ἄξονιον (or ἄξονίω) would probably imply that the noun σπάρτος has been misplaced: cf. XVIII.1 [58.15] (ἐκ δὲ τοῦ ἐς ἄξονος ἑτέρα σπάρτος ἐκδεθεῖσα) and Diorpr. 202.5-7 (ἐκ δὲ τοῦ χελωναρίου σπάρτος ἐκδεθεῖσα).

XII.3 [44.1-2] τῆς ἄγκυλης... τύλου. Schmidt was rather confused by these words. In his app. crit. he suggested either transposing them after XII.3 [42.22] (μετὰ τὴν πορείαν) or deleting them altogether, but not without noting the almost identical expression at II.9 [12.14-15] (ἐκτεσσάρως τῆς ἄγκυλης ἀπὸ τοῦ τύλου). However, in his Anmerkungen (Schmidt LIV), he speculated that Hero might be referring, just as he does at XXVIII.7 [104.10] (cf. δ in Fig. 32), to a knob on the ἄξονιον (as opposed to that found on the ἐξελύκτρα: see Schmidt 381 n. 2). An obvious objection to the latter interpretation is that, if a cord falls off its knob, the transmission of movement is interrupted (cf. note on II.9 [12.14-15]). What follows, XII.3-4 [44.3-11], describes instead the operation of the fire-starting mechanism. Likewise, I am reluctant to believe that these words were interpolated, mainly for stylistic reasons (in addition to the passage quoted, cf. V.5 [22.19-20]). A transposition would certainly contribute to bringing order into the text, but it does not accord with the way information is arranged (see Introduction, p. cxvii).

XII.3 [44.2-3] τὰ ἐξεῖς ἐπιτελεσθήσεται. It does not seem to refer to what immediately follows. See note on I.1 [2.7-8].

XII.3 [44.3-4] λαμπτήρ... τρυπήματι. Manuscript diagrams agree in showing the λαμπτήρ suspended in air (see Fig. 15), which is clearly absurd. The grate must have been provided with one or more supporting legs. Hero does not give any
information about how to light the fire or to keep the flame burning before the
sliding of the lid, a fact paralleled later on at XXVIII.3-6 [102.3-4.4]. In his de-
scription of the mechanism of Nauplius’ torch, he insists that the flame must
remain hidden until it is convenient to light the torch: XXVIII.5 [102.20-2].
There is no reason to suppose that the same is not true here. Murphy 42 n. 23
rightly pointed out that, in order to keep the fire from being extinguished too
soon, the altar should not be airtight.

The term λαμπτηρ occurs only once more in Hero (XXVIII.6 [104.3]), but,
as the context makes clear, with a different meaning (‘lantern’, LS s.v. 2).

XII.3 [44.4-6] ἐπικείσθω... ἀνάπτεσθαι. Cf. III.4 [16.18-20] with note ad loc.
Μ has the obviously incorrect ὑποκείσθω. This variant reading probably
arose under the influence of XII.3 [44.3]. Cf. also the immediately preceding
ὑποκειμένην.

XII.4 [44.8-9] ή... ταθείσα. I take the phrase ή... σπάρτος to mean that the cord
comes from the direction of the chain (as shown in Fig. 15), understanding ἐκ
loosely. Cf. XVI.3 [56.5] and XIX.3 [62.5-6]. This is also suggested by the simi-
lar description of the mechanism of Nauplius’ torch: cf. XXVIII.7 [104.7-10].
Perhaps we should add <ὑποδιδόμεν> or <ὑποδεδομέν> before σπάρτος.
Compare, in addition to XIX.3 [62.5-6], XXVI.8 [96.9]; but cf. XXVIII.7 [104.10]. Conversely, Schmidt (app. crit. ad loc.) tentatively proposed adding
<ἐκδεθείσα> after σπάρτος, a supplement which, in spite of the doubts raised in
the Anmerkungen (Schmidt LIV; cf. note on XII.3 [42.21-2]), he adopted in his
translation: ‘die an das Kettchen gebundene Schnur’ (Schmidt 1899a: 383 with
n. 3). It would, however, have been more correct if <ἐκδεθείσα> - or even
<ἐκδεδεμένη>, cf. XIX.4 [62.14] - had been put before σπάρτος. Similarly, but
without any supplement, Murphy 22: ‘the cord stretched from the chain’ (ἡ...
ταθείσα σπάρτος?). Baldi 26, followed by Couture 255-6, has the cord pulling
on the chain: ‘la catenella g, h, k, tirata dalla [ὑπό?] corda’.

XII.4 [44.11-13] τὰ δὲ αὐτὰ... εἰρήμενον. No cord slack has been previously
mentioned in connection with the kindling of the fire, a fact that has escaped the
attention of previous scholars. For the suggestion that such reference dropped
out of the text, cf. note on XII.3 [42.21-2]. In the case of the other altar, a greater slack is needed to activate the device at the appropriate time; cf. V.5 [18.15-16].

XII.4 [44.13] κατὰ τὰς ἐξῆς κινήσεις. Brinkmann's emendation μετὰ, anticipated by Baldi 26' ('dopo'), is attractive but unnecessary, since the reading of the manuscripts (κατὰ) makes sense if we take τὰς ἐξῆς κινήσεις as referring to the second series of movements constituting the apotheosis of Dionysus (cf. synopsis on III-IV). This is not implausible, considering that the reader has been invited to focus his or her imagination (τὰ δ’ αὐτὰ ἐπινοεῖσθο, XII.4 [44.11]) on the second altar. For the scribal confusion between κατὰ and μετὰ, see app. crit. to V.3 [22.2].

XIII.1-7 [44.15-48.13] Pouring of liquids
Milk and wine are conveyed through a hidden piping system leading from a double reservoir placed within the upper part of the shrine’s roof to two vertical columns, which are fitted one inside the other underneath Dionysus. The flow is regulated by a tap (κλεῖς) which, unlike extant specimens of the Roman period, admits two pipes. Details of the operation of the tap are discussed in the notes ad locc. Prou 170 n. 157 argued that since the liquids are poured twice (πάλιν δὲ... γάλα, XIII.5; cf. IV.1 and 3), the holes in the thyrus and the cup should be closed between the first and the second libation. Considering that the system works thanks to the principle of communicating vessels (as acknowledged by Prou 170), it would probably have been enough to turn off the tap.

XIII.2 [44.17-18] ὑπὸ... σωλῆν. Murphy 42 n. 25 maintains that the pipe is no longer than one palm (7.71 cm), a measure which she equates to the sum of the thickness of the shrine’s platform (κατάστροφα), the shrine’s floor and the base of Dionysus (cf. XIII.3 [46.1]). Hero, however, does not provide any measures for these elements. Manuscript diagrams show the pipe as extending all the way down to the automaton’s base (see Fig. 16). This is clearly impossible, because it does not leave much room for other components, such as the σύρμα and, possibly, the wheel and axle assembly. The pipe could not extend down beyond the architrave (ἐπιστύλιον, cf. notes on III.1 [16.2-4]), and had to pass through the
stylobate (XVI.1 [54.11]), as illustrated in Baldi 27\textsuperscript{v} unnumbered Fig. and Schmidt 387 Fig. 94a.

Schmidt suggested adding \textit{<τούτῳ>} after συμφυής, comparing XIII.3 [46.1-2] ὁ δὲ συμφυῆς τοῦτῳ [i.e. τῷ Διονύσῳ] σωλήν. This supplement is attractive, since συμφυής seems to require a dative (see LSJ s.v. II.2). It is also easy to explain palaeographically (γίνεται σῦ και τούτῳ οὐφως...συμφυής \textit{<τούτῳ>} γίνεται σωλήν). However, \textit{<αὐτῷ>} would work equally well. Cf. esp. Spir. 270.24-6 Ἕστω γὰρ ὑπὸ τὴν λυχνίαν ἀγγείον... ἢτοι συμφυές αὐτῇ ἢ καὶ ἰδία κείμενον. Cf. also Diopt. 194.9 and 246.15.

XIII.2 [44.19-21] ἡ δὲ τούτων... σκόφον. Unlike previous editors, I adopt G’s reading ἀνατείνοντα, which A and T correct supra lineam to ἀνατείνοντα, perhaps under the influence of the following φέροντα (but cf. also XIII.3 [46.2-3]). A finite verb is needed to make the sentence complete, as also shown by previous translations. φέροντα (AG) is obviously a better reading than συμφέροντα (MT). Cf. XIII.3 [46.7], XIII.4 [46.12], XIII.6 [48.4] and XIII.7 [48.12].

XIII.3 [46.2-4] τὰ δὲ... σκόφον. I deem it unnecessary to add \textit{<φέροντα>} after ἀπό, as tentatively suggested by Schmidt (app. crit. ad loc.) on the basis of the previous occurrence of the participle (XIII.2 [44.20]). The sentence makes good sense in its present form, if we suppose ἀνατείνοντα to be understood. In contrast to XIII.2 [44.19-20], the verb ἀνατείνω here is not immediately followed by a prepositional phrase introduced by εἰς.

XIII.3 [46.4-6] ἔστω δὲ... ἔν. According to LSJ s.v., the term πυρήν primarily denotes the ‘stone’ of a stone-fruit (I.1), but it may also refer to other (semi-) round objects, such as a pine ‘nut’ (I.2), a ‘grain of frankincense’ (II.1.a), a ‘head of a probe’ (IV.1) and a ‘gem’ (V; cf. Prêtre 1997b: 372 with n. 4). Here it seems to denote a ‘knob’ (so also Murphy 23; cf. XXVI.2 [90.18] πυρηνίδια) resting on the summit of the roof (cf. note on III.2 [16.8-10]; Fig. 16). Most translations render the term incorrectly, as if it were πυργίων: ‘cupola’ (Baldi 26\textsuperscript{v}), ‘concam- eratus apex’ (Couture 256), ‘Dach’ (Schmidt 385).

Murphy 42 n. 26 makes two points here. The first is that the πυρήν probably serves either as an ornament or as a base for the Nike. The second is that the
container 
C, along with the axle \( \xi \zeta \) and the pulley \( \mathcal{g} \) (cf. XIII.7 [48.15-17]), is actually placed inside the roof. The \( \pi \nu \varphi \eta \nu \) is not simply ornamental. Not only does it serve as a support for the Nike (XIII.7 [48.14]), but it also holds the container \( \nu \zeta \) (ἐν τῷ δὲ τούτῳ... \( \nu \zeta \)). The axle \( \xi \zeta \) is described as passing through the knob (how else could it be attached to the Nike?), and certainly extended down into the roof (\( \kappa \alpha \theta \epsilon \iota \sigma \theta \omega \)... διὰ τοῦ \( \pi \nu \varphi \eta \nu \), XIII.7 [48.14-15]). On the thickness of the axle, cf. XIII.8 [50.4-5]. No information is given on the location of the pulley, but nothing suggests that it should be placed inside the knob.

Most manuscript diagrams show a rectangular support at the top of the roof, and label the whole roof (containing all the above-mentioned elements) \( \kappa \lambda \mu \) (see Fig. 16). Similarly, but with a round projection supporting the Nike, Schmidt 386 Fig. 94a and Murphy 24 Fig. 7. Baldi 27ν unnumbered Fig., by contrast, has the Nike directly resting on the apex of the roof.

XIII.3 [46.9-10] τῷ καταστρώματι ἐφ' ὀ ναύσκος ἐπίκειται. Cf. III.2 [16.5-7].

XIII.4 [46.11-13] ἀκ δὲ τοῦ... σωλήνα. I follow Schmidt in marking a lacuna after ἀγγεῖον. The lacuna must have contained the main verb. In his app. crit. Schmidt doubtfully proposed two supplements, \(<\kappa \alpha \theta \epsilon \iota \sigma \theta \omega \>\) and \(<\varphi \epsilon \rho \epsilon \tau \omega \>\), citing in support of the latter XIII.3 [46.7] and XIII.6 [48.4]. \(<\varphi \epsilon \rho \epsilon \tau \omega \>\) is better than \(<\kappa \alpha \theta \epsilon \iota \sigma \theta \omega \>\), because in the Automata the verb \( \kappa \alpha \theta \iota \mu \iota \) never refers to pipes, a usage otherwise common in the Pneumatica (see, for instance, Spir. 72.14-74.1, 74.6 and 104.2). However, \(<\varphi \epsilon \rho \epsilon \tau \omega \>\) involves the deletion of \( \kappa \alpha \) \( \phi \rho \)ρον, which would result in \( \delta \mu \)οίως being misplaced. Hildebrandt's καταφέρσειον for \( \kappa \alpha \) \( \phi \rho \)ρον does not strike me as a very plausible emendation. While it has the advantage of eliminating the lacuna, it is difficult to explain palaeographically. Furthermore, the verb καταφέρσειον, as used in the treatise, refers not to pipes bearing downwards, but to falling bodies; see note on V.5 [22.16-17]. Perhaps we could fill the lacuna with \(<\xi \st\omega \>\), limiting ourselves to the deletion of the \( \kappa \alpha \). Cf. Spir. 114.5-7 ἀκ δὲ τοῦ \( \pi \theta \mu \mu \)νος σωληνάρια \( \xi \st \)το... \( \varphi \)ροντα εἰς ἕνα κρουνίσκον κοινόν.

XIII.4 [46.14] ὄν. Perhaps emend to \( \nu \). Cf. XIII.3 [46.6].
XIII.5 [46.18] ᾦ ὁ εἶν στέγη τὰ ὑγρᾶ. The subject of στέγη is the following κλεῖς, which explains Hero’s reference to what has already been said (ὡς εὑρηκαί, XIII.5 [46.19]). Baldi 26, Couture 256 and Schmidt 385 mistook τὰ ὑγρᾶ as the subject and translated the verb as if it were passive. Murphy 23, by contrast, has the correct rendering. Hero always uses στέγω in the sense of ‘keep in’, ‘hold’ (Geom. 414.14, Spir. 62.7, 78.13, 102.6 and 294.1). For the verb in this sense, see LSJ s.v. B.1.

XIII.5 [46.18-19] κλεῖς... ἐπιτόνιον. For a discussion of ancient taps (surviving from Roman times), see Kretzschmer (1960). See also, more recently, Hodge (1981: 489-91; 1992: 322-6), who emphasises the distinction between two kinds of taps: ‘discharge taps’ and ‘stopcocks’. Hero’s tap is a stopcock, as it is used to regulate the flow of liquids rather than to dispense them through an outlet spout. An ancient tap, regardless of its function, usually consisted of a cylindrical plug (also called key) perforated by a horizontal hole (or pair of holes) and rotating inside a cylindrical housing (Fig. 17). Hero’s stopcock was presumably perforated with two pairs of holes, each admitting one of the conveying pipes (cf. XIII.3-4 [46.6-13]). This is illustrated, albeit in a very rudimentary fashion, on the lower right-hand side of Fig. 16. For a modern reconstruction, see Fig. 18.

Hero uses two different words, κλεῖς and ἐπιτόνιον. κλεῖς (lit. ‘key’) synecdochically signifies the whole device (‘tap’ or ‘stopcock’). It also occurs at Spir. 124.16, the only occurrence of this meaning given in LSJ s.v. II.2. Elsewhere Hero uses the derivative κλειδίον (Drachmann 1948: 50; cf. LSJ s.v. I.2): Spir. 122.14, 190.18, 212.16, 266.24, 268.10, 268.16, 274.10 and 274.18. The synecdochic extension of meaning can still be seen in it. ‘chiave’ (Baldi 27, with Manni 1980: 178-9, 195) and Lat. ‘clavis’ (Couture 256). The equivalent French term has been used by Prou 170, but he appears to have understood it in its proper sense: ‘[u]ne clef’, κλεῖς [sic], adaptée à une douille obturatrice, ἐπιτόνιον’. Schmidt 385 and Murphy 23 have, respectively, ‘Verschluss’ (but cf. ‘Hahn’, Schmidt LV) and ‘valve’ (or ‘bolt’[?]). The word ἐπιτόνιον, which previous translators have misunderstood to mean ‘tap’/‘stopcock’ (cf. also Soubiran 1969: 304; Argoud-Guillaume 1997: 150 n. 19), signifies the ‘plug’ or ‘key’ of a tap (‘clef cylindrique’, E. Saglio in DS 2.711 s.v. Epistomium). It originally denotes a ‘tuning peg’ or ‘key’, and has been extended to apply to the handle of
either a tap (here) or σμήρισμα (Spir. 250.16-17, 250.25, 252.3 and 252.8; cf. Vitr. 9.8.11). Hero also uses it for the handle of a syringe (Spir. 254.2 and 254.8); see LSJ s.v. II.1; Puchstein (1907: 203); Drachmann (1948: 50, 60). The term seems to occur in the sense of ‘tap’ only at Ps.-Hero, Spir. 146.18-19 κλειδίον… τὸ καλούμενον παρὰ τοῖς πολλοῖς ἐπιτόμοιν. This looser, popular sense is commonly attested in Latin (epitonium: Varro, RR 3.5.16, Vitr. 10.8.3, 10.8.5, 10.8.11, Seneca, Ep. 86.6 and Ulp. Dig. 19.1.17.8). On this term, as opposed to the incorrect epitomium, cf. Cagnat (1894). Baldi 44° n. 24 glossed his translation (‘galletto’, with Manni 1980: 178-9, 199) with the word ‘epistómos’. This has been taken to mean that his exemplar had the word ἐπιστόμοι (Manni 1980: 178 n. 3, cited by Micheli 2005: 253 n. 24). I have found no such reading in the manuscripts. This alternative form was coined in the Renaissance (Puchstein 1907: 203, quoted by Drachmann 1948: 60), probably by analogy with epitomium.

I accept Brinkmann’s suggestion (endorsed by Schmidt LV and Olivieri 1901: 433) to read λ (in ?λ) instead of τ. Cf. also Xili.6 [48.7]. τ, in fact, already denotes a hole. Schmidt LV observed that in earlier manuscripts λ was written as Λ (more or less pointed) and that the latter form could easily be corrupted into τ. His basic point is right, but it overlooks the fact that the symbol for 900 (samil or παρακύσιμα) could also occur in the form Τ (among others). On the various forms of sami/parakaýisma, see especially Foat (1905; 1906); for a more complete bibliography, see Soldati (2006: 209-10 n. 4).

XIII.5 [46.20-3] περὶ δ... ὕψῳ. The participles ἔχοντα and ἀποδεδομένη should not be regarded as irredeemably corrupt (ἔχοντα καὶ ἀποδεδομένη Schmidt, suggesting in his app. crit. emendation to the genitive case), but rather as hypallage for ἔχοντας and ἀποδεδομένης. The subject of ἐπιστρέψῃ is clear enough from the context, but perhaps the words <ν σπάρτος> have dropped out after ταθείσα (AGT have σπάρτος instead of the correct σπάρτου). Cf. XII.4 [44.14].

This cord must have turned the tap 90 degrees (either clockwise or anticlockwise) in order to align the holes in the plug with the conveying pipes (cf. previous note). Another 90-degree turn (in either direction) would have been enough to shut off the tap; see Hodge (1981: 490 n. 24; 1992: 324). This means either that four different cords were used to rotate the plug 360 degrees in the
same direction or that the stopcock was turned on and off (with a 180-degree arc of rotation) by two cords, each pulling in a different direction. The mention of another cord drawing the ἐπὶ τὸν κοῖλον in the opposite direction (εἰς τὰ ἄλλα μέρη) suggests the latter: XIII.6 [48.8-10]. There, perhaps, we should read κλείεται in place of ὄνοιεται. See further note ad loc.

Manuscript diagrams show no cord wrapped around the ἐπὶ τὸν κοῖλον (see Fig. 16). Schmidt 387 Fig. 94a and Murphy 24 Fig. 7 have only one cord. Baldi 27v unnumbered Fig., more correctly, has two. Murphy added next to her diagram: ‘This cord goes to a counterweight (probably MB): Hero doesn’t explain’ (see also Murphy 42 n. 29). Hero’s use of the article (εἰς τὴν λείαιν), however, is a strong indication that the cord was attached to the main counterweight rather than to μ [XIII.8 [50.9]]. See Schmidt (1903: 275-6).

XIII.5 [46.23-48.1] πάλιν δὲ... γάλα. I take the first πάλιν to refer to the content of the main clause (δὲ... γάλα). I am tempted to delete the second πάλιν, but perhaps the repetition is merely emphatic. Baldi 27v, Couture 256 and Murphy 23 understood the first πάλιν as modifying the genitive absolute ἐπιστραφέντος τοῦ Διονύσου, which erroneously places the second libation after the second rotation of Dionysus. That would probably require a different word order (ἐπιστραφέντος δὲ πάλιν τοῦ Διονύσου). Cf. XXII.5 [72.14-15] (original word order?). Schmidt 389 (‘dagegen’) curiously assigned an adversative value to the first πάλιν.

XIII.5 [48.1-2] στρέψαται... τὴμυκοκλίου περιφέρειαν. I here follow the punctuation of AGT (M, too, punctuates heavily after οὕτως). Schmidt 386, followed by Murphy 23, placed a full stop after περιφέρεια, but did not punctuate after the adverb. The opening words, however, seem to have been intended to precede an explanation (cf. XII.2 [42.14], XIII.2 [44.17], XIII.2 [48.13-14], XIV.1 [50.17-18], XV.2 [52.9], XVI.1 [54.9-10], XVII.1 [56.12-13], XIX.2 [60.18-19], XXII.3 [70.19], XXVI.4 [86.15], XXX.5 [108.14]; cf. also XXVI.1 [90.10] and XXVIII.2 [100.11]). We can therefore dismiss Schmidt’s doubtful suggestion (app. crit. ad loc.) to read στρέφεται δὲ οὕτως ἡμικυκλίου περιφέρειαν, where the accusative περιφέρειαν is governed by στρέφεται (for comparable examples, cf. LSJ s.v. στρέφω 1.2). Brinkmann’s conjecture οὕτως [i.e. Διόνυσος] for οὕτως
is not very convincing either. All previous translators, except Murphy 23, understood the corrupt στρέφεσθαι as referring to the rotation of Dionysus rather than that of the stopcock (but see Murphy 42 n. 27, where she acknowledges the ambiguity of the text). A reference to the latter – or, more correctly, to the ἐπιτόνιον – would fit better within the context, not least because the rotation of Dionysus is discussed later on (XIII.7-9 [48.13-50.14]). A more serious difficulty lies in the words ἵμμυικύλιον περιφέρεια (†περιφέρεια Schmidt). First of all, they have no syntactic connection to the immediate context. Second, they might equally apply to the first rotation of Dionysus (cf. XIII.5 [46.23]) and to the overall rotation of the ἐπιτόνιον (cf. note on XIII.5 [46.20-3]). Baldi 27', followed by Couture 256, unintelligibly construed περιφέρεια as the subject of the following γεγονέτω (‘[s]i faccia la periferia, ò circonferenza, d’un mezo circolo per diametro ò i fori, ò s’), which, among other things, leaves ξείρα τρῆμα standing alone (XIII.6 [48.3-4]). I have put these words between cruces, wondering whether they represent a marginal scholiast that was incorporated into the main text and was originally intended to elucidate the rotation of either Dionysus or the ἐπιτόνιον. As regards στρέφεσθαι δέ οὕτως, a finite verb is certainly needed. Schmidt’s στρέφεται is attractive in itself, but perhaps it would be better to emend to ἐπιστρέφεται and to place a lacuna after δέ (ἐπιστρέφεται δέ <ὅ ἐπιτόνιον> οὕτως?). In addition to XIII.7 [48.13-14], cf. XIII.5 [46.22].

XIII.6 [48.3] γεγονέτω. This reading is preferable to γενέσθω, although the latter is handed down by the best manuscripts (A* reads γεγονέτω); see note on XI.9 [40.8-9].

In his app. crit. Schmidt hesitantly suggested adding either <ὁδε> or <οὖν> after the imperative. A connective particle would indeed be very welcome. The omission of ὁδὲ would be easy to explain (στρέφεσθαι δὲ οὕτως... γεγονέτω <ὁδε>), all the more so if the words ἵμμυικύλιον περιφέρεια had been added at a later stage (cf. previous note). However, <γάρ> would seem to fit better in the context. Cf. XI.8-9 [40.7-8] (ποιήσωμεν οὖν οὕτως· γεγονέτω γάρ, etc.) and Spir. 32.7 (οὕτως ἀποδείξωμεν· γεγονέτω γάρ, etc.), the only two occurrences of the sequence γεγονέτω γάρ in Hero. The tachygraphic sign for γάρ – in its simplest form, Γ cut across by a left oblique stroke (Allen 1889: Pl. III nos. 1-2; Gardthausen 1913: 336) – could just as easily have been omitted.
XIII.6 [48.8-10] ἀνοίγεται... μέρη. Most manuscripts read here εἰς τὰ ἔτερα βάρη. This reading does not make sense because no weights have been mentioned in the preceding context. Schmidt puts a crux before βάρη, but translates his doubtful emendation μέρη (cf. already Baldi’s ‘parte’, 27), which he supports by citing XIII.8 [50.3] ἐπὶ τὰ αὐτὰ... μέρη (of the rotation of Dionysus and Nike). This conjecture not only fits perfectly well into the context (we would indeed expect a reference to the direction of the cord: cf. note on XIII.5 [46.20-3]), but is also palaeographically plausible. The corruption probably arose from the common confusion between minuscule μ and β.

Schmidt hastily deleted the words ἀνοίγεται... τβάρη as an interpolation. In his opinion (LV1), Hero’s own principles demand the use of only one cord. While it is true that a single cord controls forward and backward motion (cf. VI.1 [22.22-24.3] with note ad loc), it is not clear how the ἐπιτόνιον could be rotated – back and forth? – by fewer than two cords. In order to allow repeated operation of the stopcock, the cords presumably had some slack to them. Using fewer than two cords would have meant a cord of excessive length. What is striking here is not so much the reference to a second cord, but rather the reference to the opening of the stopcock. Hero never mentions how the stopcock is closed. If two cords were indeed used, each one pulling in a different direction, one would expect a reference to the closure of the stopcock. One cannot help but wonder whether an original κλείεται was at some point replaced by ἀνοιγεται, possibly under the influence of ἀνοιγθήσεται in the preceding line.

XIII.7-9 [48.13-50.15] Rotation of Dionysus and Nike
The inner column underneath Dionysus is connected, by means of a hidden cord (καὶ... κρυπτέσθω, XIII.9), to an axle that lets the Nike rotate (XIII.7). The column rotates 180 degrees twice (as suggested by XIII.8 ὅπως... θέσων; cf. synopsis on III-IV), the movement being imparted by a falling weight, which is released by a trigger (σχοινογρία) of the kind used in catapults (XIII.9). Hero does not say whether the second rotation occurs in the same direction, which, however, is implied in the use of the verb ἀποκαθίσταμαι (XIII.8). Prou 169 imagined an intermittently rotating shaft extending from the base of the automaton to the figures of Dionysus and Nike (how so?) and provided with a bob-
bin to change the direction of turning. This arrangement is nowhere described in the text.

**XIII.7** [48.14-15] καθεσθω... σύν. On the position of the axle, cf. note on XIII.3 [46.4-6].

**XIII.7** [48.17] περιεληθείσα σπάρτος. The word σπάρτος is omitted by most manuscripts, including a. It appears to be a conjecture in manuscript Aa (‘σπάρτος [sic] f.’), and is replaced by the words ἀγγύλη [i.e. ἀγκύλη?] σπάρτου in the margin of M (second hand). If this word originated as a scribal conjecture (a very plausible one indeed) intended to fill a gap, one might wonder whether the original reading was ἀγύλας instead. Hero’s later reference to ‘another chain’ to be wound around pipe γῦ, XIII.8 [50.7], is somewhat perplexing. In this regard, Baldi 44v n. 25 noted that there is no reason to expect a chain rather than a cord, all the more so because no chain has been mentioned in the preceding context. He went on to suggest that perhaps Hero has in mind the chain used to slide the plate inside the altar (XII.2 [42.18], XII.4 [44.9]). This is certainly a possibility. But why would Hero use a cord and a chain instead of two cords or two chains? The verb περιειλέω is used nine times by Hero in connection with cords (in the Automata only), whereas it refers only once to the winding of a chain (XXVIII.7 [104.8]).

**XIII.7** [48.18-19] τὸ ὑπερέχον τοῦ γῦ σωλήνος. For the substantivised participle of ὑπερέχω with a subjective genitive, cf. XXIV.3 [82.6] (ἐπίουρος) and, in other mechanical writers, Ph. Bel. 66.15-16, 72.25-6 and 72.30-1. XXVI.4 [92.12] (τὸ ὑπερέχον τοῦ πίνακος) illustrates a different use of the genitive (for instances, see LSJ s.v. II.1).

Note the variation with XIII.8 [50.8] (ὑπεροχῆ).

**XIII.8** [50.3-4] ἑπί... αὐτῶν. This is rendered possible by the use of pulleys ἵ and ἰ. Cf. XIII.7 [48.16-19].

**XIII.8** [50.4-5] ἵσος δὲ... σωλήνος. ἀξίον here seems to designate the shaft of the axle rather than the entire axle (see already Schmidt 389). Manuscript diagrams
show something like an ἐξελίκτρα around the centre of axle ὑζοῦ (see Fig. 16). This seems to be intended to make the diameter of the axle shaft equal to the diameter of the pipe, and so produce equal rotations (cf. note on II.10 [12.18-19]). For the same purpose, Murphy 24 Fig. 7, explicitly following Schmidt 387 Fig. 24a, added a drum at the base of the axle. This already appears in Baldi 27a unnumbered Fig., and might have originally been based on the manuscript illustration.

XIII.8 [50.5-6] δπως... θέσιν. The verb ἀποκατασταθῶσιν is mistranslated by Baldi 28’ (‘si femino’) and Couture 257 (‘conquiescant’). Here it implies that the figures of Dionysus and Nike complete their rotation (‘come back full circle’, Murphy 23; my emphasis); see note on I.2 [2.13-14]. Schmidt 389 (‘in ihre frühere Stellung zurückkehren’) is therefore right to take θέσιν as referring to the original position of the figures. Baldi 28’, less appropriately, has ‘postura’ (στάσις? see LS) s.v. B.a.2). Similarly, but more generally, Couture 257 (‘positions’). Murphy 23 slips into overinterpretation (‘relative position’). I am tempted to restore here: μηδὲν παραλλάσσοντες κατὰ τὴν <ἐξ ἀρχῆς> θέσιν. In addition to I.2 [2.13-14] and the passages cited in the note ad loc., cf. Metr. 94.16-17 τὸ... τῆς ἐλλείψεως ἐπὶ πέπεδον ἀεὶ παράλληλον ὑπάρχειν τῇ ἐξ ἀρχῆς θέσιν.


XIII.8 [50.9] τὸ ὀ. On the secondary counterweight, see note on II.6 [10.8-10].

XIII.9 [50.10-11] ὁ δὲ... γίνεται. The words καθάπερ... γίνεται have been strangely understood by Schmidt LV1 as a reference to Hero’s own Belopoeica. In his opinion, they apply only to the σχαστηρία (‘trigger’), and not to the χεῖρ (‘claw’). This is somewhat curious, given that the claw is an integral part of the trigger mechanism of a torsion engine. The whole mechanism is first attested in non-torsion artillery (‘belly-bow’ or γαστραφέτης, cf. Hero, Bel. 78.2-79.5), as illustrated in Fig. 19. The claw, which was used to draw the bowstring, could either have two prongs (as in the γαστραφέτης) or only one, depending on the type of engine (euthytone or palintone, cf. Bel. 110.11-111.6; on the distinction between these two types of engines, see Marsden 1969: 20-3; 1971: 44-5 n. 5
with Fig. 1; see also, more recently, Schiefky 2005: 254). In palintones or stone-throwers, the bowstring was plaited into a ring (κρίκος) at its middle point, and the prong of the claw was fitted into it (Marsden 1969: 32). Schmidt LVI cast doubt on whether the χείρ would have worked correctly here, but what he had in mind was a two-pronged claw: ‘zweier handartig gebogenen Stifte’ (391).

I am inclined to think that here, as in the case of palintones, Hero adopts a one-pronged claw to be fitted into the κρίκος (Fig. 20).

It is unnecessary to emend κατεχέτω to κατεχέσθω or even κατέχεται, as suggested by Brinkmann. The weight is retained by the ring, just as at XV.3 [54.2] the boards used to release the garlands are held in place by a rotating hook (ἐπιστρεπτῷ κόρακι κατέχεται). The claw will have disengaged from the ring upon the release of the trigger, allowing the weight to fall down (XIII.9 [50.12-13]). Here previous translators, except Schmidt 389, render κατεχέτω as if it were passive. See especially Murphy 23 (‘Let a ring... be controlled’; my emphasis).

XIII.9 [50.12] ἀπό. In Hellenistic Greek the preposition is commonly used to denote agency; see LSJ s.v. A.III.4 and, more recently, Bortone (2010: 185 with n. 28). Thus we need not emend to ὑπό, as tentatively suggested by Schmidt (app. crit. ad loc.). Cf. Spir. 152.6-7 (ἀφ’ ἐκάστου ἐμβληθείς), already cited by the Teubner editor. For the confusion between ἀπό and ὑπό, see app. crit. to XIV.1 [50.21]. Cf. also XXII.6 [72.17].

XIII.9[50.15] καθάπερ... ἐξήρηται. Cf. XIII.7 [48.11-13].

XIV [50.16-52.6] Sound of kettledrums and cymbals
The device discussed here is comparable to that described at XX.4 (βροντείον), except that the latter does not include a cymbal (Murphy 42 n. 32). The basic form of the device is simply a container holding lead balls which are released to hit the instruments (XIV.1-2 ἐν τῇ... ἀποτελέσθει). There follows a modified version of the device, with balls being distributed into two compartments. The opening of the description (XIV.2 δίναται... ἐπιθέσαι) seems to suggest that this second version represents an improvement made by Hero. See Introduction, p. cxii.
XIV.1 [50.16-17] κυμβάλλον καὶ τυμπάνων κτύπον. Cf. IV.2 [18.10-11] (ἥχος) and IV.3 [18.19-20] (ψφόρος), but here the word order is reversed. The term κτύπος usually denotes an abrupt noise, like thunder (A. Pr. 923; S. Ο. C 1463) or the shutting of a gate (Aen. Tact. 20.4), and is only rarely used of musical instrument sound. LSJ s.v. record only one instance of this use: B. Fr. 3.9 ἐβῆς = 1.75 Ιβίνου (σαλπίγγων κτύπος); but cf. also Ath. 8.361e (τυμπάνων κτύπος) and Cyr. Al. in Isaiah 1.3.11-12 = PG 70.149D (of the lyre).

XIV.1 [50.18-20] ἔν τῇ... πυθμένα. Murphy 42 n. 31 suggests that the container is placed inside one of the supporting columns rather than in the base unit, essentially because, in her opinion, it seems almost as if the balls are made to drop out of the bottom of the base (cf. XIV.1 [50.20-1]). There are two problems with this suggestion. First, it openly contradicts Hero’s words, and it is not clear why the term βάσις should be taken to mean ‘pedestal’ (Murphy 23 and 43 n. 38) and not simply ‘base’. Second, it is based on a mistaken interpretation of the noun πυθμένα, which in all likelihood refers to the bottom of the ἀγγείον rather than to the bottom of the base. Cf. XX.4 [66.11-12]. Perhaps we should imagine a container divided into a number of levels, so that the balls may roll downwards from the top.

G’s reading κατάβασει for κάτω βάσει is favoured, albeit tentatively, by Schmidt, who in his app. crit., after comparing XVII.1 [56.11] (κάτω βάσεως), cites Hero, Mens. 172.4 (ἡ δὲ κατάβασις τῆς καμάρας). This is rather peculiar, since the latter passage refers to a vault’s ‘declivity’ (LSJ s.v. κατάβασις 4). Neither this nor any other meaning of κατάβασις would be appropriate in the present context. In the Diorptora Hero frequently uses the term to denote a ‘back-sight’ reading (see Schöne 1903: 339 s.v. καταβάσεως), a meaning not registered by LSJ s.v.

XIV.1 [50.21-2] κλειθρίον... δέη. On the κλειθρίον mechanism, see note on IX.5 [32.8-9].

AG’s ἀνοιγόμενον is certainly genuine. The reading of the ed. princ. (ἀπαγόμενον) most likely represents an attempt to correct the corrupt text presented by manuscripts Pa (ἀπαγόμενον), Rd (ἀποτομόμενον) and Pf (ἀποτομόμενον). Prou’s conjecture ἄνοιγμένον (i.e. ἀνεογμένον?) is not only
wrong, but also unnecessary, because the slide opens more than once (ὅταν δέην). Prou 171 n. 159 mistakenly reads ἄνοιγμενον for ἄνοιγόμενον both in the manuscripts (i.e. Pb, Pe and Pg) and in the ed. princ. (cf. the marginal ἄνοιγ, certainly intended to correct ἄνοιγόμενον).

Instead of τῆς σπάρτου, one would rather expect σπάρτου τινός, as this cord has not been previously mentioned. Cf. esp. XIX.4 [62.11-12] σπάρτος τῆς ἐπισπάσται τὸ... κλειθρίον, etc. Cf. also XX.2 [64.19-66.1]. But perhaps the presence of the article (overlooked by Baldi 28' and Murphy 24) points to a now-missing diagram. Similarly, XVI.3 [56.1].

XIV.1 [50.22-3] ὑπόκειται... κυμβάλλον. Obviously, the cymbal, too, has to be positioned at an angle in order to allow the balls to bounce onto it: cf. XIV.2 [52.2].

XIV.2 [52.5] τὰ... κυμβάλλον. Schmidt's supplement is needed to coordinate the two consecutive clauses ὀστα... σφαιρία and τὰ μὲν... ἐξῆς.

XIV.2 [52.5-6] τὰ μὲν... ἀνοιχθέντος. This modified version of the device requires a different arrangement of the instruments, each of which must now be positioned in correspondence with one of the container's compartments. Contrast XIV.1 [50.22-3]. According to Prou 171, each χώρα is provided with its own slide. Hero, however, mentions only one slide (κλειθρίον ὅμοιος ἀνοιχθέντος). This presumably means that the partition is placed in such a way as to divide the hole into two equal portions, and that, after the opening of the slide, the two sets of balls are released at the same time rather than sequentially. The implication seems to be that either the hole is made bigger (but cf. XIV.1 [50.20-1] τρήμα... ἐλάττως ἄνοιγμεν δέξασθαι τὰ σφαιρία) or the balls are made smaller.
XV [52.7-54.7] Descending garlands

As a traditional religious symbol (DS 4.1258 s.v. Serta), the garlands accentuate the sacred character of the display. Weighted garlands, woven together into a rectangular wreath (πλέγμα ἐκ στεφάνων τετραγώνων, XV.2), are released from double parapets at the top of the supporting columns. On each side (Prou 171), a hook is turned inwards by means of a cord, allowing a hinged trapdoor to swing open and thus release the wreath (XV.3-4).

XV.1 [52.7] περιστύλιον. An extremely rare term, found elsewhere only at IG 11².199 A 108 (Delos, 274 BCE); restored at IG 4.1.112.32-3 (Epidaurus, fourth-third century BCE) and AJA 9 (1905) 307.34 (Sinope). Note the variation with XV.2 [52.10] (τετράστυλον). On the need to distinguish between ‘colonade’ and ‘peristyle’, see Ginouvès (1992: 59 n. 2).

XV.2 [52.9] γίνεται δὲ οὕτως. It is unnecessary to add <καὶ τοῦτο> after δέ, as tentatively suggested by Schmidt in his app. crit. In support of this, he compared the expressions γίνεται οὖν καὶ τοῦτο οὕτως (XIII.2 [44.17] and XVII.1 [56.12-13]; cf. also XVI.1 [54.9-10]) and γίνεται δὲ καὶ τοῦτο οὕτως (XIV.1 [50.17-18]). But cf. γίνεται οὖν οὕτως (XII.1 [42.14] and XXV.4 [86.15]).

XV.2 [52.9] θωράκιον. See Rance (2009: 96). The term seems to be used to refer both to the individual parapets that run around the top of the (architrave of the) peristyle (here, as at XV.2 [52.10], [52.11] and [52.15], XV.3 [52.18]) and to the structure resulting from the combination of these (XV.2 [52.16], XV.3 [52.19], [52.22] and [54.1] [supplemented], XVI.3 [54.22]). Cf. note on XV.2 [52.14-16]. It also recurs in Book Two, where it refers to the shielded cavity (θωράκιον κούλον, XXIII.2 [74.11]) containing the door-closing mechanism (Fig. 28); see Schmidt 417 n. 2.

XV.2 [52.10-11] ἕξον... ἐξῃθ. As shown in Fig. 21a (plan view). For a side elevation, see Fig. 21b (partly drawing on Schmidt 390 Fig. 95a).

XV.2 [52.12-13] πλέγμα ἐκ στεφάνων τετραγώνων. The unusual shape of the στέφανοι is explained by the fact that the wreath is fitted between the (rectangu-
lar) parapets; cf. XV.2 [52.14-15]. The interweaving of rectangular garlands will result in a rectangular wreath; hence there is no reason to suspect τετραγόνον (Ὑτετραγόνον Schmidt) and to adopt the editor’s proposed τετράγονον. In any case, the adjective refers to the shape of the garlands, not to their number (‘four’, Murphy 25; cf. ‘a garland on four sides’, Roby 2016: 146). Manuscripts are unanimous (or nearly so) in transmitting πλέγμα (see app. crit. ad loc.). This presumably means that Baldi’s πήγμα (45’ n. 28) is due to a misreading or correction of the text.

XV.2 [52.14] εὐφραμόστως. Adverb modifying γενηθέν. It occurs only here in the mechanical corpus, whereas there are no occurrences of the corresponding adjective. Schmidt’s suggested εὐφραμόστω is therefore arbitrary.

XV.2 [52.14-16] τῶτο... θωράκιον. The wreath – or, more precisely, each of its sides – has to be folded together (πτυσσόν) in order to fit into the interstitial space between the parapets. For a similar use of πτύσσω, cf. Spir. 180.6. It is not clear whether τοῦ θωράκιον refers to the inner or to the outer parapet. Perhaps what is meant is the (ceiling of the) whole structure (inner side: XV.3 [52.21-2]; underside: XVI.3 [54.21-2]; cf. XV.3 [54.1] [supplemented]). This may motivate the contrast between the plural θωράκιοι and the singular θωράκιον. Cf. also XV.3 [52.18-19].

XV.3 [52.17] ἢνα μὴ αὐτόματον καταφέρηται. Cf. the similar expression at XV.3 [52.20-1].

XV.3 [52.19-20] ἐπιπομάσαι τὸ πλέγμα. Before Hero, the verb ἐπιπομάζω (‘cover like a lid’, ‘cap’) is attested only twice (Hp. Loc. Hom. 47 = 6.344.10 Littre; Arist. Cael. 294b15). Apart from the Automata, it occurs six times in Hero’s corpus, always with reference to the covering, or capping, of holes (Spir. 102.5; cf. ἐπιπομάννυμαι: Spir. 132.6; ‘présent isolé d’apparence faussement archaïque’, Chantraine, DELG s.v. πόμα [1]) and hollow parts (box: Spir. 192.19; pipes: Diopt. 196.16, Spir. 20.15, 184.2 and 254.2). The only other occurrence of the verb in the treatise, XV.3 [54.1] (passive), appears to refer to the act of covering the underside of the θωράκιον (taken as the whole structure).
See note ad loc. For ἐπίκομα, cf. Dioctr. 300.27 (overlooked by Hammer-Jensen 1910: 502).

**XV.3 [52.21-2]** ἐκ τῆς... μέρος. The use of the article before the numeral (LSJ s.v. ἐκ 1.c) implies an opposition between the inner and the outer side of the parapet. For a more explicit example of this usage, cf. XVI.2 [54.18] (cord end).

**XV.3 [52.22]** στροφομάτια εὐλυτα. The term στροφομάτιον is very rare, occurring only here and twice in the Pneumatica (Spir. 78.9 and 78.15; cf. Ps.-Hero, Spir. 78.26 and 78.31). Elsewhere (Bel. 89.1 and 89.2), Hero prefers the base noun to describe a removable hinge (στρόφωμα ἀφαρετόν); see LSJ s.v. l; Marsden (1971: 27). Differently, Heilman (1992: 391 n. 3), who proposes, albeit hesitantly, another meaning: ‘gain de goujon’ (‘pin sheath’). Schmidt 79 n. 3 suggested that Hero’s στροφομάτια were bone hinges, such as those found in Pompeii (on these, see Allison 2006: 30). For εὐλυτος as ‘easily moveable’, cf. Spir. 204.9 (pin). In a negative sense: XXVI.3 [92.4-5] λαὸν εὐλυτα [sc. κανόνια]... ὡς στρέφεσθαι.

**XV.3 [54.1]** ὅταν <ὁ θωράκιον> ἐπιπομασθή. I have added <ὁ θωράκιον>, whose omission is easily explained palaeographically (τοῦ θωράκιον... <ὁ θωράκιον>). The subject of ἐπιπομασθή is otherwise ambiguous. In view of ἐπιπομάσαι τὸ πλέγμα one would rather expect the subject to be ‘the wreath’, but not infrequently Hero makes use of the verb with reference to hollow objects comparable to the θωράκιον. See note on XV.3 [52.19-20]. Most translations take τὰ σανίδια (XV.3 [52.20-1]) as the unexpressed subject of the verb (Baldí 28; Schmidt 393; Murphy 26). ἐπιπομάζω, however, does not signify the act of ‘closing’ or ‘shutting’, rather, it signifies the act of ‘covering’ or ‘capping’. In other words, the subject cannot be ‘the boards’, because the verb is used passively. Couture’s ‘clausae remanent [sc. assulae]’ (259) does not correspond to ὅταν ἐπιπομασθή (omitted in translation), as implied by Murphy 42 n. 34, but to κατέχεται (cf. Baldí’s ‘acciocche riserrare rimangano chiuse’).

**XV.3 [54.1-2]** ἐκ τοῦ... ἀνοίγεσθαι. The ‘other side’ is no doubt the outer side of the parapet; see note on XV.3 [52.21-2]. The hook, or ‘raven’ (κόραξ), must
therefore have been positioned on the same side of the parapet as the hinges, but protruding towards the outside (Fig. 21b). In Schmidt 390 Figs. 95a-b, the hook protrudes beyond parapet εξῆθεν and thus opens outwards. Instead, Hero invites us to imagine the opposite arrangement. The term κόραξ recurs in Bel. 79.10-11 (twice), where it describes the pawl (or ‘clinker’, κατακλέις) which engages, on each side of a bow stock, the teeth of a ratchet (κόρακες σιδηροῖς in Bito 50.8). See Marsden (1971: 46 n. 14), who suggests that each pawl is straight rather than hooked. On κόραξ more generally, see Whitehead-Blyth (2004: 88-9), on Ath. Mech. 10.12. For ἐπιστρεπτός as ‘rotating’, cf. Spir. 134.7-8 (στόμιον) and 148.2 (τροχοῖ).

It is unnecessary to add <αὐτόματο> after μή, as tentatively suggested by Schmidt in his app. crit. The absence of independent movement of the boards has already been emphasised: XV.3 [52.20-1]. A better suggestion would in any case have been <αὐτομάτως>. Cf. Spir. 174.11-12 ἄστε… τὰς θύρας αὐτομάτως ἀνοίγεσθαι.

XV.4 [54.3-4] ἓκ δὲ… περιτίθεται. We may perhaps paraphrase as follows: ἓκ δὲ τοῦ ἐτέρου μέρους ἀγκύλη σπάρτου περιτίθεται περὶ τὸν κόρακα (‘a loop of cord is wound around the hook from the other side’, Murphy 26). The phrase ἓκ δὲ… κόρακος should be understood in connection with XV.3 [54.1] (ἕκ τοῦ ἑτέρου μέρους), which refers to the outer side of the parapet (see previous note). Hence, the ‘other side’ corresponds here to the opposite (inner) side, with ἓκ denoting the direction of the cord. Quite differently, Baldi 28', who translates the phrase as if it were ἕκ μέρους τινὸς τοῦ κόρακος. Manuscript Paris. gr. 2520 replaces περιτίθεται with ἐπιτίθεται, an obviously incorrect reading. Cf. esp. XXIII.7 [78.9-10] τὴν… ἀγκύλην… περιτίθημι. Cf. also XXIV.6 [84.8-9] and XXVII.4 [98.20-1].

XV.4 [54.4-5] ταθείσης… ἐπιστραφέντος. Note chiasmus.

XV.4 [54.6] βαρύλλια μολμα. Possibly, conical weights. The term βαρύλλιαν is first attested here and in the Pneumática (Spir. 180.4 and 218.3; both in the singular), albeit without any reference to shape. It reappears in later sources, such as Synesius (Ep. 15.8) and Elias (in Cat. 117.10-11; in Porph. 21.32). In both
authors, it refers to a cone-shaped weight, be it the balancing weight of a hydrometer (Synesius) or the bob of a plumb-line (Elias); see Lampe (1948). For ἐπικείσονται cf. also Theon Al. in Ptol. 516.5 (ḅαρύλλιον μολύβδινον κωνικόν) and 525.2.

XVI [54.8-56.10] Dancing Bacantes

The Bacantes, six in number (cf. κατά δὲ κίνω... Βάκχη, III.4), are positioned on a rotating ring (ἵνς) around the shrine (ἐπικείσονται... Βάκχαι, XVI.3; cf. XVI.1). The ring is connected to the main counterweight by means of a drummed axle, which turns together with a pulley (XVI.2-3), increasing the distance rotated. Hero later proposes a similar, although slightly more complicated mechanism to lengthen the distance travelled by the automaton (XVIII.1-2).

Schmidt 395 n. 1 does not rule out the possibility that the Bacantes might also be made to rotate around their own axis, and suggests the use of friction wheels to make this happen (394 Fig. 96a). This clearly goes beyond Hero’s intentions (Drachmann 1963a: 197). For a detailed study of the dance of the Bacantes in Ancient Greece, see Lawler (1927).

XVI.1 [54.8-9] τὸ λουπὸν... κατὰ τὸ ήψος. For δὲ δὲ, occurring only here in Hero, see Denniston, GP 259. Here δὲ seems to be used to stress the addition made by δὲ. Differently, Schmidt 393 (‘nun noch’) and Murphy 26 (‘now’), who take the particle in its proper temporal sense (LSJ s.v.). Both Baldi 29 and Couture 259 omit translating it.

There is no need to accept Schmidt’s suggested χορεύσαι. The present tense (χορεύσαι) has a generalising force, as in other introductory passages of BOOK ONE: XII.1 [42.11-13], XIII.1 [44.15-16], XV.1 [52.7] and XVII.1 [56.11-12]. One also finds the present in other modal adverbial clauses: V.2 [20.13] (ἡμέρας δὲ ψυχεῖσθαι, ἢς ἐστι, ἢ etc.) and IX.6 [32.17-18] (ὥς δὲ δεῖ... νῦν ἔρωσται). But cf. the similar passage of XXX.1 [106.4-6].

XVI.1 [54.11-12] στυλοβάτην... κατὰ τὸ ἴψος. On στυλοβάτης, see Ginouves (1992: 15-6); Hellemann (1992: 396). The term is curiously translated as ‘columnarium’ (= pulvinar? see Forcellini s.v. columnarium 3) by Couture 259. Murphy 26 has ‘foundation’, which rather invites us to think of a ‘foundation
platform' (see Ginouves 1992: 11 with n. 29). In his app. crit. Schmidt daringly, if tentatively, suggested emending τὸ ὄψως to κρόταφον. This emendation does not appear to me to be supported by the passages cited by the editor, namely XVI.2 [54.16] and VI.4 [26.1]. The phrase κατὰ τὸ ὄψως here is easily understood as referring to the elevation of the stylobate (see Baldi 45' n. 29). For a similar use, see, for instance, Bito 55.9 (of a tower).

XVI.1 [54.13–14] περὶ... ἐςθηκλμν. The term ἔτιως here does not simply denote a 'rim' (cf. Spir. 310.9 and 310.11, of cylindrical vessels), as implied by Baldi 29' ('girò') and Murphy 26 ('felloe'), but a 'Ring' (Schmidt 395; cf. 'ring', Drachmann 1963a: 197) or 'orbiculum' (Couture 259). The latter sense (not registered by LSJ s.v.) draws directly upon the mathematical sense of the word, which Hero (Geom. 374.22-4; cf. Metr. 68.21-3) defines as the space contained between the circumferences of two concentric circles (the so-called 'annulus'; see CODM s.v.). Cf. also Metr. 70.4 and 160.1.

Fig. 22a shows three concentric circles, each apparently denoted by four letters (from outside inwards: εςηθ, κλμν and αβγδ). As correctly pointed out by Schmidt LV1, the arrangement of the letters is wrong. According to the Teubner editor, two possibilities may be envisaged: (1) the inner circle (αβγδ) corresponds to the stylobate, and hence εςθκλμ are in the wrong place; (2) the inner circle indicates either the space delimited by the shrine's columns or the base of Dionysus, and hence αβγδ (but not εςθκλμ) are in the wrong place. The main problem with either of these possibilities is that the two sets of letters εςηθ and κλμν are taken to refer to the circumference of the outer circle (but see Schmidt 394 Fig. 96b), whereas they each denote (and wrongly so) distinct circles. If the outer circle corresponds to the ἔτιως (ἐςθκλμν), as the different ink suggests, κλμν are misplaced too. I have therefore taken the middle circle to refer to the stylobate (αβγδ) and the inner circle to the base of the shrine (Fig. 22b). Murphy 25 Fig. 8 has five circles, but it is not always clear which element they correspond to (from outside inwards: 'outer rim of platform' [unlabelled], εςθκλμν, αβγδ, 'roof of shrine' [unlabelled], apex of the cupola [?]).

XVI.2 [54.16-17] ἀνταπορνεύσθω. This is the only occurrence of the verb with the meaning 'turn on the lathe', and the only one known to LSJ s.v. In other in-
stances, especially late ones (see DGE s.v. 2), ἐντορνεῶτο refers to chiselling and engraving: see, for instance, Apollon. Soph. s.v. λάων; Lucianus, Adv. Indoctum 8.19; Ath. Epit. 2.2.62.23 Peppink. Once used figuratively (DGE s.v. 3): Evagri. Schol. ad Eulog. 30 = PG 79.1133B (ƙόπας ἐντορνεῶσιν). Elsewhere Hero prefers the uncombined form: XXVI.7 [94.20] and [96.2], Diopt. 314.7 (all in the perfect passive); cf. Ph. Bel. 77.21 (aorist passive) and Ath. Mech. 23.7.

XVI.2 [54.17-18] ἐν ὅ... ἐς τὸ βάθος τοῦ σωλήνος. The words ἐς τὸ βάθος τοῦ σωλήνος were rightly deleted by Schmidt as a repetition from the following line. Murphy 42 n. 35 hesitantly suggests that the phrase is being used for emphasis, apparently without realising that the position of the cord is specified by ἐν ὅ [i.e. σωλήνι]. The verb ἐγκοιμίζω literally means ‘lull to sleep’ (AP 7.260.5, Carph.). LSJ s.v. cite only the present passage for ἐγκοιμίζω used metaphorically; but cf. Ps.-Chrys. Hom. in Luc. 8.5 = PG 61.771 τὸν γεωργόν... τὴν ἀρετὰν τῇ σκηνῇ ἐγκοιμήσαντα (DGE s.v. 2). Note the stylistic contrast between ἐγκοιμίσθω and the following κεκρούσθω.

XVI.2 [54.18] ἢς ἢ μὲν μία ἀρχή. On this use of the article, see note on XV.3 [52.21-2]. For the ‘other end’, cf. XVI.3 [54.21].

XVI.2 [54.19-20] δόσε μηκέτι ἐκσπάσθαι. The expression occurs here and at XXIII.4 [76.8].

XVI.3 [56.1] ἐν τῷ τυμπάνῳ. See note on XIV.1 [50.21-2]. Both Schmidt 395 (‘in einer Welle’) and Murphy 26 (‘on a drum’) have preferred indeterminacy. Baldi 29 (‘nel Timpano’) has the correct translation. Schmidt’s proposed correction (ἐν τῷ) is awkward, since the Attic form of τῷ is never found in Hero.

XVI.3 [56.1-2] ὁ... στρεφόμενος. Prou 169 maintains that the dance of the Bacchantes is achieved by the same axle that turns the Nike and Dionysus (following his reconstruction; cf. synopsis on XIII.7-8). This is clearly impossible, because Nike’s axle is located not under the parapet, but within the roof of the shrine; cf. note on XIII.3 [46.4-6].
The correct reading must be the adverb ἐνάλυτος (AGM) rather than the adjective ἐνάλυτος (T). The adverb, in fact, is frequently used to describe the smooth rotation of an axle; see note on II.8 [12.6-7]. Murphy 26 seems to misinterpret the meaning of ἐνάλυτος (‘an axle with enough room to turn freely’; my emphasis), for she stresses (42 n. 36) that the axle should not rotate independently of the drum. Hence, she suggests that Hero means that the axle is turning on pivots which are fitted into something else. Although pivots are certainly used (cf. XI.8 [40.6-7]), there is no explicit indication in the text of how the axle is made to rotate.

XVI.3 [56.3-5] συμβήσεται οὖν... σπάρτον. A simple transmission system (‘einfache Übersetzung’, Schmidt LVII; see also Fig. 23). Cf. XVIII.2 [58.18-21] (involving a double axle arrangement).


XVII.1-2 [56.11-58.2] Concealing the cords
Hero fills in some gaps, providing information on how to keep the cords orderly and out of sight. A partition divides the σύρις into two unequal parts (XVII.1; Fig. 24), the larger part containing the millet, the smaller part concealing the cords (XVII.2). A cursory observation on the height of the σύρις (ἐπει... μηχανήσασθαι, XVII.2) provides a smooth transition to the discussion of modifications for increasing the range of motion (XVII.3-XIX).

XVII.1 [56.14] τὸ στόμα τῆς σύριγγος. Here and, with some degree of variation, XVII.1 [56.15] and XIX.1 [60.12]. For στόμα as mouth of a tube, cf. Spir. 20.14 and 254.11 (τοῦ στόματος τοῦ συριγγίου). But the term can be used of ‘any outlet’ or ‘entrance’: LSJ s.v. ii.2 (citing no Heronian instances); especially compare Spir. 280.4 (of a flask) with AP 6.251.6 ὁλπης... στόμαι (Phil.).

XVII.1 [56.15-17] διάφραγμα... στενότατον. For the phrasing, cf. Spir. 312.5-6 δύο διαφράγματα τὰ ΕΗ, ΖΘ ἀπολαμβάνοντα χώραν τὴν ΘΕΖ (syntactically reversing Spir. 306.1-2). The correction στενότατον is Schmidt’s. The manu-
script reading στεγνότατον (‘watertight’) cannot be right because, as the text that follows makes clear, the cords are made to pass through the space delimited by the partition. A similar confusion between στεγνός and στεγνός occurs at XXVII.1 [98.5] (see app. crit. ad loc.). For ἀπολαμβάνω in the sense of ‘fix’, ‘secure’, cf. DGE s.v. III.3, citing ID 504 A 11 (ἀπολαμβανον χάλκι μαρφόντως), XXIII.5 [76.12] and XXV.4 [86.21] (erroneously cited as 25.5); cf. also XXIII.4 [76.7].

Manuscript diagrams show the partition, along with the mouth of the tube, as seen from above (Fig. 24a). So, Baldi 30 unnumbered Fig., but with ‘c’ (γ) and ‘d’ (δ) inverted. For the sake of clarity (‘um der Deutlichkeit willen’) Schmidt 397 Fig. 97 with n. 1 preferred a side view (α, γ and ζ are ambiguously placed at the bottom of the tube, whereas δ and ε should not be aligned with β).

**XVII.2 [56.18-19] αὐ δὲ... ἀνεχθήσονται.** I follow Schmidt in adopting Μ’s ἀνεχθήσονται, which must be the genuine reading. Cf. XVII.2 [56.22] (αῦ κατώθεν ἀναιρέσκειν σπάρται) and XIX.1 [60.15]. Haase’s emendation ἐνεχθήσονται for AGT’s ἀνεχθήσονται is unnecessary.

**XVII.2 [56.22-58.1] πολλῶν... ὑπαρχοῦσης.** Note the variation between γενομένων and ὑπαρχοῦσης and the partial chiastic arrangement.

Without textual support, Brinkmann’s emendation μεγάλης for πολλῆς is implausible both palaeographically and stylistically. The use of the adjective πολύς to describe the length of journey (πορεία) is common enough and early enough (for instance, Pl. R. 614e2, Arist. Ph. 220b30, Cleom. Cael. 1.4 = 19.37-8 Todd). Cf. XVIII.3 [58.4] and XVIII.2 [58.23].

**XVII.2 [58.1-2] ἀνάγκη... μηχανήσασθαι.** AGT’s μὴ has been rightly deleted by Schmidt. Μ’s μὲν would here be out of place. Hero’s concern is genuine, given that the height of the σύριγξ determines the distance descended by the counterweight (Olivieri 1901: 431).

With δὲ... μηχανήσασθαι cf. XXVI.6 [94.17] δὲ προμηχανήσασθαι ταῦτα (occurring in identical sentence position). Schmidt 397 misinterprets here: ‘Daher ist noch folgende Hilfsvorrichtung zu machen’. On the other hand, Murphy 26 (‘and you must make it so’) is too bland. More appropriately, Baldi 30r
('bisogna in questo modo ancora aiutarsi con l'ingegno') and Couture 260 ('hic quoque arte utendum').

XVII.3-XVIII [58.3-60.9] Increasing the range (I). Potentially unsuccessful modifications

Three methods are proposed for increasing the distance covered by the automaton (XVII.3-XVIII.2). The first two methods involve either bigger wheels (Hero's preferred choice) or a smaller axle (XVII.3). Hero does not elaborate, perhaps because of problems arising from changes in the ratio between the axle and the wheels. The third method, applicable also to any other mechanism (καὶ... ἐπιτελεῖσθαι, XVIII.3), is nothing more than a transmission system (Fig. 25) in which an added drum amplifies the rotation of the wheel axle (Olivieri 1901: 431; cf. XVI.2-3). This is theoretically possible, but practically unlikely. A heavier, hence bigger, counterweight (cf. XVIII.3) would in fact take up too much space in the σύρηξ. The section closes with an example illustrating how mechanical transmission can be used to increase the range of other movements (i.e. rotation of Dionysus, XVIII.4).

XVII.3 [58.3-4] δόναται... παρέχειν. This obviously depends on the fact that one turn of the axle corresponds to one turn of the wheels. So, for each turn of the axle, the automaton travels a distance equal to the circumference of the wheels: XVII.3 [58.5-7]. The tacit implication is that, if the wheels' diameter is increased, the height of the base must be increased too.

XVII.3 [58.4-5] ἢ τὸ τοῦ ἀξονὸς πάχος ἔλασσον γνώμενον. Sc. δόναται πολὺ μῆκος παρέχειν. If one reduces the diameter of the axle, the wheels will turn faster, thus increasing the overall distance travelled. This option is not without disadvantages; see following note.

XVII.3 [58.5-8] ἀπαξ... ποιεῖν. These lines have been suspected by Schmidt LVI-II of being an interpolation, primarily on the grounds that διὸ... ποιεῖν contradicts the alternative of XVII.3 [58.3-5]. However, as pointed out by Olivieri (1901: 433), there is no contradiction, but rather a continuation of the argument in favour of the enlargement of the wheels. Admittedly, Hero does not bring his
argument to an end nor does he explain why he prefers the former option to the latter. Perhaps we should assume a lacuna after περιφέρεια, in which Hero illustrated the benefits of enlarging the wheels (αὐτοῦ, indeed, lacks a clear antecedent). Be that as it may, the second option does have some disadvantages. First, a thinner axle means less space for the cord slackenings and, consequently, a lower capacity to programme movements (see McCourt 2012: 196). Second, as the speed of the rotation is increased (see previous note), the automaton becomes more unstable and prone to tipping over.

With τηλικαύτην... περιφέρεια cf. the phrasing at XVIII.2 [58.19-20] τοσοῦτον... περιφέρεια (noted by Schmidt LVII).

**XVIII.1** [58.10] τοῦ συμφωνοῦ ἀυτῷ τροχοῦ. Schmidt’s emendation (αὐτῷ) is easy enough, because the wheel rotates together with the axle. XVIII.2 [58.22-3]. Most manuscripts, including a, have αὐτοῦ, a reading which probably arose under the influence of the following τροχοῦ.

**XVIII.1** [58.15-17] ἕκ δὲ... λέγειν. The first part of the sentence is elliptical, since the participle ἐπεληθεία lifts a prepositional complement: either περὶ τὸν ἄξονα (as implied by Baldi’s ‘che intorno gli è ravolta’ [301]) or ἐπὶ τὸν ἄξονα (as implied by Schmidt’s ‘wick die sie darauf’ [399]). I am inclined to favour the first interpretation. Cf. XVIII.1 [58.13-14]. Couture 261 (‘ad aequipondium... deducatur et alligetur’) misconstrues the syntax, associating ἐπεληθεία with ἀποδεδόσθω. Murphy 27 (‘Attach the other cord... to the counterweight’) omits the participle altogether.

For a similar ellipsis, cf. XXIV.4 [82.13-14].

**XVIII.2** [58.18-20] συμβήκεται... περιφέρεια. Hero gives prominence to the rotation of the axle, which both serves as a measure of the emptying of the σύριξ (τοσοῦτον... περιφέρεια, cf. XVII.3 [58.6-7]) and determines the rotation of the drum (as clearly emerges from the clause that follows; cf. also XVIII.1 [58.12-13]). Schmidt’s emendation στραφέντος gives a more precise sense than στρέφοντος. As noted in the editor’s app. crit., this emendation has been suggested to him by XVII.3 [58.5-6] (ἀπαξ γὰρ τοῦ ἄξονος στραφέντος; note the variatio in the word order). Two manuscripts (Ea, Lb) have ἀποστραφέντος, which
most probably resulted from the conflation of ἀπαξ (omitted in both manuscripts) and the corrected (or original?) reading στραφέντος.

**XVIII.2** [58.20-1] τὴν δὲ... τῶμαν. I adopt Schmidt’s proposed emendation ἐπειλεῖσθαι for AG’s ἐπειλήσαι, a reading which, if retained, would require τὴν... σπάρτον to become the direct object and τὸ... τῶμαν τὴν subject: so Murphy 27 (‘the drum ἹΘ... will wind the cord from axle AB once’). This can hardly be correct, given the correlation with the preceding clause (ὁλίγον μὲν μέρος... τὴν δὲ... σπάρτον). Schmidt (app. crit. ad loc.) also tentatively suggested adding <ἐίς> after ἐπειλεῖσθαι, and indeed, despite his Greek text (ἐπειλήσαι), translated accordingly (‘die Schnur... sich einmal auf die Welle ηθ wickelt’, 399). On the basis of XVI.3 [56.3-5] (συμβῆσεται... ἐπειλεῖσθαι ἐπί τὸ... τῶμαν τὴν... σπάρτον), I prefer to add <ἐπί>, which could have easily been omitted (ἐπειλεῖσθαι <ἐπί>). Some manuscripts (Ad, Ac, Barb. gr. 261 and Ld) have the incorrect reading ἀπειλήσαι, which implies that the drum rotates in the opposite direction. Baldi 30*-31* appears to retain ἐπειλήσαι, but mistranslates it: ‘la corda... circonda una volta sola il Timpano’.

**XVIII.2** [58.23-4] πολὺ μῆκος τῆς πορείας γίνεσθαι. An existential use of γίνομαι. So Schmidt 399 (‘ergiebt sich eine bedeutende Länge der Fahrt’). In a copulative sense: Baldi 31* (‘sia molto lungo il viaggio’, my emphasis) and Couture 261 (‘sit longius iter’). Murphy 27 translates much more freely: ‘the motion will cover a longer distance’.

**XVIII.3** [60.1-2] μέξονος... κινεῖσθαι. Hero relies here on the allegedly Archimedean principle of concentric circles (Mech. 2.7; cf. Papp. 1068.19-23; Drachmann 1963a: 61-3; Knorr 1982: 90-2), by which, following in the footsteps of Philo’s lost book on levers (Μοχλικά, cf. Ph. Bel. 59.11-12) and Ps.-Aristotle’s Mechanica, he elsewhere (Mech. 2.8-20; cf. Mech. 2.1) explains, or attempts to explain, how each of the five powers (but particularly the windlass and the lever; see following note) can move a large weight with a small force (Schiefsky 2008: 22-32; Laird 2015: 290-301), contra, argues that only the windlass and the lever are reduced to concentric circles, and that the pulley, the wedge, and the screw are explained by another principle, which he calls the prin-
ciple of dividing and sharing the load). The reference to bigger and smaller circles (not ‘wheels’, Murphy 27) is a reference to the drum ηθ and the axle οχ (see Schmidt 399 n. 2; the generalising plural also appears twice at XVIII.4 [60.7-8]). Unlike in the case of concentric circles, the moving power is applied (by means of a pulley) to the circumference of the smaller circle. Since the ratio between force and weight is the inverse of the ratio of the distances from the centre (Mech. 2.7; cf. [Arist.] Mech. 850b1-2; Schmidt 399-401 n. 3), a greater force is required to turn the drum, thereby overcoming the resistance of the wheel and axle assembly. On the basis of Dioptr. 312.20-22, where the principle is used to account for the operation of the baroulkos or ‘weightlifter’ (see the discussion in Berryman 2009: 136), Schmidt (app. crit. ad loc.) tentatively suggested adding <ὅταν περὶ τὸ ἀντὶ κέντρον κυλῶνται> after κινεῖται. This supplement is unnecessary, because it is obvious that ηθ and οχ rotate about a common axis passing through their centre: that is to say, it is obvious that they can be reduced to concentric circles.

Perhaps emend προσδεῖται to προσδεῖ (Schmidt dub. in app. crit.). The impersonal middle προσδεῖται is significantly less frequent than its active counterpart: LSJ s.v. προσδέω (B) II.2 (not noting the present passage; add Ps.-Aristeas, Ep. ad Philocr. 11.5). But see KG 1.396 (Schmidt in his app. crit. refers to ‘Kühner Gr. II 255’, but this seems erroneous, for neither the first nor the second nor the third edition contains relevant information on that page).

XVIII.3 [60.3] ταύτα... ἔστι. Or, perhaps better, ‘by means of the principles of leverage’ (μοχλικών, Brinkmann), as understood by Baldi 31’ (‘ragioni del vette’ and, more drastically, Couture 261 (‘tractatum de vecte’). By all appearances, Hero intends to clarify his reference to bigger and smaller circles. For the reduction of the lever to the principle of concentric circles and, ultimately, to the balance, cf. Hero, Mech. 2.8 (seemingly drawing on [Arist.] Mech. 850a30-850b9). When reduced to concentric circles, the arms of the lever correspond to the distances from the centre (i.e. here the radii of the drum ηθ and the axle οχ): see Schmidt LVII, 399-401 n. 3 and, more generally, previous note. The reading of AGT, μοχλιον, is certainly better than Μ’s κοχλιον (Baldi 45r n. 30 already corrected the latter reading, which he claimed to have found in his exemplar). While the screw bears little (Shiefsky 2008: 28, 30-1) or no (Laird 2015: 300)
similarity to concentric circles, μοχλίων fits much better into Hero’s explanatory
agenda for mechanical phenomena; see Schiefsky (2008: 23), who finds a paral-
lel between Hero, Mech. 2.1 and [Arist.] Mech. 848a11-14 τα μέν οὖν περὶ τὸν
ζυγὸν γινόμενα εἰς τὸν κύκλον ἀνάγεται, τα δὲ περὶ τὸν μοχλὸν εἰς τὸν ζυγὸν, τά
δ’ ἄλλα πάντα σχεδὸν τά περὶ τάς κινήσεις τάς μηχανικὰς εἰς τὸν μοχλὸν.

It is unnecessary either to transpose δῆ after γάρ (Schmidt dub. in app. crit.)
or to emend it to δῆλά (Brinkmann). Cf. Bel. 102.8-9 οὐ γάρ κατασκευάζεται
πάμπολλα δῆ πρὸς τὰς κατεπειγόντας χρεῖας. For γάρ…δῆ (hardly character-
istic of Hero), see Denniston, GP 244. In the manuscripts Ab, Ac and Bb, a
space of varying size is left blank between μοχλίων and δῆ (δὲ Bb). This is prob-
ably just a mistake, for in two cases the scribe drew a line between the words
either across (Ac) or below (Ab) the space.

XVIII.3 [60.3-5] καὶ… ἐπιτελεῖσθαι. If Hero is keeping up the analogy with con-
centric circles, as it seems, then the μικρὰ διάστημα are ‘small radii’ (Murphy
27; cf. LSJ s.v. διάστημα I.1.b and Hero, Deff. 27), and not simply ‘short dis-
tances’ (‘kleine Entfernungen’, Schmidt 401) or, even worse, ‘small lengths’ of
cord (‘piccoli spazi, cioè di corda’, Baldi 31’). μεγάλας οὕστας clearly refers to
the duration of movements (Schmidt 401); Murphy 27 ambiguously translates
‘on a large scale’.

XVIII.4 [60.6-9] ἐὰν γάρ… ὀποδείξαμεν. This passage has been unjustly suspec-
ted (Schmidt LVII-III; endorsed by Brinkmann and Olivier 1901: 433) as an
interpolation. Schmidt’s main reasons are as follows. First, the apparatus for the
rotation of Dionysus (XIII.7-9 [48.13-50.14]) is an unsuitable example of mech-
anical transmission, in that Dionysus rotates only 180 degrees (twice); the dance
of the Bacchantes would have been a much more fitting example (cf. XVI.3
[54.21-56.6]). Second, μείζονας κύκλους presupposes a repeated transmission
(i.e. a higher number of rotations), and the singular τοῦ μείζονι is awkward.
Third, the phrase ἢ δὲ εἰς τὴν λείαν, unaccompanied as it is either by
ἀποδιδομένη (as at XIX.3 [62.6]) or ἀποδειδομένη (as at XXVI.8 [96.9]), is
harsh. Fourth, ἐὰν γάρ (as used here?) is otherwise unfamiliar to Hero. As to the
first point, it is true that, unlike the Bacchantes’ dance, the mechanism for turn-
ing Dionysus does not involve a transmission system which lengthens the dis-
tance rotated. However, Hero might be developing, albeit still in an embryonic form, an alternate system that allows Dionysus (and the Nike?) to complete one or more full rotations either before or after (or both before and after) the second altar has lit. Brinkmann’s deletion of τοῦ Διονύσου (disliked by Olivieri) is, therefore, not only unnecessary but also undesirable. As far as μείζονας κύκλους is concerned, the plural should not be taken as indicating a repeated transmission but rather as a generalising plural (cf. ἐλάσσονας ἄξονας) denoting a single drum; cf. XVIII.3 [60.1-2] with note ad loc. Thus, τὸ μείζονι could be a mere slip of the pen for τὸι μείζονι. If so, it requires neither to be emended to the plural (as proposed by Schmidt in the Anmerkungen; but see already Baldi 31) nor to be supplemented by μείζων (as hesitantly proposed by Schmidt in his app. crit.). The noun phrase ἡ δὲ εἰς τὴν λείαν is not necessarily incomplete. We do find comparable expressions for cords coming from (ἐκ) a certain direction (XII.4 [44.8-9] and XVI.3 [56.5]) or passing around (περὶ) a certain instrument (XVI.3 [56.3-4]). In any case, it is clear that there are two cords – one going from Dionysus’ pipe (ὄργανον) to the drum and another going from the drum’s axle to the counterweight (in analogy with XVIII.1 [58.12-17]; cf. Figs. 25a-b) – rather than only one, as wanted by Murphy 27 (‘for if the cord moving the apparatus of Dionysus is wound around greater circles, it must then go, etc.’, my emphasis). Last but not least, ἕλαν γάρ is not at all uncommon in Hero: VIII.1 [28.4], Deff. 83.1, Diopt. 252.11 and 272.21, Mech. Frag. 2.35 =Papp. 1034.14, Metr. 6.14 (supplemented), 74.6, 74.26, 86.4, 94.1-2, 138.20 and Spir. 4.17; cf. Mech. Frag. 3.1 = Papp. 1130.18-19 (ἔλαν μὲν γάρ...ἔλαν δὲ). Unlike these other passages, here ἕλαν γάρ (‘wenn z.B.’, Schmidt 401; my emphasis) introduces a protasis without apodosis, where γάρ establishes a logical connection with the previous sentence; for comparable examples with combinations such as ὥς γάρ, ἐπεὶ γάρ and, more relevantly, εἰ γάρ, see Vahlen (1885: 128-130), already quoted by Schmidt in his app. crit. (‘Vahlen Aristot. poët. p. 1283’). So, while Schmidt’s suggested deletion of γάρ disrupts the logical coherence of the text, the apodosis can be easily supplied from the context (‘this happens’, where the pronoun more correctly refers to the idea in the previous sentence rather than to XVIII.1-2 [58.9-23], as in Baldi 31 and Couture 261). On incomplete conditional sentences, see generally Goodwin (1889: 179 n. 482) and KG 2.484-5.
XIX [60.10-62.20] Increasing the range (II). Two-counterweight system
Hero provides only a sketchy (‘summarisch’, Schmidt LVIII; cf. Schmidt 1903: 278) account of his two-counterweight system. The σύρης, and not the whole case (‘cassettone a due apartimenti’, Olivieri 1901: 432), is divided into two parts (Fig. 26), each containing a counterweight (XIX.1). One counterweight brings about forward and backward motion, the other all the remaining movements (XIX.2; cf. XIX.3-5). A more complex mechanism (involving, among other things, a greater number of cords) has been devised by Querfurth (Schmidt LVIII-IX with Figs. 99b and 99c; unduly criticised by Olivieri 1901: 431). For further discussion, including rebuttal of Olivieri’s view that the chapter is interpolated, cf. Introduction, pp. cxiii-cxv.

XIX.1 [60.10] ἐπιπορεία. The term occurs only here and at XIX.2 [60.17] in the whole corpus of Greek literature. For ἐπιπορεύομαι, cf. XIX.4 [62.11]. The change from πορεία/πορεύομαι is probably only stylistic.

XIX.1 [60.11] οἱ ξύτοθεν <τῆς πορείας> κινήσεις. Schmidt’s supplement is surely right. Cf. II.8 [12.3-4], XII.1 [42.10-11] and XVIII.3 [60.3-4]. The words τῆς πορείας may easily have dropped out owing to the proximity of ἐπιπορεία and ἀποπορεία.

XIX.1 [60.12-14] ἐκτὸς γὰρ...εὐθείας. Note the figura etymologica with the noun διάφραγμα, which is frequently used by Hero in the Pneumática: see, for instance, Spir. 102.24-104.1, 112.16-17 and 116.14-118.1 (plural). The verb διαφράσσομαι, occurring only here in the Automata, is generally employed by Hero (only in the Pneumática) to refer to horizontal partitioning; but cf. Spir. 152.9-13 (vertical partitioning). Just as in the case of the single partitioning (XVII.1 [56.15-16]), manuscript diagrams show a plan view of the σύρης (Fig. 26a). So Baldi 31v unnumbered Fig. and Schmidt 402 Fig. 99a. For a side view, see Schmidt LVIII and 403 Fig. 99b (including more details than are warranted by the text).

XIX.1 [60.14-16] δοστε...λεῖας. Perhaps we should emend κάτω to κάτωθεν (cf. XVII.2 [56.19] and [56.22]). The omission of -θεν might have arisen from over-
sight (ἐν being often abbreviated as L or ζ and written above the line: Allen 1889: 14 and Pl. IV; Gardthausen 1913: 337). Translators have been inattentive here, for they either rendered the adverb as if it were κάτωθεν (‘da basso’, Baldi 31'); ‘ab imo’, Couture 261; ‘von unten’, Schmidt 401) or omitted it altogether (Murphy 27). The plural τὰς λείας is curiously translated by Murphy 27 as ‘the counterweight’.

XIX.2 [60.20-62.1] ἐν τῇ ἐθνίδῃ. Here, too, there must have been millet seeds. If Hero does not specify, it is probably because he wants to avoid repetition.

XIX.2 [62.1-2] ἐκατέρῳ...παράγεσθαι. Hole κ's slide is connected to three cords (one that opens it, another one that closes it, and yet another one that opens it), whereas hole λ's slide has only one cord attached (it need not be closed once the millet has run out). Murphy 43 n. 42 makes (somewhat tentatively) two points. First, the opening of each slide is controlled reciprocally by either counterweight. Second, κ's slide is closed either at the same time λ is opened (by means of one and the same cord) or after λ is opened, by means of a cord pulled tight under the impulse of the second counterweight. The first point seems right, except that κ's slide is first opened manually: XIX.3 [62.3-4]; cf. IX.5 [32.10-12]. As for the second point, λ's slide is opened during forward motion (XIX.4 [62.11-12]), which means that κ must be closed at a later time. It is not entirely clear how κ's slide is closed, but XIX.4 [62.14-15] strongly suggests that it is pulled shut by the cord connected to the second counterweight (or, possibly, by another cord branching off it); see further note on XIX.4 [62.15].

On παράγον, see note on XII.4 [42.17-18].

XIX.3 [62.3] παράξεμεν. This is no doubt the correct reading, and is supported by all manuscripts. Cf. XIX.2 [62.2]. In the margin of manuscript F we find the tentative emendation προσάξεμεν (‘bring to’ or ‘upon’), which does not fit into the present context.

XIX.3 [62.4-7] ἵνα...χαλασμέτων. Cf. IX.6 [32.14-15]. The addition of μὴ (endorsed by Murphy 43 n. 41) is Schmidt’s, and has been anticipated by Baldi 31' (‘non’). The pleonasμὸν ὡρμήν λαβῶν...κινηθῇ is emphatic and is unparalled else-
where. But cf. Ph. Quod deterius potior insidiari soleat 127.5 ὃ νοῦς
eξαναστάς... ὃμήν λάβῃ ἢ κινηθεὶς ἐνδοθεν, etc. (with a variatio). The prepos-
ition ὑπέρ (rightly deleted by Schmidt) seems to be an intrusive gloss explaining
the position of the counterweight. Baldi 31v (‘le carrucole di sopra’) translates
τροχόν as if it were τροχίλων (Couture 262 follows suit, but changes the plural
to the singular). Such rendering is best explained as an attempt to make sense of the
correct reading ὑπερτροχόν, transmitted in M and other manuscripts.

**XIX.3** [62.7-9] χρόνος... χάλασμα. The equivalence between the periods of (ap-
parent) inactivity of the automaton and the length of cord slacks is first formu-
lated here. This formulation, however, is foreshadowed in the idea that the cord
slacks should be made proportional to the distances travelled by the automaton:
X.3 [34.16-17] and X.15 [38.4-5]; cf. XI.5 [38.1-3] with note ad loc.

For ἀποστάντων ἡμῶν, cf. IV.1 [18.2] (supplemented).

**XIX.4** [62.11] ἐπιπορευομένου. Cf. note on XIX.1 [60.10]. AG’s reading is
preferable to M’s πορευομένου. The omission of ἐπι- probably arose because of
its similarity with the preceding ἐπί. Cf. also XIX.4 [62.13] (πορευομένου).

**XIX.4** [62.11-12] ἐπισπάσται... αὐτῷ. For the phrasing, cf. XIX.5 [62.18-19].

**XIX.4** [62.15] ἡτίς... κλειθρίων. I take the verb ἐπισπάσται to mean, as both
Baldi 31v (‘si ritirerà’) and Couture 262 (‘retrahetur’) did (note passive sense),
that r’s slide is closed, rather than opened (‘will... open’, Murphy 27), by the
cord (Schmidt 403, more neutrally, has ‘zieht... an’, but he clearly believes that
this cord causes the slide to close: see Schmidt LX and 403 n. 1). r’s slide is
opened twice, once in order to make the automaton move forward (XIX.3
[62.3-4] παράξομεν τὸ... κλειθρίων, ὥστε ἀνοιχθήναι), and once to make it come
back (XIX.5 [62.18-19] ἐπέρᾳ σπάρτος ἐπισπάσται τὸ... κλειθρίων καὶ ἀνοίξει
αὐτό). Its second opening, therefore, occurs after, not during, the completion of
the other movements (cf. XIX.5 [62.16-18]). Its closure, on the other hand,
brings the automaton to a halt before the sequence of movements begins: XIX.5
[62.16] (καὶ οὕτως στῆσεται τὸ πλινθίον). Perhaps, then, we should assume that
the verb κλείσει has dropped out after καὶ (ἐπισπάσεται καὶ <κλείσει> τὸ... κλειθρίον). Cf. Spir. 182.5-6 βάρος... ἐπισπάσεται καὶ κλείσει τὰς θύρας.

XIX.5 [62.18-19] ἕτερα... ὁμός. There is no doubt that Hero refers here to a different cord (ἕτερα οπάρτος) from the one used for closing Ῥ’s slide. So, Schmidt 405 with n. 1 (‘eine andere Schnur’). Both Baldi 31v (‘l’altra corda, che è attaccata al chiusore k’) and Murphy 27 (‘the other cord’) use the definite article instead. Baldi is probably referring, albeit erroneously, to the cord by which Ῥ’s slide is initially opened (not explicitly mentioned in the present context, and pulled manually; see note on XIX.2 [62.1-2]). Murphy, on the other hand, seems to be referring to the cord used for closing Ῥ’s slide (XIX.4 [62.14]), since she recognises here that the latter is opened by the action of the second counterweight (Murphy 43 n. 42). This would explain why she misinterprets ἐπισπάσεται (XIX.4 [62.15]) as referring to the opening of Ῥ’s slide; see previous note.
APPENDIX 1. CONCORDANCE OF EDITIONS

The following is a concordance between the present edition and the editions by Thévenot, Prou and Schmidt. Thévenot is cited by page and line number. References to Prou and Schmidt are by chapter, section, page and line number (given in square brackets). If the section is omitted, the reference is to the entire chapter. Prou’s sections are indicated by Greek numerals.

<table>
<thead>
<tr>
<th>Grillo</th>
<th>Thévenot</th>
<th>Prou</th>
<th>Schmidt</th>
</tr>
</thead>
<tbody>
<tr>
<td>I [2.3-6.8]</td>
<td>243.10-244.38</td>
<td>-</td>
<td>I [338.3-342.10]</td>
</tr>
<tr>
<td>II [6.9-14.16]</td>
<td>244.39-246.25</td>
<td>-</td>
<td>II [342.11-348.25]</td>
</tr>
<tr>
<td>IV [18.1-20.7]</td>
<td>247.2-31</td>
<td>-</td>
<td>IV [352.5-354.9]</td>
</tr>
<tr>
<td>VI [22.21 -26.5]</td>
<td>248.15-249.12</td>
<td>-</td>
<td>VI [358.6-362.3]</td>
</tr>
<tr>
<td>VIII [28.4-30.2]</td>
<td>250.3-26</td>
<td>-</td>
<td>VIII [364.8-29]</td>
</tr>
<tr>
<td>X  [32.19-34.24]</td>
<td>251.39-252.20</td>
<td>-</td>
<td>X.1-4 [368.27-372.16]</td>
</tr>
<tr>
<td>XI [36.1-42.8]</td>
<td>252.21-255.11</td>
<td>-</td>
<td>XI [372.17-380.11]</td>
</tr>
<tr>
<td>XII [42.9-44.14]</td>
<td>255.12-256.7</td>
<td>-</td>
<td>XII [380.12-382.19]</td>
</tr>
<tr>
<td>XIII [44.15-50.15]</td>
<td>256.8-257.29</td>
<td>-</td>
<td>XIII [382.20-388.15]</td>
</tr>
<tr>
<td>XIV [50.16-52.6]</td>
<td>257.30-258.17</td>
<td>-</td>
<td>XIV [388.16-390.6]</td>
</tr>
<tr>
<td>XV  [52.7-54.7]</td>
<td>258.18-259.11</td>
<td>-</td>
<td>XV  [390.7-392.22]</td>
</tr>
<tr>
<td>XVI [54.8-56.10]</td>
<td>259.12-260.7</td>
<td>-</td>
<td>XVI [392.23-396.7]</td>
</tr>
<tr>
<td>Page</td>
<td>1921-24-09</td>
<td>1926-11</td>
<td>1928-20-09</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>XVII [56.11-58.8]</td>
<td>260.8-29</td>
<td>-</td>
<td>XVII [396.8-398.2]</td>
</tr>
<tr>
<td>XVIII [58.9-60.9]</td>
<td>260.30-261.25</td>
<td>-</td>
<td>XVIII [398.3-400.13]</td>
</tr>
<tr>
<td>XIX [60.10-62.20]</td>
<td>261.26-262.29</td>
<td>-</td>
<td>XIX [400.14-404.3]</td>
</tr>
<tr>
<td>XX [64.2-68.4]</td>
<td>263.2-264.2</td>
<td>I [206.7-210.3]</td>
<td>XX-XXI.1 [404.5-410.8]</td>
</tr>
<tr>
<td>XXI [68.5-70.3]</td>
<td>264.3-23</td>
<td>II.α-γ [210.5-212.3]</td>
<td>XXI.1-2 [410.8-412.2]</td>
</tr>
<tr>
<td>XXII [70.4-74.4]</td>
<td>264.24-265.23, 266.28-9</td>
<td>II.δ-III [212.4-215.8], V.α [220.4]</td>
<td>XXII [412.3-414.23]</td>
</tr>
<tr>
<td>XXIII [74.5-78.19]</td>
<td>266.29-268.18</td>
<td>V.β-γ [220.5-225.3]</td>
<td>XXIII [416.1-420.21]</td>
</tr>
<tr>
<td>XXIV [80.1-84.10]</td>
<td>265.23-266.23</td>
<td>IV [216.2-12]</td>
<td>XXIV [422.1-426.3]</td>
</tr>
<tr>
<td>XXV [84.11-90.5]</td>
<td>266.24-6, 268.19-269.14</td>
<td>V.α [220.2-3], VI.α-γ [225.5-229.1]</td>
<td>XXV [426.4-430.22]</td>
</tr>
<tr>
<td>XXVIII [100.5-104.13]</td>
<td>271.26-272.46</td>
<td>IX [238.6-243.2]</td>
<td>XXVIII [440.4-446.11]</td>
</tr>
<tr>
<td>XXIX [104.14-106.3]</td>
<td>272.47-273.9</td>
<td>X.α-β [243.4-244.3]</td>
<td>XXIX [446.12-25]</td>
</tr>
<tr>
<td>XXX [106.4-110.15]</td>
<td>273.9-274.32</td>
<td>X.γ-XI [244.4-248.6]</td>
<td>XXX [448.1-452.12]</td>
</tr>
</tbody>
</table>
APPENDIX 2. ADDENDA ET CORRIGENDA TO SCHMIDT

The following table lists the errors, oversights and omissions made by Schmidt in his apparatus criticus and not noted in the list of addenda et corrigenda appended to the first volume of his edition (‘Berichtigungen’, pp. 513-14). All references are made to the page and line number in Schmidt’s edition. The consensus codicum a here comprises only A, G and T.

<table>
<thead>
<tr>
<th>App. crit. ad p.</th>
<th>ERRATA</th>
<th>ADDENDA ET CORRIGENDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>340.16</td>
<td>σκερπαρνίζοντα a</td>
<td>a in AG corrige, adde σκερπανίζοντα T</td>
</tr>
<tr>
<td>340.17</td>
<td>ἀφύραις ex ἀφύρες corr. G</td>
<td>ex ἀφύρες corr. dele</td>
</tr>
<tr>
<td>342.17</td>
<td>ἀποθώσαντες T</td>
<td>ἀποθώσαντες in ἀποθώσαντες corrigre</td>
</tr>
<tr>
<td>344.7</td>
<td>πάντα AG : πάντη M : πάντι T : del. R. Schoene</td>
<td>πάντα AG : πάντη M : πάντι T refer ad 344.7 πάντα (secunda iteratione)</td>
</tr>
<tr>
<td>344.21</td>
<td>παρεντεταμένην AG</td>
<td>A dele, adde παρεντεταμένην Aρc : παρενταταμένην ( A^{\text{ac}} )</td>
</tr>
<tr>
<td>344.21</td>
<td>οὐδενὶ ἵ δεῖ (οὐδενὶ ex οὐδενὸς corr.) G</td>
<td>ἵ δεῖ in ἵ δεῖ corrigre</td>
</tr>
<tr>
<td>354.11</td>
<td>ἀποπορείας T</td>
<td>ἀποπορείας in εὐπορείας corrigre</td>
</tr>
<tr>
<td>354.15 (vide etiam Supplementum 111)</td>
<td>εὐθείας ( A_1 )</td>
<td>εὐθείας in εὐπερθείας corrigre</td>
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<tr>
<td>356.11</td>
<td>ἐπειλείσθω T : ἐπειλείσθη A (?) G</td>
<td>(?) dele, A ante T transpone</td>
</tr>
<tr>
<td>358.6</td>
<td>ἦ M : εἶ a</td>
<td>refer ad 358.7 ἦ</td>
</tr>
<tr>
<td>376.4</td>
<td>περικειμένηνα</td>
<td>4 post a transpone</td>
</tr>
<tr>
<td>-------</td>
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<td>----------------------------------------</td>
</tr>
<tr>
<td>376.14-16</td>
<td>οθεν… χοινκιδι G</td>
<td>οθεν in ἡρξάμεθα corrige</td>
</tr>
<tr>
<td>(sed vide Supplementum 113)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>376.15</td>
<td>ἐν a</td>
<td>a in AT corrige</td>
</tr>
<tr>
<td>382.2</td>
<td>ἀποδεδομένον G : ἀποδεδομένων A (?)</td>
<td>(? dele, A ante G transpone</td>
</tr>
<tr>
<td>382.2</td>
<td>ἐντὸ T</td>
<td>ἐντὸ in ἐν τὸ corrige</td>
</tr>
<tr>
<td>384.1</td>
<td>ἀνατείνοντα Amg. GT2 : ἀνατείνονται A1T1</td>
<td>G inter A1 et T1 transpone</td>
</tr>
<tr>
<td>384.4</td>
<td>τρύπημα τι T</td>
<td>τρύπημα τι in τρύπημα corrige</td>
</tr>
<tr>
<td>384.8</td>
<td>ὁ om. G</td>
<td>refer ad 384.7 ὁ</td>
</tr>
<tr>
<td>388.14</td>
<td>κρυπτέσθω M : κρυπτέσθῳ a</td>
<td>a in AGacT corrige, adde Gpc post M</td>
</tr>
<tr>
<td>388.23</td>
<td>δέῃ AG (ex δεήσει corr. A)</td>
<td>δεήσει in δεήση corrige</td>
</tr>
<tr>
<td>400.10</td>
<td>ἀποδίδοται codd.</td>
<td>codd. in AGT corrige (alii codices ἀποδίδοται habent, alii ἀποδίδοται)</td>
</tr>
<tr>
<td>404.11</td>
<td>βουλόμεθα AT : βουλόμεθα G</td>
<td>βουλόμεθα dele, G inter A et T transpone</td>
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<tr>
<td>410.5</td>
<td>παρατίθηται codd.</td>
<td>codd. in AGpesT corrige (alii codices παρατίθηται habent, alii παρατίθεται)</td>
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<tr>
<td>410.20</td>
<td>ἦ AT : καὶ G</td>
<td>καὶ G dele, AT in a corrige</td>
</tr>
<tr>
<td>414.8</td>
<td>αἱ νῆς om. T1 : add. T2</td>
<td>refer ad 414.7 αἱ νῆς</td>
</tr>
<tr>
<td>414.9</td>
<td>παρεκολούμβοιν ἐὰν a</td>
<td>a in ApcM corrige, adde parekoloumbon δὲ ApcG</td>
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<tr>
<td>416.2</td>
<td>τὸν A : τὴν GT</td>
<td>G post A transpone</td>
</tr>
<tr>
<td>420.1</td>
<td>αἱ μέντοι M</td>
<td>αἱ μέντοι in καὶ αἱ μέντοι</td>
</tr>
<tr>
<td>422.1</td>
<td>Καὶ ταῦτα μὲν οὖν inserit R. Schoene l.l. p. 74</td>
<td>corriges</td>
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<td>424.21</td>
<td>αὐτῷ scripsi : αὐτῷ a</td>
<td>scripsi in Prou corriget</td>
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<tr>
<td>426.4</td>
<td>f. μὲν &lt;οὖν&gt;</td>
<td></td>
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<tr>
<td>428.7-8</td>
<td>ὑπὸ κάτω a : corrixi</td>
<td></td>
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<tr>
<td>430.16</td>
<td>οὗτως G : οὗτω AT</td>
<td>G in Gaur corriget, inter A et T adde Gaur</td>
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<tr>
<td>430.23</td>
<td>οὖν om. A</td>
<td></td>
</tr>
<tr>
<td>430.24</td>
<td>μηδὲν ἐμφαίνεσθαι Prou</td>
<td>Prou in M. Egger corriget (vide Prou 230 n. a)</td>
</tr>
<tr>
<td>432.10</td>
<td>προκείμενα GM</td>
<td>M dele, adde : προσκείμενα M</td>
</tr>
<tr>
<td>432.22</td>
<td>ὑποστρέφοντας Prou</td>
<td>ὑποστρέφοντας in ὑποστρεφόντας corriget</td>
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<tr>
<td>434.19</td>
<td>οὗτως G</td>
<td>οὗτως G in οὗτως Gaur : οὗτος Gaur corriget</td>
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<td>436.1</td>
<td>ἔστω γὰρ GT2 : om. AT1</td>
<td>A dele (γὰρ tantum omittit A)</td>
</tr>
<tr>
<td>438.11</td>
<td>ἔστω &lt;δὲ&gt; eis Prou</td>
<td>&lt;δὲ&gt; dele</td>
</tr>
<tr>
<td>440.15</td>
<td>καὶ om. G</td>
<td>om. dele, καὶ in ἐκ corriget</td>
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<td>442.1</td>
<td>ἐπὶ* μὴ κειμένη ed. Paris., ‘*f. ἡ’ in margine</td>
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<td>442.13</td>
<td>κιβωτίν (= κιβότρου?) AG</td>
<td>κιβότρου in κιβοτηρίου vel κιβοτέρου corriget (de superscripto compendio τρ vide Bast 1811: 792)</td>
</tr>
<tr>
<td>448.2</td>
<td>ὃ τε Brinkm. et Prou : ὃτε a</td>
<td>a in GM corriget, ante Brinkm. adde A</td>
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<td>450.7</td>
<td>ἀπογράφεται Prou</td>
<td>ἀπογράφεται in ἀπογράφεται corrigē</td>
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<tr>
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<td>452.10</td>
<td>f. τοιούτων</td>
<td>videtur referendum ad 452.11 τούτων</td>
</tr>
</tbody>
</table>
APPENDIX 3. STEMMATA CODICVM
APPENDIX 4. FIGURES
Fig. 1 Hero’s mobile automaton.
Courtesy of Dr. Duncan Keenan-Jones. Image modified by the author.
Fig. 2 Drive mechanism of Hero’s mobile automaton. Courtesy of Arch. Riccardo Ravecca. Image modified by the author.
Fig. 3 Bearing arrangement of the axle of Hero’s mobile automaton.
Fig. 4 Configuration for straight-line motion (plan view): (a) manuscript diagram (A, f. 198v); (b) modern reconstruction.
Fig. 5 Bobbin and cord arrangement for straight-line motion: (a) forward; (b) forward and backward; (c) forward and backward with pause.
Fig. 6 Side elevation of case and tube: (a) manuscript diagram (A, f. 198v); (b) modern reconstruction (courtesy of Arch. Riccardo Ravecca).
Fig. 7 Circular motion: (a) manuscript diagram (A, f. 199r); (b) modern reconstruction.
Wheels πρ, στ and υφ correspond, respectively, to αβ, γδ and εζ as first introduced in X.1. Axle ξο corresponds to ηθ, whereas the axle of wheel υφ/εζ is later labelled ζο (cf. Fig. 10).

Fig. 8 Configuration for rectangular motion (plan view): (a) manuscript diagram (A, f. 199v); (b) modern reconstruction.
Fig. 9 Configuration for rectangular motion (side view). A, f. 200°.

Fig. 10 Mechanism for raising and lowering wheel εζ/υφ.
Fig. 11 First configuration for snake-like motion (plan view): (a) manuscript diagram (A. 201'); (b) modern reconstruction, with rear wheel encased in a frame as in putative archetype.
Fig. 12 Wheel $\overline{\pi} \rho$ mounted on hub (left) and close-up of hub with cord wound around it (right).
Fig. 13 Second configuration for snake-like motion (plan view).
Fig. 14 Third configuration for snake-like motion (plan view): (a) manuscript diagram (A, f. 201v), (b) modern reconstruction, with rear wheel encased in a frame as in putative archetype.
Fig. 15 Kindling altar of Dionysus (front view). A, f. 201v.
Fig. 16 Piping system for libation of milk and wine (front view).

A, f. 202v.

276
**Fig. 17** Modern gas tap (left) vs ancient water tap (right). Reprinted from Kretzschmer (1960: 91 Fig. 25).

**Fig. 18** Hero’s double-piped tap. Courtesy of Dr. Duncan Keenan-Jones. Image modified by the author.
Fig. 19 Trigger mechanism for Hero’s belly-bow (γαστραφέτης). Reprinted from Marsden (1971: 48 Fig. 4).

Fig. 20 Trigger mechanism for weight $\mu$. Courtesy of Dr. Duncan Keenan-Jones. Image modified by the author.
Fig. 21 Parapet(s) for descending garlands: (a) manuscript diagram (plan view; A, f. 202'); (b) modern reconstruction (side view).
Fig. 22 Stylobate, ring (ἲτυς) and base of the shrine (plan view): (a) manuscript diagram (A, f. 203'); (b) modern reconstruction, with letters corrected as in putative archetype (clipart courtesy FCIT; image modified by the author).
Fig. 23 Transmission system for dancing Bacchante.
Fig. 24 Single σύριγξ: (a) manuscript diagram (plan view; A, f. 203'); (b) modern reconstruction.
Fig. 25 Transmission system for extending the range of the mobile automaton: (a) manuscript diagram (side view; A, f. 230v); (b) modern reconstruction.
Fig. 26 Double σύριγξ: (a) manuscript diagram (plan view; A, f. 203v); (b) modern reconstruction.
Fig. 27 Bottom of double σύριγξ with slides (front view).
Fig. 28 Door mechanism for Hero’s stationary automaton (front view).

A. f. 206f.
Fig. 29 Starwheel and ὑσπλήγγιον assembly for moving arms (side view).
A, f. 205°.
Fig. 30 Papyrus scroll for sailing ships (front view).
A, f. 207'.
Fig. 31 Axle and pulley assembly for plunging dolphin (plan view).

A, f.207'.
Fig. 32 Mechanism for Nauplius’ torch (front view). A, f. 208'.
APPENDIX 5. SOME CONSIDERATIONS ON MASÌÀ (2015)

In the following section, I outline the main argument of Masìà’s fairly recent article “On dating Hero of Alexandria”, *AHES* 69.3 (2015) 231-255, and I discuss its implications for the question of Hero's date. I then summarise the main problems that I have identified with this article. For the sake of clarity, I have divided my account into sections, and I am grateful to Enrico Bellazzzecca, PhD candidate in Social Sciences at the Yunus Centre for Social Business and Health, Glasgow Caledonian University, for helping me with the statistical analysis in Masìà’s article (see section (C) below). A detailed evaluation of, and engagement with, Masìà’s arguments are essential not only owing to the recent date of publication of his article but also because it is, I would argue, less reliable than it has been thought to be so far.

Masìà discusses the evidential value of the eclipse mentioned in *Dioptr* ch. 35 for the purposes of dating Hero. Masìà’s main argument is that the eclipse of *Dioptr* ch. 35 was invented as an example and, therefore, that it cannot be used to determine Hero’s life. He does not exclude the possibility that the eclipse data were derived from actual observation, astronomical records (whether reworked or not) and/or invention (any combination of these is possible, according to Masìà), but stresses that there are no arguments supporting the thesis that Hero observed the eclipse.¹ The implication of Masìà’s argument, which is evident throughout his discussion, is that we do not actually know with any certainty Hero’s date. He (p. 246) refers the reader to Acerbi-Vitrac’s (2014) edition of Hero’s *Metrica* for a discussion of the other (internal) pieces of evidence on Hero’s date and accepts two possible intervals within which Hero lived, that is, to use his own words, a maximal interval (200 BCE – 350 CE) and a minimal but quite plausible interval (50 BCE – 200 CE).

Masìà’s article is problematic on many levels. After a brief introduction, Masìà (1) discusses how time was expressed in ancient Greek (esp. in Greek astronomy) and how we refer to ancient dates (pp. 233-40), (2) gives a (questionable) interpretation of *Dioptr* ch. 35, along with some information on

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¹ Masìà (2015: 244, 252). He does not, however, cite any arguments supporting the thesis that Hero did not observe the eclipse.
actual eclipses that (in his view) fit his interpretation (pp. 240-46) and, finally, (3) derives from the interpretation of the text a ‘simple probabilistic model’, which he uses to calculate the probability that an eclipse happened under the conditions given by the text and in a period of time coinciding with the suggested timeframes for Hero’s life (pp. 246-52). He then concludes his discussion by choosing a particular combination of ‘parameters’ as the most plausible (however, he does not justify his choice of this combination) and by saying that what he has adopted is not a ‘confirmative methodology’ (pp. 252-54). He expressly states (p. 253) that he does not wish to refute or confirm any particular hypothesis and that he is just presenting ‘facts’ and assessing them, in some cases associating them with some probabilities.

I have identified a number of problems with this argument, which I summarise in the following sections: (A) interpretation of *Diopt. ch. 35*; (B) (calculation) errors and inconsistencies; (C) statistical analysis.

**(A) Interpretation of *Diopt. ch. 35***. The main problems here concern the constitution and translation of the text.

(1) Masià discusses the restitution of the article in the following sentences: (a) τετηρήσθω ὁ ἐν τῇ Ἀλεξάνδρείᾳ καὶ Ἐρμῆ <ἡ> αὐτῇ ἔκλειψις τῆς σελήνης *(Diopt. 302.17-18)* and, later on in the text, (b) ἐστω ὁ ὁ ὁ ἐν οὑρημένη ἐν τοῖς εὐρημόνοις κλίμασιν αὐτῇ <ἡ> ἔκλειψις, ἐν Ἀλεξάνδρείᾳ μὲν νυκτὸς ὀρας ε, ἐν Ἐρμῆ δὲ ἡ αὐτῇ νυκτὸς ὀρας γ *(Diopt. 302.22-5)*. He accepts the first supplement but rejects the second, essentially because ‘it is surprising that in a document with so few article restitutions [i.e. the *Dioptra*], there are two such errors so close’ (p. 241). He argues that in both cases the reference is to an indeterminate eclipse in view of the fact that the whole passage is formulated in mathematical style and that the second supplement is unnecessary.

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2 The meaning of this phrase is unclear to me.
3 On the problems involved in the use of this term, see section (C) below.
4 The last part of the sentence is corrupt in the manuscripts: δὲ ἐν αὐτῆς νυκτὸς ὀρας τρεῖς.
5 In a footnote (p. 241 n. 27), he says that the Greek αὐτῇ ἔκλειψις (misspelled as ἔχλειψις) is correct, which is equally perplexing.
6 In another footnote (pp. 241-2 n. 29), he gives a number of examples of the neutralisation of the semantic opposition ‘definite/indefinite’ in Greek mathematics, but the passages that he cites are not parallel passages.
(2) Masià says that in the passage there is an ‘articulation’ – does he mean alternation? – of the verbs ‘to observe’ (τηρεῖν) and ‘to find’ (ἐὑρίσκειν), and that in sentence (b) the phrase ‘in the records’ must be added to emphasise such articulation (he translates thus: ‘let an eclipse be found <in the records> – this one, in the stated regions: in Alexandria in the fifth hour of the night, and the same one in the third hour in Rome’). The reason for his supplement is that ‘the sentence “to find an eclipse in the stated regions” sounds a bit strange in Greek, and it is much more reasonable to repeat the complement of the same verb where the verb last appeared’ (p. 242 n. 31, with no further explanation). This understanding of the text leads Masià to suppose that Hero found the eclipse data in an astronomical record (p. 242), which contrasts with his main line of argument. Another, perhaps more significant, problem has to do with Masià’s adherence to the Greek text. It is unclear whether Masià adheres closely to the text (and hence to the eclipse data given in the text) or not, although he seems to end up preferring a looser interpretation. His looser interpretation does not take into account the eclipse data for Rome, but he does not substantiate this choice. Furthermore, it is the looser interpretation, not the stricter one, that is adopted in the probabilistic analysis, and Masià (p. 245 n. 43) states that in the probabilistic section of his paper he will assess statistically the consequences of this interpretation, even if he has not found any indication to support it. Why, then, choose such an interpretation?

(B) (Calculation) errors and inconsistencies. I have found throughout Masià’s article a number of errors, inaccuracies and inconsistencies. There are two main inconsistencies. First, in his interpretation of the text the author chooses the 2013 times of the sunset to calculate the beginning of the night, whereas in his probabilistic analysis he chooses the 2012 times. Second, the author’s attitude towards margins of error is inconsistent. For example, he seems to tolerate the fact that the time difference between Alexandria and Rome as inferred from the text is a ‘raw approximation’ (that is, between one and three

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7 Both choices contrast with his statement that ‘the nocturnal hour of a particular place should be deduced from the UTC time zone, the hour of the sunset in this place on that particular night and the duration of that night’ (p. 235); what immediately follows is unclear: ‘[t]he hour of the sunset must be exact and not related to the time zone’ (my emphasis).
hours, following his calculations), but he does not accept similar margins of error in the case of the correspondence between the eclipse data from the text and the actual eclipse of 13 March 62 CE. What is more important, however, is that the author's calculations for the eclipse data given in the text seem to be incorrect. He states (p. 243) that 'if we assume that the night starts at 18:07 in Alexandria and at 18:14 in Rome, and calculate the exact nocturnal hours, an eclipse observed between 22:09 and 22:17 in Alexandria would be observed between 21:09 and 21:17 in Rome. In Alexandria, this is the fifth nocturnal hour, whereas in Rome this is the third nocturnal hour'. If I understand the argument here correctly, the intervals given do not correspond to whole nocturnal hours, and hence Masià's claim that the time of the eclipse of 62 CE as observed in Alexandria at 22:39 does not fit the interval he has given is pointless. More generally, the fundamental problem seems to be that, if we do not know the time of the sunset in Alexandria and in Rome on 13 March 62 CE, we cannot say whether and to what extent the eclipse of 62 CE does not fit Hero's data. Masià (p. 244 n. 39) remarks that 'our ignorance of the exact time of sunset in Alexandria and Rome on that day introduces uncertainties that cannot be estimated' (my emphasis). What, then, is the point of his study?

(C) Statistical analysis. In addition to the fact that the 'key criterion' (KC) for associating a triad (nocturnal hour, day, month) to an eclipse that actually happened within the chosen timeframes for Hero's life is derived from a

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8 As Masià (p. 234 n. 9) notes, the eclipse is sometimes recorded as having occurred on 14 March. This depends on the use of the Terrestrial Dynamical Time (TDT or TD) or Terrestrial Time (TT), a modern astronomical standard first introduced in 1976 for time measurements of astronomical observations made from the surface of the Earth. TT does not take into account the irregularities in the rotation of the Earth and can be used, among other things, to calculate the so-called TD of Greatest Eclipse, namely, 'the instant when the center of the Moon passes closest to the axis of the Earth's umbral shadow' (NASA 2016). On TT, see IAU Resolutions (2000) s.v. Resolution B1.9.

9 Masià (p. 243 n. 37) observes that on March 13 nocturnal hours are almost one hour long.

10 Masià takes the time of the eclipse as observed in Alexandria from the NASA tables (NASA 2016). It is important to note that 22:39 − 22:17 = 00:22. As Masià himself reminds us (p. 239 n. 23), the mean error in the eclipse observations made by Greek astronomers and recorded in Ptolemy's Almagest is − 00:23 hours. See esp. Ptol. Alm. 4.6 = 314.16-315.12 Heiberg, with Steele (2000: 103-4).
loose interpretation of the text (see above under (A)). I have identified the following problems. The author does not specify:

1. the statistical model(s) that has/have been used – ‘simple probabilistic model/framework’ could mean anything;

2. the estimators, that is, how the data have been treated and how the model(s) fits/fit the data;

3. what the data distribution looks like (this is important because it affects the type of analysis that can be carried out; if the data distribution is not normal, the data should be either normalised or modelled through other techniques that deal with non-normal distribution in order to draw statistical inferences);

4. the robustness checks, that is, how the author has validated his analysis and findings.

There are also problems with the parameters. First of all, the so-called parameters ‘scenario’ and ‘framework’ are not parameters. The scenario is

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11 The key criterion appears to be that ‘[t]he triad must have a nonzero intersection with the period from the beginning to the end of the eclipse’ (p. 247). Masià does not explain what a ‘non-zero intersection’ is, but presumably means that the data must be significantly different from zero. Since the exact day of the eclipse of 62 CE cannot be inferred from Dioptra ch. 35 with any degree of accuracy (the eclipse is said to have occurred 10 days before the vernal equinox, but we do not know when Hero or his source started counting the days), Masià accepts a margin of error of one day. This introduces an ‘extended key criterion’ (EKC), which Masià (p. 248) defines as follows: [t]he triad must fit some instant between the beginning and the end of an eclipse that actually happened, or of an eclipse that actually happened exactly 1 day before or exactly 1 day after’. He performs his calculations according to both criteria.

12 Did he employ, for instance, linear regressions, vector autoregressive models or hierarchical models? On econometric modelling, see Dougherty (2011: 83-530).

13 Normalisation (i.e. scaling of variables) is risky because it may yield spurious data, but nonetheless it is an acceptable practice depending on the nature of the data. See Härdle-Simar (2015: 135-7).

14 For Masià (p. 248), the ‘scenario’ is ‘[t]he length of the time interval, measured in years, in which Hero’s life span is entirely included’. He identifies two scenarios, a maximal scenario (–200, +350) and a minimal scenario (–50, +200), which correspond, respectively, to the maximal interval and the minimal interval mentioned above. Each scenario admits of two ‘frameworks’, namely ‘the intervals within which the observed eclipses are recorded’ (p. 248). The first framework, which is associated with KC, ‘exactly matches the scenario’, whereas the second framework ‘extends the lower limit of the scenario [i.e. applies EKC], including the possibility that the eclipse could be drawn from an almanac’ (p. 248). It is unclear to me how the framework differs from the scenario.
nothing more than a scenario (this applies, by extension, to frameworks 1 and 2). Second, the author (p. 248) states that the eclipse of 62 CE is unique over a long period of time. As a result, he imposes the following restriction: ‘[i]n the triad’s hour, the eclipse must be unique among all registered eclipses’. He calls this restriction ‘uniqueness’. It is unclear what this parameter means. Additional problems include: (1) why does the author not take into account the year during which an eclipse has occurred? (reason not explained); (2) non-zero intersection seems to mean that the data must be significantly different from zero (cf. above, n. 11), but the author does not say whether the parameter estimates are negative or positive.\(^{15}\) Overall, it is not clear how we should interpret Tables 1-4 (pp. 249-51). Did the author employ F statistics in combination with P values to determine the goodness of fit of his model(s)?\(^{16}\) If he did, we still do not know the statistical significance of his results because we are given neither the P values nor the standard errors relating to the parameters.\(^{17}\) I would hazard the guess that the author has simply calculated the probability that something has happened (that is, in this particular case, the probability that a randomly chosen triad fits an actually occurred eclipse) but without telling us whether the data fit his model(s).

For all of these reasons, it is difficult to determine whether Masià’s analysis has real statistical value.

In my detailed assessment of Masià’s article, I have shown that there are several problems with his argument. The purpose and methodology of his study are unclear, and there are many inaccuracies, inconsistencies and errors in his treatment of the eclipse question. His interpretation of \textit{Diöptr.} ch. 35 leaves much to be desired, leaving us to wonder how an actual eclipse record can be considered the result of invention.\(^{18}\)

\(^{15}\) This allows one to know how the variables are associated.

\(^{16}\) F statistics are critical values that inform acceptance or rejection of a null hypothesis in statistical inferences. P values indicate the probability that inferential results have (not) occurred by chance. On these indicators, see Dougherty (2011: 145-8).

\(^{17}\) The standard errors indicate the extent to which the estimators deviate from a standard deviation.

\(^{18}\) The reader who wishes to look deeper into the eclipse question may refer to Acerbi-Vitrac’s (2014: 18-21, 103-115) recent edition and discussion of \textit{Diöptr.} ch. 35 (with further bibliography).
APPENDIX 6. INDEX TERMINORVM TECHNICORVM

This index gathers together (a) technical terms (or occasionally phrases), (b) particular occurrences of terms used in a technical sense, and (c) terms which are reminiscent of a technical usage. Terms belonging to category (c) are indicated with a superscript asterisk. Technical terminology here comprises specialised words used in the domains of mechanics, mathematics, philosophy, art criticism, architecture and construction, and the guiding principles for the identification of such terms are monoreferentiality and referential precision (see generally Gotti 2008: 33-7). Some exceptions to these principles include terms which are quite generic but whose specialised meaning can be inferred from the context (for instance κανόνιον). I have deliberately avoided arranging terms into categories according to disciplines because it is often not possible to make a firm distinction between mechanical and architectural terms. References give the page and line numbers of the present edition. Emendations, additions and deletions are indicated by the use of italics.

ἀγκύλη (‘loop’ of cord) 12.14, 22.5, 22.9, 22.19-20, 44.2, 46.20, 54.3, 78.7, 78.9, 78.11, 86.20, 88.5, 88.7, 88.14; see also ἀγκυλλᾶ, ἀγκυλῶμαι, ἀπαγκυλόω and προσαγκυλόμαι

ἀγκυλλᾶ (‘loops’ of cord) 78.8; see also ἀγκύλη, ἀγκυλῶμαι, ἀπαγκυλόω and προσαγκυλόμαι

ἀγκυλόμαι (‘to be looped’, of cord) 84.8; see also ἀγκύλη, ἀγκυλλᾶ, ἀπαγκυλόω and προσαγκυλόμαι

ἀετός (‘pediment’) 100.18

ἀπαγκυλόω (‘make a loop in’ a cord) 98.20-21; see also ἀγκύλη, ἀγκυλλᾶ, ἀγκυλῶμαι and προσαγκυλόμαι

ἀποδιδῶμι (‘attach’; Med., ‘pass’, ‘extend’) 22.14, 24.3, 24.14, 36.16, 38.19, 42.18, 42.21, 46.21, 48.17, 50.9, 54.21, 56.3, 56.12, 56.20, 58.14, 58.16, 60.7, 60.16, 62.6, 84.4, 88.11, 94.7, 96.7, 96.9, 100.1

ἀποκαθίστημι* (‘return full circle’) 50.5

ἀπολαμβάνω (‘secure’) 76.7-8, 76.12, 86.21
ἀποπορεία ('backward motion' of mobile automaton) 20.9, 20.14, 22.22, 24.8, 24.10, 30.7, 42.9, 60.10, 60.18, 62.19; see also πορεία

βάσις ('base' of cone) 28.4, 28.8

βεβηκώς ('standing', of cone) 28.12

γύγλωμος ('hinge') 64.17

γόμφοi ('dowels') 34.9

γομφωτήρια ('tenons') 98.5; see also ἐκκοπή

dιαθεσις 'arrangement', 'disposition' of figures) 2.19, 4.4, 4.6, 70.10, 80.5; (mechanical 'arrangement', 'configuration') 6.4, 64.12

dιάμετρος ('diameter') 26.9, 26.16; see also κατὰ διάμετρον

διαμπυρώομαι ('to be arranged in hanks', of cord) 34.16, 42.6, 56.7

dιάπηγμα ('partition') 40.9, 40.13; see also διάφραγμα

dιαρρινάω ('file down') 88.3; see also περιρρινέω

dιαστήματα ('radii' of circle) 60.5

dιάφραγμα ('partition') 46.6, 52.3, 56.15-16, 60.13, 60.15; see also διάπηγμα and διαφράσσομαι

διαφράσσομαι ('to be partitioned') 60.12-13; see also διάφραγμα  δίχα τέμνομαι/τέμνομαι...δίχα ('to be bisected') 26.15, 28.13-15; see also διχοτομία

διχοτομία ('point of bisection') 26.10; see also δίχα τέμνομαι

ἐκβάλλομαι ('to be generated', of geom. figure) 28.14

ἐκκοπή ('notch', 'mortise') 34.6, 98.12-13, 98.18, 106.8, 106.11, 106.13-14, 106.18, 108.3-4; see also γομφωτήρια

ἐξείλα ('thread' of screw) 34.11

ἐμπυελίδες ('sockets') 8.6; see also ἐμπυελίδα and πυελίς

ἐμπυελίδα ('sockets') 32.21, 32.22-34.1, 40.10, 90.19; see also ἐμπυελίδες and πυελίς

ἐνειλέομαι ('to be screwed on') 34.8, 34.9

ἐνέργεια ('actualisation') 6.7; cf. 4.20 ('mechanism', 'action')

ἐντεταμένος' ('stretched', of surface) 16.9

ἐντορνεύομαι ('to be turned on the lathe') 54.16-17; see also ἐντορνος, τετορνευμένος and τόρνος

ἐντορνος ('turned on the lathe') 90.19; see also ἐντορνεύομαι, τετορνευμένος and τόρνος

ἐξαρτύω' ('string', of automaton) 10.1-2
ἐξελίκτρα (‘bobbin’, lit. ‘unwinder’) 22.2, 22.10-10, 22.17, 24.1, 24.3, 24.14, 26.2-3, 26.21, 94.20, 96.6, 100.13-14, 102.2 ἐπιξέγνυμι (‘to be joined’, of lines) 26.11 ἐπικράτησις (‘prevalence’) 30.1 ἐπίπεδος (‘plane’) 28.4, 28.12, 28.14 ἐπιπορεία (‘forward motion’, of mobile automaton) 60.10, 60.17; see also πορεία ἐπιτόνιον (‘plug’, of stopcock) 46.19, 46.22, 48.9; see also κλείς εὐθεία (‘straight line’, of geom. figure) 60.14; cf. 20.13, 20.18, 36.19, 36.27, 38.5, 40.2 εὐθύγραμμος (‘rectilinear’, of figure) 36.3 ή ἐκ τοῦ κέντρου (‘radius’ of circle) 28.5; see also κέντρον ἡμικύκλιον (‘semicircle’) 28.16-17, 28.18, 28.20, 28.21, 48.1 ἡμιτόνιον (‘half-spring’ of catapult) 10.8 θωράκιον (‘parapet’, in mobile automaton) 52.9, 52.10, 52.11, 52.15, 52.16, 52.18, 52.19, 52.22, 54.22; (‘enclosure’, in stationary automaton) 74.11, 74.16, 98.4, 98.6, 98.18, 100.4, 104.23-24, 106.13 ἵσοπλευρος (‘equilateral’) 90.15 ἱσορροπέω (‘to be in equilibrium’) 26.19; see also ἱσόρροπος ἱσόρροπος (‘in equilibrium’) 28.13; see also ἱσορροπέω ἱσοσκελής (‘isosceles’, of cones) 28.10 ἱσχάριον (‘joint’) 104.22, 106.2 ἵπτος (‘ring’) 54.14, 56.5, 56.10 κανόνιον (‘bar-frame’) 34.1bis, 34.3, 34.5, 34.7, 34.9, 34.13, 34.18 κατὰ διάμετρον (‘diametrically opposite’) 48.3 κεφαλαί (‘capitals’) 16.2; see also κεφάλια κεφάλια (‘capitals’) 16.2; see also κεφαλαί κέντρον (‘centre’ of circle) 26.8, 28.5, 28.6; see also ἡ ἐκ τοῦ κέντρου κλεισθρίον (‘slide’) 32.8, 32.12, 32.14, 50.21, 52.6, 62.1, 62.4, 62.12, 62.15, 62.19 κλεῖς (‘tap’, ‘stopcock’) 46.18, 48.9; see also ἐπιτόνιον κνώδαξ (‘pivot’ for wheel) 8.5, 20.19, 26.19, 32.21, 34.19, 36.7-8, 40.7, 40.11, 40.14, 40.15-16, 42.8, 48.16, 58.11; see also χοινικίς κόραξ (‘hook’) 54.2, 54.3, 54.4
κορυφή (‘vertex’ of cone) 28.6, 28.8, 28.11, 28.20-21, 28.21, 28.24
κοχλίας (‘screw’) 34.10, 34.11, 34.12, 34.15, 34.20
κύκλος (‘circle’) 12.19, 26.7, 28.2, 28.5, 28.7, 28.8, 28.10, 28.18, 60.2, 60.7; cf. 20.15, 26.6
κυμάτιον (‘moulding’) 14.18-19, 16.6-7
κόνος (‘cone’) 28.4, 28.6, 28.8, 28.10, 28.12
λεία (‘counterweight’) 10.10, 12.1, 12.6, 12.11, 12.16, 14.6, 24.3, 24.4, 24.15, 26.4, 32.3, 32.6, 36.16, 36.17, 36.24, 38.19, 42.21, 42.22, 46.21, 56.3, 56.11, 56.14, 56.20, 58.17, 60.1, 60.7, 60.16, 60.17, 62.7, 62.14, 76.2, 78.3, 78.7, 78.18, 82.7, 82.15, 82.19, 82.20, 84.5bis, 88.12, 94.15, 96.9, 96.12, 100.2, 104.10; see also σήκωμα
μεσολαβέω (‘take in the middle’, of wheel) 40.18, 42.3
μηρύματα (‘hanks’ of cord) 14.4, 24.20, 38.4, 38.7-8; see also μηρυμάτιον and μήρυσμα
μηρυμάτιον (‘hank’ of cord) 24.12
μήρυσμα (‘hank’ of cord) 36.24
μολύβδιον (‘lead weight’) I08.2

ὀρθογώνιος (‘rectangular’, of parallelogram) 20.17, 30.3, 36.2
ὀρθός (‘perpendicular’) 26.9, 26.15, 28.14, 66.1; see also πρὸς ὀρθός
παραλληλόγραμμον
(‘parallelogram’) 20.16-17, 30.3, 30.19, 30.21-22, 30.24, 36.2
παράλληλος (‘parallel’, of line) 26.13
παραστάς (‘pilaster’) 90.13; (‘doorjamb’) 94.3; see also παραστάδιον
παραστάδιον (‘doorjamb’) 94.6
παραχαλασμάτιον (‘slack’ of cord) 78.15; see also χάλασμα and χαλασμάτιον
πελεκήνος (‘dovetail’) 34.1, 34.4
περιρρινέω (‘file down’) 98.8; see also διαρρινάω
περιστύλιον (‘peristyle’) 52.7
περιφέρεια (‘arc’ of semicircle) 48.1-2, 54.16
πλευρά (‘side’ of cone [i.e. generatrix]) 28.6, 28.13, 28.14; cf. 22.6, 30.19, 30.22
πυελίς (‘socket’) 8.25, 20.20; see also ἐμπυελίδες and ἐμπυελίδια
πυργίον (‘small cupola’) 16.8-9, 18.13
σαμβύκαι (‘sambucas’ [sc. musical instruments]) 106.12
σήκωμα (‘counterbalance’) 104.22; see also λεία
σημεῖον (‘point’ of geom. figure) 26.20, 28.9
σπερίον (‘base-moulding’) 16.1
στατόν (‘stationary (automaton)’) 2.16, 4.20, 6.7, 12.10, 20.4, 64.1, 64.7; see also ύπαγον
στρογγυλόγλυφος (‘with rounded carvings’) 90.4
στροφεῖς (door ‘pivots’) 74.13, 74.17, 74.18, 76.3, 76.4, 76.5, 76.15, 90.11, 98.4
στροφωματία (‘hinges’) 52.22
στυλοβάτης (‘stylobate’) 54.11, 54.14
σφίγμα (‘tube’) 12.6, 12.8, 12.11, 22.12, 22.14, 22.15, 22.16, 26.2, 26.3, 32.4, 32.5, 32.7, 36.16, 56.14, 56.15, 58.1, 58.16-17, 58.19, 60.12, 60.13, 60.17, 60.20, 76.2, 78.6
συσμηρίζομαι (‘to be fitted tightly together’) 8.8, 46.8
σφίγμα (‘jamming’) 8.11
σχαστηρία (‘trigger’) 50.11, 50.12; see also χείρ

πτερύγια (‘wings’) 102.1
τετορνεμένος (‘turned on the lathe’) 94.20, 96.2; see also ἐντορνεύομαι, ἔντορνος and τόρνος
tετράστυλον (‘tetraestyle’) 52.10
tόρνος (‘lathe’) 36.9, 36.12; see also ἐντορνεύομαι, ἔντορνος and τετορνευμένος
tρίγλυφοι (‘triglyphs’) 100.12
tροχίλος (‘pulley’) 22.13-14, 48.17, 48.18, 50.8, 54.21, 56.21, 58.16, 98.21-100.1
tύλος (wooden ‘block’) 34.8, 34.11, 34.13
ὑπαγον (‘mobile (automaton)’) 2.15, 4.22, 6.3, 6.17-18, 10.8-9, 10.18, 12.8, 20.4, 64.2, 68.5, 70.3; see also στατόν
ὑπερθύριον (‘lintel’) 94.7; see also ὑπέρθυρον
ὑπερθύριον (‘lintel’) 90.3, 106.18-19, 106.19; see also ὑπερθύριον
ὑποσανίδιον (‘underside of board’) 108.6
ὑσπλήγγιον (hysplēngion [sc. ‘bar’]) 82.13, 82.14, 82.17, 82.18, 94.21; see also ὑσπλήγξ
ὑσπλήγξ (hysplēnx [sc. ‘trigger board’]) 10.6bis, 10.9, 12.1, 12.3; (= hysplēngion) 82.16, 84.6; see also ὑσπλήγγιον
χάλασμα (‘slack’ of cord) 14.3, 14.4, 14.6, 32.2, 34.16, 34.21, 36.21-22, 36.24, 38.1, 38.12, 38.18-19, 38.21, 38.24-40.1, 42.5, 44.12, 46.20, 56.6-7, 56.8, 62.9, 62.14; see also παραχαλασμάτιον and χαλασμάτιον
χαλασμάτιον (‘slack’ of cord) 32.15, 62.7; see also παραχαλασμάτιον and χάλασμα
χείρ (‘claw’) 50.10; see also σχαστηρία
χοινικής (‘collar’) 8.7; (wheel ‘hub’) 36.10, 36.13, 36.15, 36.18, 36.24, 38.15, 38.17, 38.22, 40.3; see also κνώδαξ
**BIBLIOGRAPHIC ABBREVIATIONS**


Catalogue 1853 = *Catalogue of the Manuscripts at Ashburnham Place*, part 1, London 1853.


Formigé 1921 = J. F., “Note sur les machines des décors mobiles dans les théâtres antiques”, BSAF(1921) 190-195.


Gandz 1940 = S. G., “Heron’s Date. A New terminus ante quem (+ 150)”, Isis 32.2 (1940) 263-266.

Gardthausen 1913 = V. G., Griechische Palaeographie, II. Die Schrift, Unterschriften und Chronologie im Altertum und im byzantinischen Mittelalter, Leipzig 1913² (1879¹).


Haase 1847b = F. H., De militariu scriptorum Graecorum et Latinorum omnium editione instituenda narratio, Berlin 1847.


Locker 1932, 1933 = E. L., “Die Bildung der griechischen Kurz- und Kosenamen”, Glotta 21 (1932) 136-152 (part 1); id. 22 (1933) 46-100 (part 2).


McCourt 2012 = F. M., “An Examination of the Mechanisms of Movement in Heron of Alexandria’s On Automaton-Making”, in T. Koetsier-M.


Nachmanson 1941 = E. N., Der griechische Buchtitel, Gothenburg 1941.


Reinhardt 1930 = L. R., De Heronis Alexandrini dictione quaestiones selectae, Diss. Borna 1930.

Relazione 1884 = Relazione alla Camera dei Deputati e Disegno di legge per l’acquisto di codici appartenenti alla Biblioteca Ashburnham descritti nell’annesso Catalogo, Rome 1884.


Villa 1767 = A.T. V., Addizioni e correzioni di Angelo Teodoro Villa milanese alla Biblioteca degli Volgarizzatori del segretario Filippo Argelati bolognese, V [= IV/2], Milan 1767.


Viviers 2014 = D. V., “Quand le divin se meut. Mobilité des statues et
construction du divin”, in S. Estienne et al. (eds.), Figures de dieux.

médecine et mécanique à Alexandrie”, in G. Argoud-J.-Y. Guillaumin
(eds.), Sciences exactes et sciences appliquées à Alexandrie, Saint-Étienne

Webb 2009 = R. W., Ekphrasis, Imagination and Persuasion in Ancient
Rhetorical Theory and Practice, Ashgate 2009.

chrétienne d’après les Αὐτοματοποιικά d’Héron d’Alexandrie, par M.
Victor Prou, ingénieur civil”, JS (1882) 416-424.

Welch 2007 = K.E. W., The Roman Amphitheatre. From Its Origins to the

Weller 1999 = J.A. W., “Roman Traction Systems”,

Werner 1997 = W. W., “The Largest Ship Trackway in Ancient Times: the
Diolkos of the Isthmus of Corinth, Greece, and Early Attempts to Build a


(Πολιορκητικά). Translated with Introduction and Commentary, Stuttgart
2010.


Machines (Περὶ μηχανημάτων), Stuttgart 2004.

Wikander 2008 = Ö. W., “Gadgets and Scientific Instruments”, in Oleson (2008:
785-799).


