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On the Authenticity and Reception of Aristotle's *Mechanical Problems*

Feb. 1, 2022

Until the nineteenth century there was little doubt among scholars as to the authenticity of the Aristotelian *Mechanical Problems*. There were some doubters among the Renaissance humanists, but theirs were general doubts about the authenticity of a large class of writings, not doubts based on the individual characteristics of this particular work. Some Humanists distrusted any text that hadn't been passed by the Arabs to the Latin West in the High Middle Ages. On occasion a scholar doubted a work he did not like.[1] However, by the end of the 18th century after Euler and Lagrange, the *Mechanical Problems* had ceased to be read as part of science and had become the object of history of science; and there the reading of the text becomes quite different from the Renaissance readings. In his *Histoire des mathématiques* J.E. Montucla[2] (1758) dismisses the *Mechanical Problems* with such epithets as "entirely false," "completely ridiculous," and "puerile." William Whewell remarks in the *History of the Inductive Sciences*[3] (1837) that "in scarcely any one instance are the answers, which Aristotle gives to his questions, of any value." Neither of them, however, cast doubt on the authenticity of the work. Abraham Kaestner's *Geschichte der Mathematik* (1796–1800) mentions doubts – but does not share them.[4]

Serious doubts about the authenticity of the *Mechanical Problems* as an individual work seem to be more a consequence of the disciplinary constitution of classical philology, particularly in nineteenth-century Germany. Some time between about 1830 and 1870, the opinion of most philologists shifted from acceptance to denial of the authenticity of the *Mechanical Problems*.[5] There is however very little documentation of the reasons for this change of opin-

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[1] Burja 1796 (p. 268) mentions Girolomo Cardano and Francesco Patrizi – as do Rose/Drake (1971, 72). See Cardano, *Opus novum de proportionibus…* Prop. 109, p. 103; Cardano doubts whether the book is Aristotle's because it (uncharacteristically) smacks of the obscure: "ut dubitem ne non suus sit ille liber, qui eius penè nihil sapiat obscuritatem."

[2] *Histoire des Mathématiques,* vol. 1*,* Paris: Jombert, 1758: "Ils trouveront sans doute que la plûpart des explications qu'il donne sont entiérement fausses, et que la principale et la premiere est tout-à-fait ridicule. … *Aristote* la cherche dans les propriétés merveilleuses du cercle, dont il fait la puérile énumération;…" p. 205. Abel Burja (1796) contradicted this view in an Academy lecture in 1791.

[3] *History of the Inductive Sciences* (1837) vol. 1, p. 68 [third ed. p. 51].

[4] "Some scholars doubt whether it is the work of the Philosopher, but most recognize it as his because of the style – and also the acuteness." ["Einige Gelehrte zweifeln, ob es des Philosophen Arbeit sey, die meisten aber erkennen es dafür, wegen der Schreibart, auch der Scharfsinnigkeit."] *Geschichte der Mathematik seit der Wiederherstellung der Wissenschaften bis an das Ende des achtzehnten Jahrhunderts* (Göttingen 1796–1800; vol ii, p. 130).

[5] The first German translator of the *Mechanical Problems* (1829) could still write in his introduction: "The style and method of the essay in general is so very Aristotelian, according to the unanimous judgment of all editors and explainers of the works of this philosopher, that precisely these must be taken as a major proof of the authenticity of this writing, and this belongs to the few that are recognized as authentic without any objection." ["Die Schreibart und Methode der Abhandlung im Allgemeinen ist so sehr Aristotelisch, nach einstimmigem Urtheil aller Herausgeber und Erklärer der Werke dieses Philosophen, daß eben jene für einen Hauptbeweis gelten der Ächtheit dieser Schrift, und diese zu den wenigen gehört, die ohne allen Widerspruch für ächt erkannt werden."] (F. T. Poselger, "Über Aristoteles Mechanische Probleme" in: *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin aus dem Jahre 1829* [Berlin 1932] p. 65). The first (?) English translator, Thomas Taylor (1812, p. xxviii) writes: "The next treatise, or 'The Mechanical Problems,' is replete with that fecundity of conception, and admirable ingenuity, with which the writings of Aristotle so remarkably abound. The text is unfortunately very incorrect…"

ion.[6] Part of the self-understanding of the academic disciplines of classical philology and history of ancient philosophy was the hermeneutic authority to separate genuine works of the masters from other works later smuggled into a corpus. With regard to the *Mechanical Problems* there is however very little by way of argumentation to be found and especially little philological argument. Two genuinely philological arguments against the authenticity are occasionally adduced: (1) the prologue on wonders and circles is stylistically unaristotelian[7] and (2) the *Mechanical Problems* is a mathematical text and Aristotle produced no [other!] mathematical texts and himself even says that he wrote no mathematical texts.[8] These two arguments are flanked by a third consideration, which Valentine Rose (1854) claimed to disregard but nonetheless could not resist mentioning: that the text is trivial and confused (*questionum minutias et confusionem*). Thus, an evaluation of the intellectual quality of the work similar to that of Montucla and Whewell unofficially underwrites the philologists' conclusion that the author cannot have been Aristotle. French scholars have tended to take the same position as the German scholars already cited: Paul Tannery, for instance, considered the

[6] Christian Brandis, *Geschichte der Entwickelungen der griechischen Philosophie*, 2 vols. (Berlin 1862-4, vol. 1, p. 397). Brandis says about a number of doubtful works (including the *Mechanical Problems* and *De motu animalium*): "For the most part it is decidedly unaristotelian, and even if by means of a more rigorous examination we were to be able to demonstrate some Aristotelian parts – our knowledge of the doctrinal system would not be fundamentally enriched or corrected." ["Größtenteils ist es entschieden unaristotelisch und sollte sich bei genauerer Prüfung einiges Aristotelische darin nachweisen lassen, – unsre Kenntniß des Lehrgebäudes würde dadurch nicht wesentlich bereichert oder berichtigt werden."] See also Eduard Zeller, *Die Philosophie der Griechen in ihrer geschichtlichen Entwicklung Part II,2* [1879] (4th ed. Leipzig 1921, p. 90n); I quote his entire argumentation on the subject: "Ohne nähere Angabe nennt SIMPL. Categ. 1, ζ (Bas.) Aristoteles' γεωμετρικὰ τε καὶ μηχανικὰ βιβλία. Unsere Μηχανικὰ jedoch (D. 123. An. 114: μηχανικὸν oder -ῶν), die richtiger (wie bei Ptol. 18) μηχανικὰ προβλήματα genannt würden, sind gewiss nicht aristotelisch. (Vgl. auch Rose a.a.O. 192.)" Wilhelm Windelband, *Geschichte der alten Philosophie*, (2nd ed., Munich: Beck, 1894) just says: "Eine Anzahl besonderer Abhandlungen sind verloren, die erhaltenen *mêkanika* unecht, ebenso *peri kosmou* …" (p.148)

[7] A recent version of this argument is De Gandt ("Force et science des machines," in J. Barnes et al., *Science and speculation: studies in Hellenistic theory and practice*, Cambridge Univ. Press 1982): "Ce morceau de rhétorique sur les merveilles et les contraires me parait déplacé ici, peu digne de la sobriété d'Aristote. D'ailleurs le Philosophe avait remarqué ces propriétés du mouvement circulaire, et les avait mentionné d'une manière beaucoup plus brève et sèche" (p. 119).

[8] This argument derives from Valentine Rose (*De Aristotelis librorum ordine et auctoritate commentatio*, Berlin, 1854, p. 192): "That the *Mechanical Problems,* which deals with the balance and the lever and various other things (…), is not by Aristotle, even disregarding the composition itself and the details and confusion of the questions (…), follows (…) from the discourse of the prologue on the wonder-working circle from which all the θαύματα of mechanical motions are derived (…) and [from the fact] that if we listen to him himself, it is clear that he is the author of no mathematical writing at all." [This translation of Rose's nineteenth-century Latin may be somewhat conjectural: Valentine Rose *De Aristotelis librorum ordine et auctoritate commentatio*, Berlin, 1854, p. 192: "Mechanica vero Problemata quae versantur circa libram et vectem aliaque deinde varia (ad vectem autem ceterarum rerum mechanicarum explicationem referendam esse vult omnium p. 848, 13) non esse Aristotelis si negligas compositionem ipsam et quaestionum minutias et confusionem (multis tamen quae bene vereque intellecta exposuit auctor refertarum cf. van Cappelle p. 152 sqq. et 184, ita ut in huius libri laude multi essent antiquiores ut Monantholius cuius cf. Praef. et Comm., p. 211) et ex praefationis sermone circuli ex quo mechanicorum motuum θαύματα omnia repetit mirabilia efferentis (847b17 sqq. cf. Vitruv.10, 1. 8) et ex. eo sequitur (nihili enim sunt. quae pro Aristotele auctore verba fecere Henr. Monantholius in Comm. ad Ar. Mech. Paris. 1599 p. 1–2 et van Cappelle in ed. Mech. Amstelodami 1812 Animadverss. p. 127, quem cf. de cod. Paris. p. 125, sermonem Aristotelis et disputandi modum agnoscentes) quod si ipsum audimus nullius omnino scripti mathematici auctorem eum fuisse patet." Fritz Krafft, the leading advocate of the authenticity of the *Mechanical Problems*, singles out Rose as presenting the only serious argument against the work's authenticity, but he does not actually report what he takes that argument to be, nor does he address it directly. See Krafft, *Dynamische und statische Betrachtungsweise in der antiken Mechanik*, Wiesbaden: Steiner, 1970 esp. pp. 15 and 69.

Mechanical Problems to be "a collection without order or method." [9] British scholars of the 20th century tended to deny that Aristotle is the author, without however being outraged at the attribution of the work to Aristotle or taking such a negative attitude towards its quality.[10] Two other arguments of no great consequence should also be mentioned for the sake of completeness: (3) the failure of ancient authors such as Archimedes, Hero, Athenaeus, and Pappus to mention Aristotle as the author,[11] and (4) the purported fact that the incorporation of the *Mechanical Problems* into the Aristotelian corpus began with Bessarion, who had a special liking for mechanics.[12]

At some point however, philologists and historians of philosophy also decided that the *Mechanical Problems* was unaristotelian in its subject matter.[13] The most prominent such argument, adduced by Gercke in *Pauly*, at the end of the 19th century and also echoed by Forster in the preface to his translation of the *MP* is that: "Whilst the scientific standpoint of the *Mechanica* is certainly Peripatetic, the writer's interest in the practical application of the problems involved is quite un-Aristotelian."[14] Gercke and Forster's argument is not very convincing. Farrington, for instance, dismisses it out of hand; Clagett points out, that this "is

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[9] See in particular Paul Tannery, "Sur les Problèmes mécaniques attribués à Aristote" (*Memoires scientifiques III*, Paris, 1915, p. 33): "Tout d'abord, il est bien certain que nous ne sommes pas en présence d'un ouvrage d'Aristote, c'est-à-dire d'un penseur auquel on ne peut dénier, en tout état de cause, d'avoir constamment visé la séparation des concepts emmêlés dans les significations imprécises des mots du language usuel. […] Si, d'autre part, j'ai parlé de compilation à propos des Mechanica, j'ai voulu seulement constater qu'il s'agit d'un recueil, sans ordre et sans méthode, de questions très diverses à la solution desquelles l'auteur n'a pas su imprimer le sceau d'une originalité personelle (où par conséquent ont pu être intercalés postérieurement, sans qu'on ait les moyons de le reconnaître, des problèmes étrangers à la composition primitive)." See also De Gandt 1982.

[10] Typical are: David Ross (1923) *Aristotle*, London: Methuen, p. 12; G.E.R. Lloyd (1970) *Early Greek Science: Thales to Aristotle*, New York: Norton, p. 135.

[11] Who said this? Rose/Drake? No! See below for Athenaeus mentioning Aristotle.

[12] Paul L. Rose and Stillman Drake, "The Pseudo-Aristotelian Questions of Mechanics in Renaissance Culture," In: *Studies in the Renaissance XVIII* (1971) 65-104, pp. 75–6: The manuscript, Ms Z.Gr.200 (1547) "is the first known manuscript in which the *Mechanica* appears together with the genuine works of Aristotle": [This would seem to be made irrelevant by the existence of Pachymeres' *Philosophia*. Is it even true?]

[13] "Among the better of the pseudo-Aristotelian writings are the Mechanical Problems, which however contain too few hints at philosophical propositions for us to linger with them." ["Zu den besseren unter diesen pseudo-aristotelischen Schriften gehören auch die mechanischen Probleme, welche aber zu wenig Anklänge an philosophische Sätze enthalten, um hier bei ihnen zu verweilen."] Zeller, *Die Philosophie der Griechen*, II,2, p. 940.

[14] This is Forster's *entire* argument. Cf. Gercke (1895, in *Pauly, II,1,* 1044): "The *Mechanica* starts from general points of view that correspond to those of the oldest generations in the Peripetos; however the individual problems and solutions aim at practically useful application, which (Rose, *De ord.* 1929) is completely unaristotelian." ["Die Μηχανικά gehen von allgemeinen Gesichtpunkten aus, die denen der ältesten Generationen im Peripatos entsprechen, jedoch zielen die Probleme und Lösungen im einzelnen auf praktische Nutzanwendung hin, was (Rose De ord. 192) ganz unaristotelisch ist."] The new *Pauly* (*Der neue Pauly: Enzyklopädie der Antike*, Stuttgart: Metzler 1996ff) is solomonic: The article on Aristotle (Dorothea Frede) considers the *Mechanical Problems* inauthentic; the article on Mechanics (Fritz Krafft) considers it to be authentic. On the whole, historians of ancient technology are more likely to see the work as authentic than are other scholars; see Helmut Schneider, *Das griechische Technikverständnis: von den Epen Homers bis zu den Anfängen der technologischen Fachliteratur*, Darmstadt: Wiss. Buchges., 1989, 234f and Astrid Schürmann, *Griechische Mechanik und antike Gesellschaft: Studien zur staatlichen Förderung einer technischen Wissenschaft*, Stuttgart: Steiner, 1991, 33f. Rhill (2018) is ambivalent, using both "Aristotelian" and "pseudo-Aristotelian" to refer to the *MP*. But cf. also Wilson 2008. Classical philologists, on the other hand, still tend to take the work not to be Aristotle's. Representative is Hellmut Flashar's treatment in the new *Überweg*: "The work belongs to the genre of *problemata*. After a general introduction, 33 [sic!] problems are raised and answered in the typical question-answer form. A number of questions relate to the laws of lever action. Such an extensive technical application of mathematical laws is [otherwise!] without example in Aristotle. The work is generally taken to be not by Aristotle but to derive from the early Peripetos" (Flashar 2004, 290). Cf. also Schiefsky 2009.

doubtful reasoning at best, considering the enormous range of intellectual activity of Aristotle during his last years at the Lyceum."[15] And in fact the analysis of oars and masts, wedges and tooth extractors is carried out not to apply or improve such mechanical devices, but rather to show that a wide variety of technical situations in which the motion (effect) seems not to be proportional to the force (cause) – and thus to be incompatible with a fundamental principle of Aristotle's physics – are in fact compatible. A second argument based on subject matter has somewhat more substance: The analysis of circular motion into a "natural" tangential component and an "unnatural" centripetal component, as carried out in Problem 1, is difficult to reconcile with the usual picture of Aristotle.[16] Furthermore, Heiberg argues that *one* of the mathematical terms used in the *Mechanical Problems* was actually coined by Euclid thus making the work later than Aristotle – though he admits this is conjectural.[17] There appears to be just one hard fact in all this speculation: the simple use of letters to locate figures and points in Euclid's *Elements* ('circle ABC') and the circumstantial use of letters (*epi A* or *to eph' hou AB*) in many works before Euclid.[18] The *Mechanical Problems* is pre-Euclidian in its use of letters for locating figures. Whoever actually wrote this treatise either worked before (or not long after) the Euclidian standardization or deliberately used an archaic style.

Contemporary researchers often date the *Mechanical Problems* somewhat later than traditional scholarship did, putting it at 270 B.C. or even later.[19] In a sense any dating within a generation before or after 300 B.C. (or whenever Euclid's *Elements* was actually written) is as plausible as it is arbitrary. Krafft argues (not convincingly) for a date even earlier than 330 B.C. None who date the work later than 270 B.C. present anything like an argument for such a late dating that accounts for the pre-Euclidean use of mathematical labeling. However, if the author could be shown to be Strato, who seems to be making a comeback, a dating up to 268 B.C. would of course be plausible. However, in this case it is not a firm dating based on text or tradition that is used to ground the possible authorship, but rather it is the possible authorship by Strato that is grounding the dating.[20]

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[15] Benjamin Farrington, *Greek Science,* (Baltimore: Penguin, 1961) pp.186–7; Marshall Clagett, *The Science of Mechanics in the Middle Ages* (Madison: Univ. of Wisconsin Press, 1979) p. 4.

[16] De Gandt 1982, 126.

[17] According to Heiberg ("Mathematisches zu Aristoteles" in *Abhandlungen zur Geschichte der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen 18*, 1904, 3–49) the word τετράπλευρον ('four-side' used at 848b20 in the course of the analysis of compounded motion) was coined by Euclid to denote a quadrilateral figure since the existing term τετράγωνον (quadrangle) had already acquired the meaning "square" for the Pythagorians (pp. 15, 32). Krafft (1970, 92) disputes this judgment, pointing out that the mathematical terminology used in this passage to introduce the letters marking points in the diagrams is unequivocally pre-Euclidean, and arguing that the term τετράπλευρον may well have already existed in colloquial usage and that the context makes it clear that it is the four *sides* of the figure not its angles that are of interest. Interestingly, Heiberg begins his discussion with the assertion that this one word is the *only* terminological aspect of the work that speaks against an Aristotelian origin. Heath (1921, I, 344), too, argues for terminological reasons that the *MP* "was written before Euclid had made the terminology of mathematics more uniform and convenient."

[18] Heiberg 1904, See Heath (1921, I, 344), Krafft 1970, 91–92 and Netz 1999.

[19] De Groot 2014, 21; Schiefsky 2009; Berryman 2009, 107. Pierre Hadot even conjectures [if this is not a typo] that the *MP* is up to a hundred years later, saying it was probably compiled in the Peripatetic school "à la fin du III° ou au début du II° siècle av. J.-C." (2004, 116). On the other hand, Dosch and Schmidt (2018) push the *MP* back closer to Aristotle himself.

[20] Ferrini (2010, p.14) inclines towards Strato. See especially Berryman 2009, 107–8 and 2020, 231, 246fn, who offers a new text-based argument. The idea seems to be that the reference in the Prologue of the *MP* to bronze and iron wheels in temples suggests that the author was in Egypt (Alexandria) where such wheels were common – thus placing the author in the time of the Ptolemaic dynasty (after 305 BC). And if the text is in fact from this time and place, then Strato is a plausible candidate. This is indeed an interesting conjecture; but Bodnár (2011) makes a rather convincing case that Strato cannot be the author. Dosch and Schmidt (2018) also reject Strato and see no convincing argument against viewing the work as early peripatetic.

If we drop Rose's specious and non-philological background argument, that the subject matter and the quality of the work don't fit Aristotle, we are left with a critique of the style of the prologue and a purported claim by Aristotle not to have written a mathematical work. If in view of the tradition of attributing the work to Aristotle we place the burden of proof on denial, it would seem that a rational justification for denying the authenticity of the work could only be based on an analysis of its content; and here the last-mentioned objection must be taken seriously. But none of the traditional arguments against the authorship of Aristotle himself provides any reason to doubt that the author was someone from his school who flourished in the later days of his life or perhaps in the school's next generation.

If we list up all serious remaining evidence against the default setting, Aristotle, we have: (1) The mathematical style of argument in several of the Problems – especially the proof in Problem 1 – is unusual for Aristotle. (2) The analysis of circular motion into "natural" tangential and "unnatural" centripetal components carried out in Problem 1 is not quite coherent with Aristotle's other positions. (3) The text of the first Problem (according to Heiberg) contains one instance of post-Euclidean mathematical terminology.

Against the conclusions of nineteenth and early twentieth-century scholars, a number of misgivings are justified, since scarcely any of those denying the authenticity of the work were aware of the Arabic tradition of the writing as Aristotle's. In fact, in the twentieth century, there is a strange disparity in the reception of the work: Historians of technology (but not classical philologists) knew about the Arabic tradition,[21] while the philologists (but not the historians of technology) knew of a significant literary source[22] indicating how widespread the balance with unequal arms was in Greece: Aristophanes describes a steelyard without *naming* it. The situation has changed, and later generations of scholars have turned to a serious analysis of the content and tradition of the work.

Points relevant to the question of authenticity

A. A number of ancient sources refer to a *Mechanics* in Aristotle's works[23]

   1) All three traditional lists of Aristotle's works mention a mechanics:
      a) Diogenes Laertius (traced back to 3rd century BC)
      b) the *Vita Hesychi* (traced back to 3rd century BC)
      c) Ptolemaeus Chennus – traced back to 1st century AD)[24]

[21] In his dissertation, *Die Waage im Altertum und Mittelalter* (1908), Thomas Ibel cited the medieval Arabic translation and published a German translation of that Arabic text done his supervisor Eilhard Wiedemann (pp. 123–124).

[22] As is clearly explained in the footnotes to the Oxford edition of Aristophanes' *Peace* (421 BC, lines 1245–49), Aristophanes makes a joke about a using an unsold war trumpet as a simple Danish steelyard: as "something to weigh out the figs for your slaves in the field" (καὐτό σοι γενήσεται τὰ σῦκ᾽ ἐν ἀγρῷ τοῖς οἰκέταισιν ἱστάναι). In contrast to the later "Roman" steelyard, which has a *movable* counterweight, the Greek steelyard (now called a bessemer or "Danish" steelyard) had a *fixed* counterweight and a movable suspension point. Such a device is analyzed in detail in Problem 20 and compared to a lever that hangs from its fulcrum like a balance.

[23] Düring 1957, Hein 1985, van Leeuwen 2012. István Bodnár (personal communication) suggests that the significant question is not just *whether* these lists attribute a mechanics to Aristotle but rather where within the Aristotelian system they locate that mechanics.

[24] Ptolemaeus Chennus was called the unknown (*xevos, al-Garib*) to distinguish him from Claudius Ptolemy; he flourished in Alexandria in the 1st c. AD and may or may not be the author of the biography and list of works attributed to him. The list is known from a (presumably) tenth-century Arabic translation [of a Syriac translation] of the lost Greek source. Ptolemy says: "His book called On Mechanical Problems. It is called μηχανικὰ προβλήματα. Two sections." (Rovati 2020, p. 22).

2) Simplicius (6th c.) *In aristotelis categorias commentarium* mentions (as did Elias)[25] Aristotle's Mechanics. *Commentaria in aristotelem graecae* viii, Berlin 1907, p. 4, l. 26; οἷα γεωμετρικὰ τε καὶ ἀυτῷ γέγραπται καὶ μηχανικὰ βιβλία.

3) Athenaeus Mechanicus (1st c. BC) "On Machines" dismisses Strato, Hestiaeus, Archytas and Aristotle as just beginners' stuff – not for real practitioners.[26]

4) Vitruvius discusses several problems from the *Mechanical Problems* in Bk. 10 of *De architectura,* but without ascription. In Bk. 7 he mentions 12 writers on machines – without including Aristotle among them.[27]

B. The text was known to the medieval Arabs.

One of the largest collections on mechanics in Arabic entitled *Book of the Balance of Wisdom* (compiled by Al-Khazini around 1120) includes an extract from the *Mechanical Problems*, that had presumably been translated earlier by Al-Mustaffar al-Isfizari in the late eleventh century. Under the title *Nutaf min al-hiyal* (*Elements of mechanics*) extracts from the Prologue and Problem 1 are attributed directly to Aristotle. These two short passages are preceded by a section that provides a technical discussion of the behavior of a material beam balance that seems to indicate some familiarity with Problem 2 of the *MP*. Later references to a *Mechanical Problems* by Aristotle in the bio-bibliographical dic-

[25] See Hein, 1985 p. 304.

[26] István Bodnár (2011) points out that Athenaeus thus must have had access to both Strato's and Aristotle's writings on mechanics, which would certainly speak against Strato's possible authorship of the *Mechanical Problems*. See D. Whitehead and P.H. Blyth, *Athenaeus Mechanicus On Machines*. (Περὶ μεχανημάτων), Wiesbaden: Steiner 2004, pp. 44–45: "This, you see, is how anyone setting about a practical treatise should have *benefited*: having carefully understood himself on the basis of the famous Delphic precept, rather than the works of Strato and Hestiaeus and Archytas and Aristotle and the others who have written works similar to theirs. For younger devotees of knowledge they would be useful [as a training] in elementary principles; but for those already wanting to *do* something they would be altogether irrelevant and detached from practical thinking."

[27] T.N. Winter in the introduction to his translation of the *Mechanical Problems* argues that since Vitruvius [allegedly] had the actual text of the *Mechanical Problems* and knew its author, that author cannot be Aristotle – otherwise he would have been mentioned. Winter (p. iv) takes Vitruvius' list (Book 7, Intro, §14) of people who wrote about machines to be his actual sources on machines; and by a process of elimination of 11 of the 12 predecessors (Agesistratus, Archimedes, Archytas, Charias, Ctesibios, Democles, Diades, Diphilus, Nymphodorus, Philo Byzantius, Polyidus, Pyrrhus) he arrives at Archytas of Tarentum as the probable author. The argument is not particularly convincing, since the mechanical parts of the *Mechanical Problems* are not about how to build machines but rather about how to explain them theoretically by reducing them to the lever, balance and circle. The context of the list is also somewhat peculiar: Book 7 is not about the construction or analysis of machines, but about floors, the design of façades and wall colors. Carl Huffman, in his book on *Archytas* (2005, 28–9), points out that Diogenes mentions five different men named Archytas – one of whom was an architect. This Archytas may have been meant by Vitruvius in this passage. Archytas of Tarentum, on the other hand, is in principle a candidate for authorship because he is said (by Diogenes) to have been the first to base mechanics on 'mathematical' principles. But even that assertion is based on a reconstruction: The actual text of Diogenes reports, unfortunately, that Archytas based mechanics on *mechanical* principles – whatever those are – but the editor, H.S. Long (and the experts support him here), emended the text to say 'mathematical' principles instead. Furthermore – as István Bodnár (personal communication) reminds me – all the genuine fragments that we possess from Archytas of Tarentum are written in the Doric dialect; thus, he is pretty much excluded as author of the Attic *Mechanical Problems.* According to Huffman (2005, p. 31), Archytas was later taken as a "model for Doric prose." Nonetheless, if Vitruvius did indeed have access to something at all close to our text (he obviously knew the content of some of the Problems) and if this text was at that time attributed to Aristotle, then it is puzzling that he did not mention Aristotle in Bk 10. The same puzzlement is justified for Hero of Alexandria a century later. On the other hand, the *Mechanical Problems* is not the work of practical-mechanics that nineteenth century philologists took it to be, and since early technicians would not have been confused about this, they would have had no reason to refer their readers to it.

tionaries of Ibn Abi Usaybia and Ibn al-Qifti from the thirteenth century document the acceptance of this attribution, but they themselves provide no independent evidence.[28]

C. There *may* have been a Latin (partial) translation.

1) The *Falkenbuch* of Friedrich II (early 13th c.) mentions and quotes a *Liber de ingeniis levandi pondera* of Aristotle: "quod magis facit levari pondus maior circulus".

2) Jordanus de Nemour (early 13th c.) is familiar with the content of some of the problems.

3) Various bibliographic sources suggest the existence of a Latin mechanics of Aristotle:
   a) A book list at the University of Padua, from 1401 lists a "Liber mechanicorum" under Aristotle.[29]
   b) In an export license from Bologna (1413) for books, there appears the title, "Repertorium super mechanica Aristotilis." [30]
   c) Henricus de Villena (1384–1434)[31] had two books of "Mechanicas" catalogued under Aristotle in his library.
   d) A statute of the University of Paris for 1366[32] mentions a "librum Mechanicae" among the required Aristotle texts for a degree from the Faculty of Arts. [However, a different source reports "librum Metaphysice".]

4) *However*, none of these sources provides hard evidence of the existence of a *complete Latin* text:[33] Friedrich II was fluent in Arabic and needed no Latin translation in order to cite excerpts from the *MP* in his *Falkenbuch*. Jordanus cites no sources for

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[28] See Abattouy 2001.

[29] Marshall Clagett, "Three Notes," *ISIS* 48 (1957) 182–83; and *The Science of Mechanics in the Middle Ages*. Madison 1959, 71, n.5; based on *Chartularium Studii Bononiensis*, Vol. 2, Bologna, 1913, 222, item 18,

[30] Marshall Clagett, "Three Notes," *ISIS* 48 (1957) 182–83; and *The Science of Mechanics in the Middle Ages*. Madison 1959, 75-76, n. 6; based on A. Gloria: *Monumenti della Università di Padova* (1318-1405), Vol. 2, Padua 1888, 385.

[31] See J.E. Brown*, The '*Scientia de ponderibus' *in the Later Middle Ages*, Diss. Univ. of Wisconsin, 1967, p. 203 and Emilio Cotarelo y Moro, *Don Enrique de Villena, su vida y obras*, Madrid 1896, p. 157. The Spanish library in Madrid is supposed to have possessed a ms of two books of mechanics listed under Aristotle – a friend from Spain, who worked on the *MP,* inquired after them in the library in Madrid (Biblioteca El Escorial) but did not find them.

[32]The Papal Legates, the Cardinals, Giles de Montaigu and John de Blandy imposed a body of "Statutes" on the University of Paris in 1366, which included the following passage: "Item quod nullus admittatur ad Licentiam in dictâ Facultate [Artium], nec in examine B[eate] Mariae, nec in examine B. Genovesae, nisi ulterius praedictos libros audiverit Parisius, vel in studio Generali librum Physicorum, de Generatione et Corruptione, de Coelo et Mundo, Parva Naturalia, videlicet libros de sensus & sensato, de somno & vigilia, de memoria & reminiscentia, de longitudine & brevitate vitae, librum Mechanicae, vel qui actu audiat eundem, et quod aliquos libros Mathematicos audiverit." (Bulaeus iv, 390 [César Egasse Du Boulay, *Historia universitatis parisiensis* … Paris 1668, vol. 4 (Reprint: Frankfurt/M. Minerva 1966f)]). See Hastings Rashdall, *The Universities of Europe in the Middle Ages*, vol 1. Salerno, Bologna, Paris (Reprint: Oxford: Clarendon Pr., 1987) p. 437. István Bodnár has pointed out to me that another (more modern) source collection (*Chartularium universitatis Parisiensis* (ed. H. Denifle) vol. 3, Paris: Delalain, 1850–1894, p. 145), whose documentation is otherwise almost word for word the same, has the phrase "librum Metaphysice" instead of "librum Mechanicae" – which does make somewhat more sense, especially if the final work in the list is not parsed as being part of the *parva naturalia*.

[33] Brown (1967, 203) [who seems not to know about the Arabic translation!] remarks: "Interestingly, it is the first two chapters (that is, questions 1 and 2) of the Mechanical Problems that seem to be reflected in the medieval sources. The comparative silence about the thirty-three remaining chapters raises the possibility that only a fragment of the original work circulated in medieval times. A fragment containing two detached Aristotelian questions might have been recorded by Henricus' cataloguer as two distinct mechanical treatises."

his knowledge. The notices of 3a and 3b could also refer to a Latin translation of the Arabic extract or just to the Arabic extract itself. Source 3c mentions *two* books of mechanics, and the Arabic abstract had two chapters. As for 3d, the citation of a "book of mechanics" in the Paris statute may well be due to a simple transcription mistake since a different title is cited in an alternative source.

D. The two "mathematical" problems (1 and 24), on which almost all arguments against Aristotle's authorship are based, are anomalous.

   1) the (not very convincing) proof of the composition of motions in Prob.1 plays no role in the rest of the work (not even in the rest of Prob. 1) and interrupts the argument of the program of reduction, which then continues after the digression as if nothing had happened. It can be cut without loss for the reduction argument, and no part of the mathematical digression is contained in the Arabic extract of Prob. 1.
   2) Problems 1 and 24 (Prob. 24 deals with the so-called "Wheel of Aristotle") are exceptional in length – much longer than any others: three and two times as long as the next longest Problem (Prob. 23). They are respectively 6 and 4 times the mean length of problems (see appendix).
   3) Problems 1 and 24 – alone – do not begin with "dia ti" but with a different (albeit equivalent) expression.
   4) Problem 23, the third longest, is also about the geometry of moving points. And Problem 5 is fourth in length because its mechanical argument is interrupted by a geometrical argument. Thus, more than one third of the treatise, as we now have it, is purely mathematical, not mechanical.

E. All surviving mss of the *MP* (except the Arabic extract) seem to go back to one ms in Byzantium of the 9th century.[34] The earliest physical document is a ms copied in the 14th c. Near the end of the 13th c., the Byzantine scholar, Georgios Pachymeres (1242–1310), who travelled through Europe,[35] wrote a Greek compendium on Aristotle, entitled *Philosophia*, which contains an almost verbatim paraphrase of the *MP*. Thus, the Byzantine tradition considered the *MP* as Aristotle's work.

F. *ad hominem*: none of the scholars who originally disputed the authenticity of the *Mechanical Problems* were aware of the Arabic tradition or of the evidence [whatever it is worth] for a lost Latin tradition. And even after Duhem's analysis, none of them seem to have seen the program of reduction in the first three problems.

Remaining puzzles

1. Manuscript tradition: The section of Pachymeres' *Philosophia* on the *Mechanical Problems* is not really a paraphrase, but rather a direct quotation with occasional word changes and interventions and about a dozen sentences of his own.[36] Some of these interventions have made their way into many editions, in particular into the first printed edition of Aristotle's works (Venice 1495f) Two of the mss in Bottecchia's (1982) stemma [F 1.10 and a T. 9. 21 (76)] are not Aristotle manuscripts, but rather copies of Pachymeres' *Philosophia.* The manu-

[34] van Leeuven 2016.

[35] The autograph of Pachymeres' *Philosophia* still exists and is preserved in Berlin. There are dozens of manuscript copies of this work, many made in the 15th and 16th centuries.

[36] How close Pachymeres' paraphrase is can be seen by consulting the appendix to Bottecchia 1982, where the differences to a Pachymeres manuscript (taken to be Aristotle's) are listed. See also van Leeuven 2013, 193–95.

script tradition is clarified by Joyce van Leeuwen's dissertation (2012; published with *Boston Studies* 2016).

2. The Arabic translation of the Prologue and Problem 1 is in a sense *mathematically* a better text than our Greek: It is more precise, more parsimonious; but it does not summarize or paraphrase (much). For the most part it presents a *selection* and literal translation of passages from the Greek: EITHER the translator selected *whole sentences and clauses* from the Greek and excluded extraneous sentences and was thus perhaps a better mathematician than the author [he was also lucky enough not to have to *rewrite* much, he only had to choose the necessary sentences and exclude the superfluous ones]; OR he had a different text – for which there is, however, *no other evidence*. EXCEPT: In Problem 1, lines 849b24–31 (after the irrelevant proof), – in all editions – the word *plastinx* (pan) occurs three times where apparently *phalanx* (beam) is meant – at least, every (!) translation [O.K., I have only checked 8 different ones] fudges here, rendering *plastinx* as 'librum', 'balance', 'arm' or 'beam': Hett tries 'balance pan' in Prob. 1 – but in Prob. 20, where the same thing happens again, he translates *plastinx* as 'steelyard'! The Arabic text, on the contrary, translates whatever was in its Greek source consistently with *'amud'* the standard technical term for 'beam' or 'pole'. The Arabic document is part of an early twelfth-century compilation (the translation itself is from the late 11th c.) and thus 150 years older than any physical Greek document that we have. It does not contain the long proof of the composition of motions. AND: Ptolemy reports that Aristotle's book *Mechanica Problemata* has *two* "sections."[37] Since the text that we have inherited from Byzantium has no obvious division into two parts, this may indicate that a text somewhat different from ours once existed (and may have been available to the Arabs) – or merely that Ptolemy was actually referring to an entirely different work.

However, in view of the fact that the mathematical terminology of the proof and the use of letters in labeling figures in our Greek text of Prob. 1 is pre-Euclidean, then if this part of the text was not part of the original Peripatetic tradition, there must have been an independent tradition of the proof from Aristotle's time onward. If these passages were later interpolated into the *Mechanical Problems* by some Byzantine scholar, he was using fourth-century-B.C, material – a very shaky speculation.

3. One possible solution (speculative, but not quite as wild as the above) would be to distinguish among the problems based on their content. Although almost all the problems seem to deal with motion (usually but not always, circular motion) we can distinguish four different "collections" within the treatise: (a) the reduction program of technical devices to the lever-balance-circle (1, 2, 3, 4, 6, 9, 13, 14, 15, 16, 17, 18, 20, 21, 22, 26, 27, 29); (b) the geometry of moving points (*most* of 1, *part* of 5, *all* of 23 and 24, and 25 – which does geometry, but without motion); (c) increasing the motion of things that are already in motion (or *starting* the motion of things that *tend* to motion) (7, 8, 10, 11, 12, 19, 31); (d) projectile motion (32, 33, 34). It is thus possible that the results of several minor collection projects in the peripatetic school – perhaps even from different periods – were joined together in this work. (But what do we do with 28 and 35?) Most likely, problem collections from at least two different projects in the school – one mathematical and one mechanical – were later integrated.

4. The law of the lever itself (stated in Prob. 3) is the only explicit proportionality formulated in the *mechanical* parts of the work, and it is not in fact *used* anywhere in the argumentation. Furthermore, it is actually formulated one sentence before it can make any sense (see Renn/McLaughlin 2019). Instead of saying: "For always the more distant [the mover] is from the fulcrum, the more easily it will move," and then *specifying* this relation as a strict proportionality, the text does just the opposite. It begins with the proportionality: "Thus the

[37] For comparison: "24. His book On Spirit. It is called περὶ πνεύματος. Three sections." (Rovati 2020, 22)

weight [*baros*] moved is to the mover as the length to the length inversely." Only after this proportion has been stated is the more general principle adduced.[38] Thus, the author first says that the function is linear, and then he says it is monotonic.

Not only is the law of the lever formulated in the wrong place, it is also never actually applied. The reductive core of the *Mechanical Problems* does not use any genuine quantification. Aside from the law of the lever itself (perhaps a later interpolation) there are no proportions used in the non-geometrical problems. The formulations are generally adverbial: the more, the quicker. The closest we get to "mathematics" is a formal hosô…tosoutô (*tantum-quantum*) formulation such as in Prob. 16: the greater, the more.

And, if it is taken literally, the law of the lever, as formulated, is self-contradictory: The weights and lengths are indeed inversely proportional in equilibrium, but in equilibrium there is no motion: neither moving weight, nor weight moved. The charge of self-contradiction was famously raised by Simon Stevin in 1586 in the following syllogism.[39]

That which hangs still does not describe a circle;
Two weights in equilibrium hang still;
Two weights in equilibrium do not describe a circle.

But it is clear that the author of the *MP* is primarily interested in explaining the *motion* of the loads not their equilibrium.

[38] The reception of the law of the lever is in one regard particularly strange: The first three (Latin) translators were apparently so impressed by the correlation found between weights and distances from the fulcrum – the fact that we can substitute distance for weight or force – that they failed in their translations of the passage to specify that the proportionality was an *inverse* one: Vittore Fausto, *Aristotelis mechanica ... ac latinitate donata* (Paris, 1517); Niccolò Leonico Tomeo, *Quaestiones mechanicae* (*Opuscula nuper in lucem aedita* …, Venice, 1525); Philippo Bechio, *Georgii Pachymerii Hieromnemonis in universam fere Aristotelis philosophiam epitome* (Basel, 1560). The same holds for Thomas Taylor's English translation (London, 1812).

[39] Stevin 1586/1955 p. 507/8; McLaughlin 2001, p. 566.

Translations of the *Mechanical Problems*

Latin

Fausto, Vittore (1517) Aristotelis mechanica ... ac latinitate donate, Paris.

Tomeo, Niccolò Leonico (1525) *Quaestiones mechanicae. Opuscula nuper in lucem aedita*, Venice (many re-editions).

Bechio Philippo (1560) *Georgii Pachymerii Hieromnemonis in universam fere Aristotelis philosophiam epitome,* Basel: Froben [contains a Latin translation of Pachymeres' word-for-word paraphrase of the *MP*].

Monantheuil, Henri de (1599) *Aristotelis Mechanica graeca, emendata, latina facta, et commentariis illustrate*, Paris [2d. ed., 1600].

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English / German / Italian (I know of no French translation.)

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Reception of Aristotle's *Mechanics* in the Renaissance

1495f *Corpus Aristotelicum* printed in Venice

1517 Vittore Fausto, Latin translation

1525 Niccolò Leonico Tomeo, Latin translation and commentary (the standard translation)

1545 Diego Hurtado de Mendoza, Spanish translation *ms* (perhaps of Pachymeres' *Philosophia*) (publ. 1898)

1546 Niccolò Tartaglia, *Quesiti* Bk. 7

1547 Alessandro Piccolomini, Latin commentary (2nd ed., 1565)

1554 Matthaeus Christianus, *De mechanicis questionibus* (ms)

1560 Philippo Bechio, Latin translation (as part of Pachymeres' *Philosophia*)

1564/65 Petrus Ramus lectures on the *Mechanica*

1566 Pedro Nuñes, partial Latin commentary (boat questions)

1569 Francesco Maurolico, abridged translation and Latin commentary with additions (publ. 1613)

1570 Girolamo Cardano, *Opus novum de proportionibus*

1570f Pietro Catena lectures on the *Mechanica*

1573 Antonio Guarino, Italian translation from Greek

1574 Antonio Guarino, Italian commentary

1576 Giuseppe Moletti, ms *Dialogues on Mechanics* (publ. 2000)

1577 Guidobaldo del Monte, *Liber mechanicorum*

1580 Bernardino Baldi, Latin commentary (publ. 1621)

1581 Giuseppe Moletti, *In librum mechanicorum* (ms) (Bibl. Ambr. Milan)

1581 Filippo Pigafetta, Italian translation of del Monte

1582 Oreste Vannocio Biringucci, Italian translation of Piccolomini

1585 Giovanni Battista Benedetti, *Speculationum* (section on mechanics)

1590 Francesco Buonamici lectures on the *Mechanica*

1594 Galileo Galilei, *Le Mecchanice*

1597 Niccolo Stelliola, *De gli elementi mechanici* (*ms*)

1598 Galileo lectures on the *Mechanica*

1599 Henry Monantheuil, Greek text + Latin translation and commentary (2d ed. 1600)

1615 Giuseppe Biancani (Blancanus) Latin commentary

1626 Marin Mersenne, *Synopsis mathematica* (partial Latin paraphrase? [not yet seen!] only two copies: Paris and Princeton; possibly the same as *Synopsis* 1644)

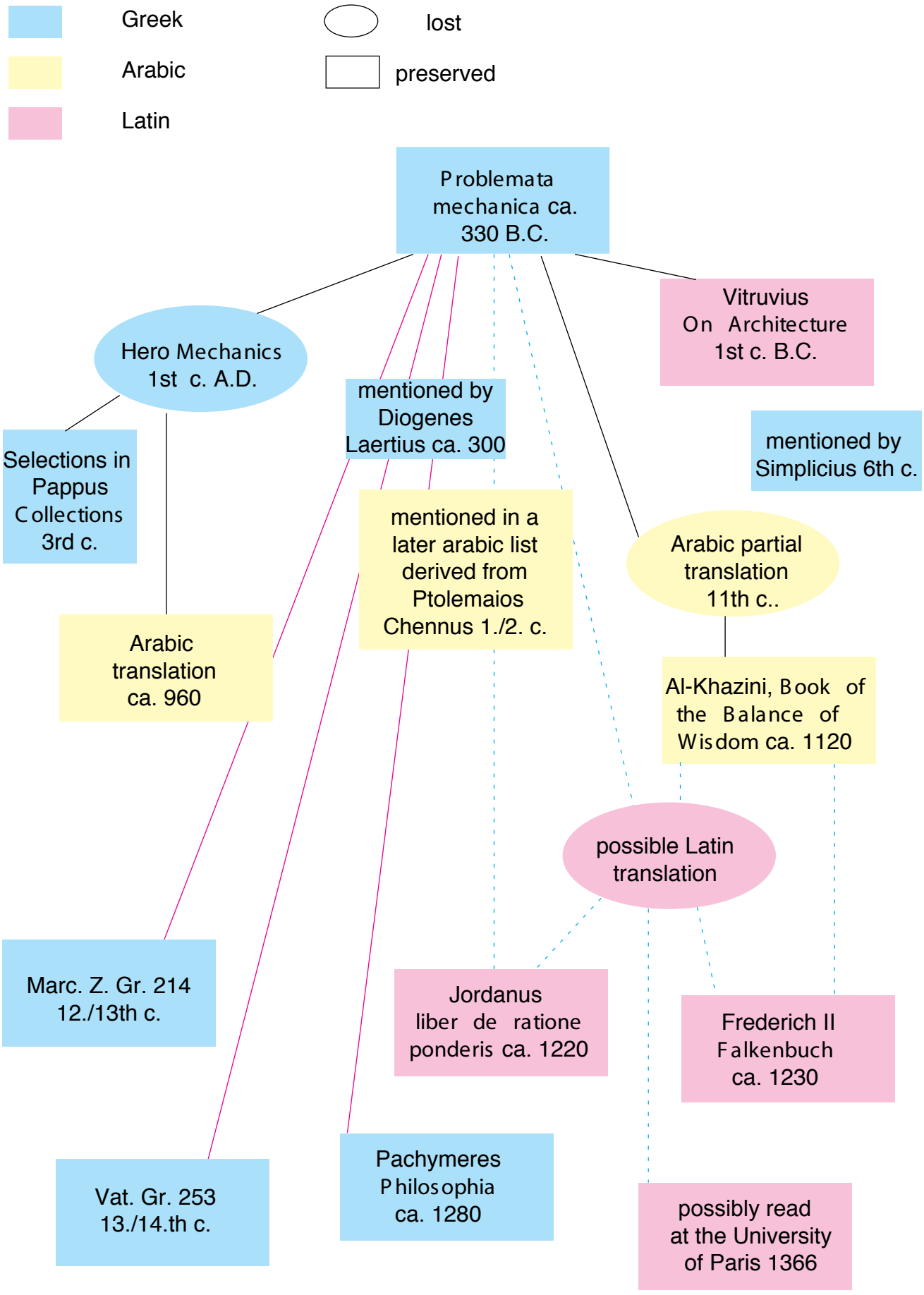
1627 Giovanni de Guevara, Latin commentary

1629 Daniel Mögling, German translation/paraphrase of Baldi's commentary

1634 Giovan Battista Zupi, *Exercitationes in Mechanicis Aristotelis* (lectures based on Galileo and Baldi; publ. 2006)

1644 Marin Mersenne, *Tractatus mechanicus theoreticus et practicus*, Paris: Bertier

1644 Marin Mersenne, *Universae geometriae, mixtaeque mathematicae synopsis*, Paris: Bertier


Greek
Arabic
Latin
lost
preserved
Problemata mechanica ca. 330 B.C.
Vitruvius On Architecture 1st c. B.C.
Hero Mechanics 1st c. A.D.
mentioned by Diogenes Laertius ca. 300
mentioned by Simplicius 6th c.
Selections in Pappus Collections 3rd c.
mentioned in a later arabic list derived from Ptolemaios Chennus 1./2. c.
Arabic partial translation 11th c..
Arabic translation ca. 960
Al-Khazini, Book of the Balance of Wisdom ca. 1120
possible Latin translation
Marc. Z. Gr. 214 12./13th c.
Jordanus liber de ratione ponderis ca. 1220
Frederich II Falkenbuch ca. 1230
Pachymeres Philosophia ca. 1280
Vat. Gr. 253 13./14.th c.
possibly read at the University of Paris 1366

Greek
Arabic
Latin
Latin (renaiss.)
Vernacular

Text
Commentary
Lost

Aristotle
Mechanical Problems

Heron
Mechanics

Vitruvius
On Architechture

Arabic partial
translation 9th c.

Arabic translation

Book of the Balance
of Wisdom ca. 1120

Possible Latin
translation

Jordanus, de
ponderibus, ca. 1220

Friedrich II
Falcon book, ca. 1230

Pachymeres
Philosophia: almost
verbatim paraphrase
ca. 1280

Corpus aristoteli-
cum, 1495-98

Translation
Fausto 1517

Translation and
commentary,
Tomeo, 1525

Spanish translation
Mendoza, 1545

Translation, Bechio
1560

Commentary
Nuñes, 1566

Commentary
Christianus, 1554

Tartaglia
Quesiti, 1546

Commentary
Piccolomini, 1547

Translation and
Commentary
Maurolico 1569/1613

Cardano, Opus
novum, 1570

Translation and
commentary
Baldi, 1580/1621

Commentary
Moletti, 1576/81

Italian translation
Biringucci, 1582

Translation and
commentary
Monantheuil, 1599

Italian translation
and commentary,
Guarino, 1573/74

Benedetti
Speculationum
1585

Commentary
Stelliola, 1597

Commentary
Biancani, 1615

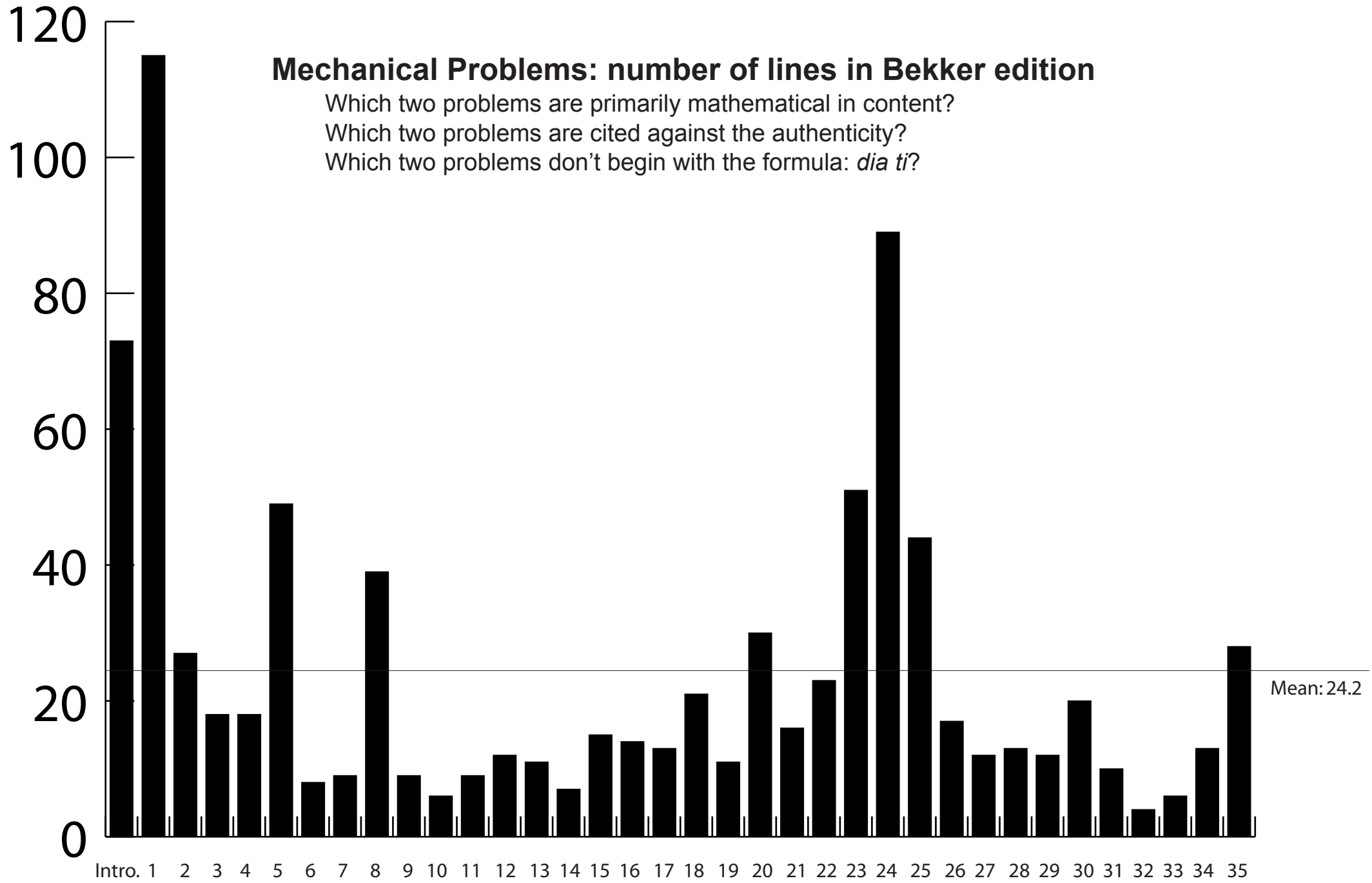
Commentary
Guevara, 1627

Commentary
Mersenne, 1626

German translation
and paraphrase
Mögling, 1629

Latin translation
by Golius (ms) ca 1650

300 B.C.
100 B.C.
AD 100
AD 800
AD 1000
AD 1200
AD 1300
AD 1400
AD 1500
AD 1600


Mechanical Problems: number of lines in Bekker edition
Which two problems are primarily mathematical in content?
Which two problems are cited against the authenticity?
Which two problems don't begin with the formula: dia ti?
120
100
80
60
40
20
0
Mean: 24.2
Intro. 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35