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Paper Title:
'Necessity is the Mother of Invention': Recognizing the Contributions of Ancient Near Eastern Technology

Abstract:
While it may be the case that 'necessity' is an inspiration or impetus for invention and innovation, we may suppose there are other equally potent factors, including the threat of invading forces, climate change, economic cycles, cultic practices, megalomaniacs and their egos, the desire to make life easier, and just plain curiosity. In his work, *The Histories*, Herodotus (ca. 484-425 BCE), identifies a number of technological systems that were extant in the Near East both contemporaneously with, and centuries prior to, his research and writing (Strassler 2007). Yet, the ancient Near East is often overlooked as a cradle of science, mathematics, technology, literature, and art. Indeed, the region was a crucible of inventive and innovative inquiry, inspired by the needs and demands of complex cultures and historic events.

Beginning with the Neolithic period through the Persian period, the peoples of the Near East made significant contributions to numerous aspects of technology, resulting from their constant and diligent research, discovery, and innovation. The knowledge that they accumulated established the foundational data upon which later technological development would build and spread to neighboring regions. For example, the Babylonians, Sumerians, and Assyrians offered equally significant contributions to mathematics, astronomy, and timekeeping, while the Egyptians applied their knowledge of mathematics, physics, and construction techniques to the construction of pyramids and temples, many of which remain standing centuries later.

If we adopt as a broad definition of technology, "the practical application of knowledge, scientific or otherwise, to resolve a problem, achieve a goal, satisfy curiosity, make life easier or to accomplish change" (Baker 2019:4), a wide range of architecture, contraptions, mechanisms, and conveniences can be included in a discussion of ancient technology. As a result, a myriad of remarkable technologies from the ancient Near East can be identified; some more obvious than others, some more spectacular than others. Nevertheless, each

is impressive and consequential in its own unique way. This paper will focus on several Near Eastern technologies that will serve as case studies: Canaanite fortification systems (Burke 2008, Chadwick 2017), olive presses (Gitin 1990, Eitam and Heltzer 1996), and the so-called Baghdad battery (Pazthory 1989).

Although narrow in scope, these seemingly mundane topics represent a wide range of technologies that illustrate not only the ingenuity and knowledge ancient peoples possessed, but also the impact and interaction technology had on and with contemporaneous society, culture, economy and history.

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Textile technology as anchor for innovation in archaic Greece?

Giovanni Fanfani (Deutsches Museum, Munich), Annapurna Mamidipudi (Deutsches Museum, Munich), Ellen Harlizius-Klück (Deutsches Museum, Munich)

This presentation argues that in archaic Greece, the logic and technology of weaving on the warp-weighted loom was able to represent a pre-scientific paradigm of knowledge-through-order which the emergence of technical (philosophical and mathematical) literature obscured and somewhat relegated to the realm of metaphor.
We present as a case for discussion the so-called 'dyadic arithmetic', a theory dealing with odd and even numbers, their features and relationships. The relevant corpus constitutes an archaizing section of Euclid's *Elements* (definitions opening book 7, and propositions 21-34 in book 9), generally traced back to early Pythagorean number theory, where the notion of *arithmos* points to structural features and the arrangement of units rather than to a countable quantity (Philolaus 44 B4, B5 D-K). From the point of view of the history of mathematics, there is no anchor for this dyadic arithmetic in any practice (apart from pebble arrangements; see Epicharmus 23 B1 D-K), and it is called a pure invention of Greek genius (i.e. an innovation, a rupture of the traditional way to count or calculate; cf. Szabó 1960).

However, in the *Statesman* Plato prominently refers to this dyadic arithmetic (as *arithmetikē technē*) as being pure knowledge (and opposed to applied knowledge, 258d-e) in a context where weaving is presented as a *paradeigma* for the art of the statesman, and (implicitly) as a model for the diaeretic method itself. Indeed our project results show that the way of reasoning reflected in the definitions and propositions of dyadic arithmetic is exactly what weavers need to do when ordering and organizing their patterns on the warp-weighted loom.

In archaic Greek literary sources, weaving is an epistemic anchor for conceiving of complex structures (the woven cosmos of Pherecydes of Syros) and a model for the perception and generation of pattern in both nature and craft (the *poikilia* of the woven pattern and the woven *hymnos* in choral lyric metapoetics). However, this anchor is deliberately cut. Plato, again in the *Statesman*, claims that "no one in his right mind would ever consider to pursue the explanation of weaving for its own sake." (285d) It appears that re-connecting the new to a craft that is mainly in the hands of women is not appropriate. This is underlined by the fact that later, when the anchor is indeed lost, male weavers are introduced into the most important parts of this tradition (Akesias and Helikon for the Panathenaic peplos: Athen. *Deipn*. 2.48b; the cosmos as a huge fabric woven by a godly weaver: Philo of Alexandria *De Somn*. 1.203ff.).

We thus propose to see the case of dyadic arithmetic as an instance of a larger transition of knowledge that, un-anchored from its root in the logic and technology of ancient weaving, comes to be channeled into disciplinary boundaries. As a result of the revolution in Greek mathematics, mathematical objects always already pre-exist, and are therefore only to be discovered. They can now be cast as innovation, that is tied to rupture rather than the continuity of tradition.

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(Greek texts in appendix)

The impulse for this paper arises from a broader investigation into ancient weaving technology as site of knowledge – a kind of integrated, pre-scientific knowledge that, we argue, is best graspable in the fluid epistemic landscape of archaic Greek thought. Our focus here is on tracing the function of weaving knowledge, as an instance of 'anchoring technology', in the transition to the emergence of formalized, abstract mathematics, and to forms of 'rationalistic' cosmology.

Ancient textile technology presents a composite spectrum of techniques, and we find the language and imagery of weaving, plaiting and braiding being appropriated, *qua* technical terminology and thus as technological anchor, by authors of archaic and classical Greek lyric to advertise innovation in instrumental music (Pind. *Pyth*. 12.5-8, Telestes *PMG* 806) or convey features of choral performance (Pind. *Nem*. 4.44f.), and by early theorists of rhythm to illustrate the generation of metrical patterns (Plat. *Resp*. 400a-c). (slide with texts)

The aspect that best encapsulates the essence of weaving as epistemic anchor is, however, the logic of generating patterns on the warp-weighted loom, which we propose to see as a mode of ordering through the manipulation of numbers embodied in threads.

(Slide and short explanation of weaving technology)

On close analysis, pattern weaving is grounded on a specific modality of counting/reckoning and manipulating threads: more than just a material instantiation of number, the thread displays both the feature of spatial continuity and of discreteness. Grasping and separating threads in the process of pattern construction goes hand in hand with complex logical-arithmetical calculations (factorizations into even and odd repeats, avoiding or adjusting prime numbers, interference patterns obtained through coloured threads) that allows the weaver to create the combinations for letting the pattern emerge on the fabric.

The knowledge of pattern weaving cannot be, and has not been historically, transmitted prescriptively or descriptively through written sources, across cultures past and present: as a mode of knowledge in-dwelling in the performance of weaving, with the rules of the craft imposing themselves through the material affordance of threads, weaving resists being approached as applied science. In other words, it resists the split of pure mathematics (as operation of numbers) and applied knowledge (then applied onto threads).

Instead, as we shall see more closely for dyadic arithmetic, the complex operations that are at work in the threads as weaving is performed are abstracted into dyadic arithmetic: it is from the operation that the principles emerge – whether in weaving or in 'pure' arithmetic. That's what we mean by 'anchoring'.

In fact, and here we come to our first example of weaving knowledge as technological anchor, recent scholarship on early Greek philosophy has laid emphasis on ways in which technological innovation, and an interest in applied mathematics, may have triggered in 6th century BC Ionia the elaboration of the *physiologoi*'s cosmologies: for instance, Anaximander's column drum model of the cosmos would be a projection of monumental temple building, in turn seen as an achievement of applied geometry. A contemporary of Anaximader, and the earliest Greek prose

writer (according to the doxographical tradition), Pherecydes of Syros casts the woven pattern as a template for the structure of the universe (slide with fr. 68 Col. 1 5-6 Schibli = 7 B2 D-K). This, we suggest, is no less a rationalistic and technologically-inspired endeavour than Anaximander's; indeed, the semantics of *kosmos* as both 'ordered structure' and 'ornament, adornment', perfectly illustrates the nature of weaving technology, where ornament and structure coincide – the pattern emerges as the result of the crossing of two sets of threads and is never superimposed on the material. The verb used by Pherecydes for Zas' act of cosmological weaving, *poikillein*, conjures up the perception of pattern in both nature and *tēchnē* as a complex structure made of discrete elements.

Pattern generation in weaving may be also addressed as thinking about forms in terms of numbers – and thinking about numbers in terms of possibilities of form; every geometric or figurative shape appearing on the fabric is generated through considerations of ratios between numbers and properties of integers (evenness, oddness, primality, and the respective combination). In fact, the notion of 'form' of numbers resonates with a modality of number manipulation that is traced back to early Pythagoreanism, namely the practice of arranging *psēphoi* (pebbles) as a heuristic method of finding out relations between odd and even numbers (Epicharmus 23 B1 D-K), of generating the sequence of square numbers (through placing successive odd numbers round the unit: Arist. *Phys*. 203a10-15), of representing the shape/structure of different beings through the number/pattern associated with each one (Eurytus 45 3 D-K = Aristot. *Met*. 1092b9-10, where Aristotle compares Eurytus' practice to "those who cast numbers in the shape of a triangle or a square"). (slide with texts). More than just a means of engaging with and manipulating figured numbers by inferring the properties of integers, pebble arithmetic has been heralded as providing the proofing mechanism for a deductive corpus of Pythagorean arithmetic: the doctrine of even and odd, an archaizing section of Euclid's *Elements* (the definitions opening book VII and book IX prop. 21-34) (slide with Euclid's text).
While the doctrine of odd and even numbers has a recognizable root in early Pythagoreanism (Philolaus 44 B4, B5 D-K), it is highly regarded as a paradigm of pure knowledge by Plato; Socrates' definitions of *arithmētikē* and *logistikē* in the *Gorgias* (451a-c, see slide) seem as well capable of describing the arithmetic of pattern creation: grouping threads and working with their relations (often in terms of proportions) rather than counting or calculating their amount. However, Plato is also the author who first and most prominently seems to be cutting the technological anchor of weaving knowledge by severing it from the form of pure *epistēmē* represented by arithmetic, and notably dyadic arithmetic, in the *Statesman* (258d-e, 259e, 262e3-5, 285d). That same dialogue though, whether ironically or not, stages weaving as a) a *paradeigma* for the art of the statesman, b) a model for method of *diairesis* itself, and c) a *technē* that, we argue, partakes of the two types of ἐπιστήμη illustrated in *Pol*. 258d-e (the 'pure', i.e that of ἀριθμητικὴ and of the other τέχναι ψιλαὶ τῶν πράξεών, and the one which is 'inherent and congenital to the applications' of crafts, thus a knowledge-in-use).

Appendix: Greek texts

Pind. *Pyth*. 12.5-8, 18-22
δέξαι στεφάνωμα τόδ' ἐκ Πυθῶνος εὐδόξῳ Μιδᾳ
αὐτόν τέ νιν Ἑλλάδα νικάσαντα τέχνᾳ, τὰν ποτε
Παλλὰς ἐφεῦρε θρασεῖαν <Γοργόνων>
οὔλιον θρῆνον διαπλέξαισ' Ἀθάνα·

(I pray you to) receive this crown from Pytho offered by famous Midas and welcome the man himself, who defeated Hellas in the art (*sc*. αὐλετικὴ τέχνη) which Pallas once invented by plaiting/weaving together into music the Gorgons' deathly dirge

Telestes 806 *PMG* (Athen. 14.617b)
ἢ Φρύγα καλλιπνόων αὐλῶν ἱερῶν βασιλῆα,
Λυδὸν ὃς ἅρμοσε πρῶτος
Δωρίδος ἀντίπαλον μούσας νόμον αἰολομόρφοις
πνεύματος εὔπτερον αὔραν ἀμφιπλέκων
καλάμοις
3 νόμον Dobree αἰολομόρφοις Wilamovitz : νομοαίολον ὀρφναι cod.
or the Phrygian king of the fair-breathing holy pipes, who was the first to tune the Lydian *nomos*, rival of the Dorian muse, weaving/plaiting around it [*sc*. Λυδὸς νόμος] on his reeds of quick-moving forms the well-fledged breeze of his breath

Pind. *Nem*. 4.44-47
ἐξύφαινε, γλυκεῖα, καὶ τόδ' αὐτίκα, φόρμιγξ,
Λυδίᾳ σὺν ἁρμονίᾳ μέλος πεφιλημένον 45
Οἰνώνᾳ τε καὶ Κύπρῳ, ἔνθα Τεῦκρος ἀπάρχει
ὁ Τελαμωνιάδας·
Right now, sweet phorminx, weave out this song too in Lydian *harmonia*, one beloved by Oinona and Cyprus, where Teucros rules in exile, the son of Telamon.

Pla. *Resp*. 400a-c (Glaucon, asked by Socrates what the ῥυθμοί κοσμίου τε καὶ ἀνδρείου βίου (399e) are, answers the following)
ὅτι μὲν γὰρ τρί' ἄττα ἐστὶν εἴδη ἐξ ὧν αἱ βάσεις πλέκονται, ὥσπερ ἐν τοῖς φθόγγοις τέτταρα, ὅθεν αἱ πᾶσαι ἁρμονίαι, τεθεαμένος ἂν εἴποιμι
Based on what I have been studied, I may say that there are just three kinds of rhythms from which (all) the steps/movements are interlaced (woven together), just as in notes there are four, from which come all the *harmoniai*.
Cf. πλοκή as one of the subsections of the ἀπεργαστικόν in Lasus test. 14 Brussich = Marz. Cap. *De Nupt*. 9.936 with Lomiento 2004

Pherecydes of Syros, fr. 68 Schibli = 7 DK B2, P. Grenf. 2.11 Col. 1
κἀπειδὴ τρίτη ἡμέρη γίγνεται τῶι γάμωι, τό τε Ζὰς ποιεῖ φᾶρος μέγα τε καὶ καλόν, καὶ ἐν αὐτῶ[ι]
π̣ο̣ι̣χ̣[ίλλει Γῆν] καὶ Ὠγη[νὸν καὶ τὰ Ὠ]γηνοῦ [δώματα …
And when the third day of the wedding comes, then Zas makes a robe, great and beautiful, and in it he pattern-weaves Earth, Ogenos, and the houses of Ogenos …

Epicharmus 23 B1 DK = Diog. Laert. 3.10.4
αἰ πὸτ' ἀριθμόν τις περισσόν, αἰ δὲ λῇς πὸτ' ἄρτιον, | ποτθέμειν λῇ ψᾶφον ἢ καὶ τᾶν ὑπαρχουσᾶν λαβεῖν, | ἦ δοκεῖ κά τοί γ' <ἔθ'> ωὐτὸς εἶμεν; - οὐκ ἐμίν γα
'A. - If someone wants to add one stone (*psephos*) to an odd number, or for that matter to an even, or to take one away from those at hand, are you really of the opinion that the number still remains the same?' B. – 'Not at all'

Aristotle *Physics* 3.4 203a10-15 (cf. Ugaglia – Acerbi in *CQ* 2015)
καὶ οἱ μὲν τὸ ἄπειρον εἶναι τὸ ἄρτιον· τοῦτο γὰρ ἐναπολαμβανόμενον καὶ ὑπὸ τοῦ περιττοῦ περαινόμενον παρέχειν τοῖς οὖσι τὴν ἀπειρίαν· σημεῖον δ' εἶναι τούτου τὸ συμβαῖνον ἐπὶ τῶν ἀριθμῶν· περιτιθεμένων γὰρ τῶν γνωμόνων περὶ τὸ ἓν καὶ χωρὶς ὁτὲ μὲν ἄλλο ἀεὶ γὶγνεσθαι τὸ εἶδος, ὁτὲ δὲ ἓν·
And they [i.e. the Pythagoreans] said that the unlimited is the even. For when this is cut off, enclosed, and limited by the odd, it provides the things that are with the element of infinity. A sing of this is what happens to numbers: the gnomons being placed around the one and separately, now the species becomes continuously different, now it is one.'

Aristotle *Metaph*. 1092b8-13 καὶ ὡς Εὔρυτος ἔταττε τίς ἀριθμὸς τίνος, οἷον ὀδὶ μὲν ἀνθρώπου ὀδὶ δὲ ἵππου, ὥσπερ οἱ τοὺς ἀριθμοὺς ἄγοντες εἰς τὰ σχήματα τρίγωνον καὶ τετράγωνον, οὕτως ἀφομοιῶν ταῖς ψήφοις τὰς μορφὰς τῶν φυτῶν '… the way in which Eurytus assigned what is the number of what, for

example this one of man, and this one of horse, reproducing with pebbles the shapes of natural creatures, like those people who put numbers into figures, the triangle and the square..'

Euclid *Elements* VII deff. 6-16
ς΄. Ἄρτιος ἀριθμός ἐστιν ὁ δίχα διαιρούμενος.
ζ΄. Περισσὸς δὲ ὁ μὴ διαιρούμενος δίχα ἢ [ὁ] μονάδι διαφέρων ἀρτίου ἀριθμοῦ.
η΄. Ἀρτιάκις ἄρτιος ἀριθμός ἐστιν ὁ ὑπὸ ἀρτίου ἀριθμοῦ μετρούμενος κατὰ ἄρτιον ἀριθμόν.
ϑ΄. Ἀρτιάκις δὲ περισσός ἐστιν ὁ ὑπὸ ἀρτίου ἀριθμοῦ μετρούμενος κατὰ περισσὸν ἀριθμόν.
[ι΄. Περισσάκις ἀρτιός ἐστιν ὁ ὑπὸ περισσοῦ ἀριθμοῦ μετρούμενος κατὰ ἄρτιον ἀριθμόν].
ια΄. Περισσάκις δὲ περισσός ἀριθμός ἐστιν ὁ ὑπὸ περισσοῦ ἀριθμοῦ μετρούμενος κατὰ περισσὸν ἀριθμόν.
ιβ΄. Πρῶτος ἀριθμός ἐστιν ὁ μονάδι μόνῃ μετρούμενος.
ιγ΄. Πρῶτοι πρὸς ἀλλήλους ἀριθμοί εἰσιν οἱ μονάδι μόνῃ μετρούμενοι κοινῷ μέτρῳ.
ιδ΄. Σύνθετος ἀριθμός ἐστιν ὁ ἀριθμῷ τινι μετρούμενος.
ιε΄. Σύνθετοι δὲ πρὸς ἀλλήλους ἀριθμοί εἰσιν οἱ ἀριθμῷ τινι μετρούμενοι κοινῷ μέτρῳ.
ις΄. Ἀριθμὸς ἀριθμὸν πολλαπλασιάζειν λέγεται, ὅταν, ὅσαι εἰσὶν ἐν αὐτῷ μονάδες, τοσαυτάκις συντεθῇ ὁ πολλαπλασιαζόμενος, καὶ γένηταί τις.

Euclid *Elements* IX 21-34

κα΄

Ἐὰν ἄρτιοι ἀριθμοὶ ὁποσοιοῦν συντεθῶσιν, ὁ ὅλος ἄρτιός ἐστιν.

κβ΄

Ἐὰν περισσοὶ ἀριθμοὶ ὁποσοιοῦν συντεθῶσιν, τὸ δὲ πλῆθος αὐτῶν ἄρτιον ᾖ, ὁ ὅλος ἄρτιος ἔσται.

κγ΄

Ἐὰν περισσοὶ ἀριθμοὶ ὁποσοιοῦν συντεθῶσιν, τὸ δὲ πλῆθος αὐτῶν περισσὸν ᾖ, καὶ ὁ ὅλος περισσὸς ἔσται.

κδ΄

Ἐὰν ἀπὸ ἀρτίου ἀριθμοῦ ἄρτιος ἀφαιρεθῇ, ὁ λοιπὸς ἄρτιος ἔσται.

κε΄

Ἐὰν ἀπὸ ἀρτίου ἀριθμοῦ περισσὸς ἀφαιρεθῇ, ὁ λοιπὸς περισσὸς ἔσται.

κς΄

Ἐὰν ἀπὸ περισσοῦ ἀριθμοῦ περισσός ἀφαιρεθῇ, ὁ λοιπὸς ἄρτιος ἔσται.

κζ΄

Ἐὰν ἀπὸ περισσοῦ ἀριθμοῦ ἄρτιος ἀφαιρεθῇ, ὁ λοιπὸς περισσός ἔσται.

κη΄

Ἐὰν περισσός ἀριθμὸς ἄρτιον πολλαπλασιάσας ποιῇ τινα, ὁ γενόμενος ἄρτιος ἔσται.

κθ΄

Ἐὰν περισσὸς ἀριθμὸς περισσὸν ἀριθμὸν πολλαπλασιάσας ποιῇ τινα, ὁ γενόμενος περισσὸς ἔσται.

λ΄

Ἐὰν περισσὸς ἀριθμὸς ἄρτιον ἀριθμὸν μετρῇ, καὶ τὸν ἥμισυ αὐτοῦ μετρήσει.

λα΄

Ἐὰν περισσὸς ἀριθμὸς πρός τινα ἀριθμὸν πρῶτος ᾖ, καὶ πρὸς τὸν διπλασίονα αὐτοῦ πρῶτος ἔσται.

λβ΄

Τῶν ἀπὸ δυάδος διπλασιαζομένων ἀριθμῶν ἕκαστος ἀρτιάκις ἄρτιός ἐστι μόνον.

λγ΄

Ἐὰν ἀριθμὸς τὸν ἥμισυν ἔχῃ περισσόν, ἀρτιάκις περισσός ἐστι μόνον.

λδ΄

Ἐὰν ἀριθμὸς μήτε τῶν ἀπὸ δυάδος διπλασιαζομένων ᾖ μήτε τὸν ἥμισυ ἔχῃ περισσόν, ἀρτιάκις τε ἄρτιος ἐστι καὶ ἀρτιάκις περισσός.

Philolaus, 44 DK B4 (Stob. 1.217b)
καὶ πάντα γα μὰν τὰ γιγνωσκόμενα ἀριθμὸν ἔχοντι. οὐ γὰρ ὁτιῶν ⟨οἷον⟩ τε οὐδὲν οὔτε νοηθῆμεν οὔτε γνωσθῆμεν ἄνευ τούτου.
And certainly everything that is known possesses number. For it is not possible either to understand or to know anything without this.
6.1 Philolaus, 44 DK B5 (Stob. 1.21.7c) ὅ γα μὰν ἀριθμὸς ἔχει δύο μὲν ἴδια εἴδη, περισσὸν καὶ ἄρτιον, τρίτον δὲ ἀπ᾽ ἀμφοτέρων μειχθέντων ἀρτιοπέριττον· ἑκατέρω δὲ τῶ εἴδεος πολλαὶ μορφαί, ἃς, ἕκαστον αὐταυτὸ σημαίνει ‘Number certainly possesses two proper species, odd and even, and a third species

that comes from the mixture of both of these, even-odd. There are many forms (πολλαὶ μορφαί) of each of the two species, which each thing itself indicates (ἕκαστον αὐτὸ σημαίνει)

Plato *Pol*. 258d-e
ΞΕ. Ἆρ᾽ οὖν οὐκ ἀριθμητικὴ μὲν καί τινες ἕτεραι ταύτῃ συγγενεῖς τέχναι ψιλαὶ τῶν πράξεών εἰσι, τὸ δὲ γνῶναι παρέσχοντο μόνον;
ΝΕ. ΣΩ. Ἔστιν οὕτως.
ΞΕ. Αἱ δέ γε περὶ τεκτονικὴν αὖ καὶ σύμπασαν χειρουργίαν ὥσπερ ἐν ταῖς πράξεσιν ἐνοῦσαν σύμφυτον τὴν ἐπιστήμην κέκτηνται, καὶ συναποτελοῦσι τὰ γιγνόμενα ὑπ᾽ αὐτῶν σώματα πρότερον οὐκ ὄντα.
ΝΕ. ΣΩ. Τί μήν;
ΞΕ. Ταύτῃ τοίνυν συμπάσας ἐπιστήμας διαίρει, τὴν μὲν πρακτικὴν προσειπών, τὴν δὲ μόνον γνωστικήν.

VIS. Are not then arithmetic and certain other kindred arts separated (free, devoid of) from practical applications, while they only provide (the) knowledge?
YOUN. SO. Quite true.
VIS. On the contrary, the arts relating to carpentry and to the whole of handicraft possess the knowledge (science) as, in a sense, inherent and congenital to their applications, and together they bring to completion the corporeal substances proceeding form them, which did not previously exist.
YOUN. SO. To be sure.
VIS. In this way, then, divide all science into two, calling one practical, and the other one purely theoretical.

INNOVATION IN BOOK CRAFT IN ROMAN EGYPT

Between the 2nd and 4th centuries CE, the bookroll gradually made way for the codex as the most commonly used book form. Scholarship on book craft in antiquity has tended to focus on this transition, explaining the success of the new form by citing the efficient use of material and the practicality of its format, as well as early Christians' mass endorsement of the codex. Egyptian evidence unearthed in recent decades invites further study of the adoption of the codex (the standard works are still Turner 1977 and Roberts and Skeat 1983[1]), as well as wider research into innovation in book craft.

In this paper I explore three issues that may serve as starting points for such a larger project: (1) innovation in book craft beyond the codex; (2) local variation in the development of book production; (3) the effect of the new book form on the arrangement and transmission of literary texts.

In antiquity, the versos of literary texts were often re-used for documents or other literary texts, and we also find documents with literary texts on the back. Of a different kind, and few, are true opisthographs: rolls with one text (or multiple texts by a single author) on the recto continuing on the back, by the same hand. Finally, there is a neglected corpus of rolls with different texts in roughly contemporary hands on the two sides of the roll. A significant number of these contain paraliterary texts, and they may be evidence of an alternative innovation that emerged in educational contexts.

The evidence for the development of the codex has generally been regarded as a homogeneous data set, but data from individual sites suggests that developments in book production were to an extent locally defined. The test case of Antinoupolis shows that there, for unknown reasons, the parchment codex was most commonly used even for non-Christian literature as early as the 3rd century CE.

Finally, we may consider what the development of the codex meant for the transmission of archaic and classical authors. Features of the roll were inherited by the new form, such as the use of multiple narrow columns on the page, but the codex also created new possibilities for the juxtaposition of text and commentary, and the gathering of multi-roll corpora in single volumes. The effects of these new opportunities on the physical shape of literary texts have gone largely undiscussed in scholarship.

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[1] Later studies, such as Szirmai 1999 and Boudalis 2018, have focused on the physical make-up of (near-)complete codices, and have not considered the fragmentary remains published by different papyrus collections—this drastically reduces the available data.

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TITLE

Anchoring Political Change: Coins between Social Imagination and Contemporary Reality in the Greek World.

ABSTRACT

This paper discusses the use of coins to anchor political developments in the Greek world, exploring different case-studies from the late Classical to the Hellenistic periods. Since its inception, coinage occupied an increasingly important role both within political (civic) contexts and in interstate relations. Coins bore symbols specific to their issuing authorities to address the need to anchor the innovation of minting and circulation; soon, however, the coins acted as agents of civic expression, reinforcing local and/or civic identity. Coinage, in effect, became a means for both the confirmation and public declaration of authority.

The role of coinage as an expression of identity developed during the Classical period, next to the monetisation of the Greek economy, with ideological implications. However, it is during the Hellenistic period that the increase of coin circulation greatly impacted the role of coins not only in actual economic but also in ideological terms. Coins, next to their intrinsic value, acted as social agents, conveying messages and reproducing narratives in a tangible, omnipresent way. Both the iconographical choices and their legends are intentional messages to internal and external audiences and, as such, they were heavily instrumentalised in the power struggle and competition among the different authorities, be they *poleis*, federal unions or Hellenistic rulers. It is during the Hellenistic period that the coins became one of the most visible expressions of identity, incorporating traditions, cultural memory and narratives of power in a single object, which was both meant to be circulated and could easily travel across the Hellenistic world.

The paper will discuss two locales from the Peloponnese, Megalopolis and Sparta, and Athens. Since the late Classical period and the foundation of Megalopolis, shortly after the defeat of the Spartans at Leuktra (371 BCE), the Megalopolitans minted coins with

clear links to the Arkadian past and the local minting tradition. These links are still attested and expressed in series minted in the Hellenistic period when Megalopolis was part of the Achaian *Koinon*. During the early Hellenistic period, the Spartans, under the reign of Areus I (c. 309-265 BCE), minted their first civic coins. This unconventional act opposed the Lykourgan legislation but also bore clear elements of Spartan traditions and aspirations for power – arguably an intentional act, part of the civic renewal of Areus. Finally, Hellenistic Athens, now free from Makedonian control (229 BCE) inaugurated a continuous series of 'new-style' Athenian Owls with issues from c. the first quarter of the 2nd century up to the sack of the city by Sulla (87/86 BCE).

What are the links between the iconographical choices and ambient political developments? In each case-study, coinage plays a central role in the expression of a political (and social) identity, and this is precisely under consideration in this paper. The common denominator in every case is the need to anchor political developments and enhance social coherence by appropriating anything new within the pre-existing, cultural memory. This 'intentional' narrative should be approached as a vivid expression of the collective imagination of every society which must, therefore, be disseminated to internal and external audiences.

STORIES IN GLASS: THE HISTORY OF INNOVATION IN IMPERIAL ANECDOTES

Serena Connolly - Rutgers University

A craftsman, proud at his discovery of a glass that would not break, brought his invention, in the form of a bowl, to the emperor. In a bold move, he pretended to drop it, and its infrangibility shocked the emperor. When the craftsman admitted that he alone knew how to produce the glass, his head was cut off. Why? Because an unbreakable glass would become more valuable than gold.

This well-known story of the unlucky craftsman, told in Petronius' *Satyrica* 51 (variants appear in Plin. *NH* 36.195 and Dio 57.21), is a tall tale that uses an innovation in technology to comment on contemporary circumstances; these are, I argue, the financial crisis of AD 33. An unbreakable glass would satisfy the high demand for glassware, rendering metalware—and precious metal currency too—less desirable and less valuable. The emperor, Tiberius, intending to solve the crisis with an injection of currency into the economy, realized that the invention would have thwarted his efforts; his execution of the craftsman was the only way to prevent the rapid and widespread adoption of unbreakable glass at such an economically critical moment.

This paper demonstrates that Tiberius' rejection of the craftsman's invention runs counter to the contemporary widespread adoption of rapidly appearing innovations in glass manufacture. It goes on to argue that the story (in its various forms) is probably not true, but rather may have arisen around the crisis and that it used unbreakable glass as its vehicle. This and several other attested tall tales – for example, those that present Nero as watching the games through a glass-like material (Plin. *NH* 37.64) and drinking water boiled and chilled in a glass (Plin. *NH* 31.40) – grew up around innovations in glass technology, as tends to happen with new technologies that fascinate the public. These stories, as presented in our sources, became for some ancient authors a means to reflect on the personalities of the emperors who rejected or embraced the technologies described in them. But if re-read in the context of the history of technology, they provide valuable insights into the social, political, and economic roles of technological innovation.

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Anchoring Technology in Greco-Roman Antiquity
9-11 December, 2020

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STORIES IN GLASS: THE HISTORY OF INNOVATION IN IMPERIAL ANECDOTES

This paper is concerned with anecdotes and technology, specifically with one anecdote that is told in three different ways, by different authors, at different times, and in quite different contexts. I should stress at the outset what these—and indeed all anecdotes—do not guarantee to do: and that is, tell the truth.

Instead, I will argue, an anecdote tells us what people thought about something or someone. In the case of the anecdote I will discuss, it purports to tell us about the Roman emperor Tiberius' response to a technical innovation, specifically an innovation in glass manufacture, an area that had been developing rapidly. It also helps us to see how people imagined that an emperor might respond to an innovation, and as we will see, Tiberius' response was swift and severe. While Tiberius' generally suspicious nature might provide a broad explanation for his reaction, we could search also for a more immediately compelling motivation. One possibility is the financial crisis of 33 CE; it would help to explain references in the anecdote to the disastrous effect of unbreakable glass on precious metals. The anecdote is first a vehicle for presenting Tiberius as controlling, even controlling of innovation and technology; second, it demonstrates the broader notion that sometimes authorities may obstruct innovation; and third, it provides an example of the fact that innovations could be regarded as dangerous.

The Anecdote in the Elder Pliny

Pliny devotes book 36 of his *Natural History* to stone and minerals. Towards the end, he surveys the history of glassmaking and different types of glass, before turning to the development of Volturno in Italy as a new site for glassmakers, where new raw materials and methods have resulted in a clear and colorless glass that has proven immensely popular.[1] Then comes Pliny's version of the story (*NH* 36.195): *Ferunt Tiberio principe excogitato vitri temperamento, ut flexile esset, totam officinam artificis eius abolitam, ne aeris, argenti, auri metallis pretia detraherentur, eaque fama crebrior diu quam certior fuit* ("They say that when Tiberius was emperor, after a craftsman had carried out investigations into producing a glass that would have the quality of pliancy, his entire workshop was destroyed so that the value of bronze, silver, and gold should not decline, and the frequency with which this story was told was greater than its credibility").[2]

A craftsman has produced some sort of new glass. What Pliny seems to be referring to is an unbreakable glass, though the lack of a thorough and technical precision here or in the other versions prevents us from a complete understanding of what is being described. An unbreakable glass is an impossibility, though that may not have been known in the first century.[3] The anecdote was perhaps inspired by witnessing the process of glass-blowing and from a belief that pliant molten glass was unbreakable;[4] alternatively, someone may have observed craftsmen producing cameo or relief work on

[1] On Pliny's treatment of glass manufacture in these sections of the *Natural History*, see Freestone 2008, especially 82-90.
[2] All translations, unless otherwise specified, are my own.
[3] The one exception is the Prince Rupert's Drop, for which the Corning Museum of Glass provides a visual demonstration at https://www.cmog.org/video/prince-ruperts-drop and description at https://www.cmog.org/article/prince-ruperts-drop-and-glass-stress. Modern glass products marketed as unbreakable either comprise glass panels reinforced with a thermoplastic interlayer or are made not of glass, but a composite of polycarbonate, acrylic, and other plastics.
[4] Stern 2007, 355-57, believes that the story developed around a much-embellished account of seeing molten blown glass dropped and reformed while still hot. See also Lattermann 2017, 2-3. Glassblowing provides an attractive explanation for the apparent problem that Pliny calls the glass *flexile*, pliable. I argue that he does this not in order to describe it as permanently pliable, but rather to liken it to the various woods that are pliant and can

glass by means of hammers, chisels, and files. Whatever it was that the craftsman produced, it was sufficiently different form other glass and sufficiently similar in its properties and desirability to precious metals that the emperor Tiberius had the entire workshop destroyed.

Pliny emphasizes the development of the new glass and on the workshop. The craftsman presumably lives, but his invention is killed off thanks, we might surmise, to the destruction of everything within the physical space where it has been developed and, as a consequence, the ability to make it again. A new and exciting development has now been stifled. The success of that glass would have had a serious consequence, so Pliny reports: non-frangible and beautiful, just like precious metals, the popular new product would have driven down the value of precious metals. Pliny doubts the story's credibility, though he does not specify why. Perhaps such glass was impossible to manufacture; perhaps the singularity of the invention was improbable; maybe the justification was far-fetched; or it was unlikely that Tiberius would have acted in this way.

Pliny introduces the story with *ferunt*, "they say", to emphasize that the story originates not with him but with unknown others. He is letting us know that it is not his story and also that he does not know the authors. He follows later with *fama*, signaling not only that he does not know the originators, but also that he does not trust what they have to say. Pliny chooses to use the Latin word *fama,* meaning a story or a tale, especially one that is of dubious credibility or one that is told by regular folk, by the masses, in large numbers.[5] And as he says, "the frequency with which this story was told was greater than its credibility" (*eaque fama crebrior diu quam certior fuit*). It was told a lot, either because it was believed, or because it was a good story to tell and enjoyable to hear. And it was told for longer,

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be bent to form objects, such as baskets, that then hold a rigid form (for references, see n. 2, above). Similarly, the glass is easily manipulated, through blowing or molding, into whatever form the craftsman requires. Pliny (*NH* 36.198) also describes molten blown glass as *sequax*: *nec que est alia nunc sequacior materia* ("and now there is no other material more pliable"), a term he uses also of woods (e.g. *NH* 11.127 and 16.174), which he otherwise calls *flexilis* (e.g. *NH* 16.74, 209, and 219).

[5] See *TLL*, s.v. "*fama*," II and *OLD*, s.v. "*fama*," 2 and 3.

suggesting that this was a popular story. Pliny, for one, does not believe it, though he still includes it. After all, it is a good story.

Tiberius' reaction is severe: Pliny tells us that the entire workshop is destroyed. The anecdote leads us to believe that the discovery really was an important one, and consequential too: Pliny emphasizes the metals, spelling out for us that the values of bronze, silver, and gold would have been dragged down as a result of that glass. Could a discovery have such an impact?

Pliny likes to tell stories, and some, like this one, have technology as their focus. They are entertaining and, amid technical discussion, as here, they provide light relief.[6] They can also use technology to reflect on contemporary events. It turns out that this story—in its various versions—is perhaps the earliest example of stories featuring "the improved product," a product markedly better than any created before, one that promises or threatens to be revolutionary.[7] Henrik Lassen, scholar of English literature, explored these in a widely cited article from 1995, which you will find in the bibliography.

Here's a salient and relatively recent example that Lassen reports: tales circulated in the U.S. during the fuel crisis of the 1970s, that inventors had redesigned cars to run with extraordinary fuel efficiency, even 200 miles per gallon, which would have been a boon to drivers.[8] The possibility of these marvelous cars has been debunked. But the untimely deaths of some of their inventors have fueled claims that car manufacturers, the oil industry, perhaps the government were trying to keep these inventions a secret. The reason, so it was believed, was that these parties believed the re-tooled cars would destroy the car industry, or perhaps would destroy the economy: the impact on gas consumption and tax revenues would be immense. According to the anecdote that Pliny reports, the invention of unbreakable glass had to be destroyed because of its negative impact on the value of precious metals.

[6] On Pliny's story-telling, see for example Darab 2012.
[7] Lassen 1995.
[8] Crewdson 1978, Haitch 1979, and White 1995.

The period from 50 BCE through the end of the first century CE saw an increase in the volume and geographical spread of glass production as it grew in popularity, as well as major developments in glass technology.[9] During the Julio-Claudian period, the cost of some types fell sufficiently that Strabo (*Geog*. 16.2.25) even claims glass bowls and drinking cups could be bought at Rome for a copper coin, though this is probably exaggeration. In Petronius' *Satyrica* (50), Trimalchio claims: *ego malo mihi vitrea...quod si non frangerentur, mallem mihi quam aurum; nunc autem vilia sunt* ("I love glass...except that it breaks, I would prefer it to gold; but at least it is cheap").

Perhaps, if an unbreakable glass had been widely produced, it could have satisfied the popular demand for glassware and glass. Indeed, the new glass might have become so popular that people would prefer it to that other beautiful and non-frangible material: metal. Pliny (*HN* 36.198-99) supports that suggestion when he tells us that glass that is "white and translucent, however, has the highest value, which is the closest in likeness to crystal. Its use in drinking vessels has displaced that of silver and gold" (*maximus tamen honos in candido tralucentibus, quam proxima crystalli similitudine. usus eorum ad potandum argenti metalla et auri pepulit*). Indeed, in the anecdote, Pliny specifies which metals are at risk (*aeris, argenti, auri metallis*), spelling out for us that the values of bronze, silver, and gold would have been dragged down (*pretia detraherentur*) as a result of that glass.

[9] See the helpful surveys in Tatton-Brown 1991, Stern 2002, and Prior 2015, 21-36. Among roughly contemporary innovations in glass, the Elder Seneca (*NQ* 1.6.5) describes glass pebbles filled with water that were being used as magnification aids: "I said just now that aids to vision were being made, which could enlarge the image of an object. I will add this: that everything is much larger when seen through water. And so letters, no matter how tiny and unclear, can appear larger and sharper through a glass ball that is filled with water" (*Dixi modo fieri specula, quae multiplicent omne corpus, quod imitantur. Illud adiciam, omnia per aquam videntibus longe esse maiora: litterae quamvis minutae et obscurae per vitream pilam aqua plenam maiores clarioresque cernuntur*). Krug 1987, 461, points out that Seneca believed that magnification was achieved thanks to the water, not the glass that surrounded it. Pliny (*HN* 37.10.28) also states that glass was being employed by doctors to magnify the sun's rays and so aid in cauterizing: "I find that among doctors that, when they need to cauterize a body, they think nothing is more useful than crystal balls held against the rays of the sun" (*invenio apud medicos, quae sint urenda corporum, non aliter utilius uri putari quam crystallina pila adversis opposita solis radiis*). Pliny (*HN* 36.67.199) records the same technology causing clothing to burn: "Glass balls, when filled with water and held against the sun, become so heated that they can burn clothing" (*cum addita aqua vitreae pilae sole adverso in tantum candescant, ut vestes exurant*).

The collocation *aes argentum aurum*—bronze, silver, gold—appears elsewhere. It was used in the title of officials who oversaw the mints, as Probus (*De Notis Iuris* 3.11.1) records in his expansion of the abbreviation *AAAFF*: *aere argento auro flando feriundo* ("the casting and striking of bronze, silver, gold." The collocation appears also in a letter of Cicero to Trebatius (*Ad Fam*. 7.13.2; Shackleton-Bailey 36.2): *sed ut ego quoque te aliquid admoneam de vestris cautionibus, Treviros vites censeo. audio capitalis esse; mallem aere argento auro essent* ("I advise you to keep clear of the Treviri—I hear they are capital customers, like their Roman namesakes. If you want a Board of Three, better try the ones in charge of bronze, silver, gold!").[10] Here Cicero refers, in a shorthand form, to the mint officials as the *tresviri aere argento auro*. Pliny may be using the collocation in his anecdote to refer to coinage, just as Cicero had done; elsewhere, and sometimes with variation, Pliny and others use the collocation in lists of precious metals that are mined and will be worked into luxury objects. So, for example, as Pliny tells us (*NH* 3.30) *metallis plumbi ferri aeris argenti auri tota ferme Hispania scatet* ("nearly all of Spain is rich in mines of lead, iron, copper, silver and gold"), and referring now to Italy (*NH* 37.202), *metallis auri, argenti, aeris, ferri, quamdiu licuit exercere, nullis cessit terries* ("no territory outdid this one in gold, silver, copper or iron, as long as it was permitted to mine them").[11] But even if Pliny is thinking here of luxury objects, rather than coins, he is still focused on their intrinsic value: *ne*...*pretia detraherentur* ("lest their value decline"). The noun-verb combination *pretium detrahere*, with its notion of dragging down value, appears elsewhere often in economic discussions of the market value of items.[12]

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[10] Trans. Shackleton-Bailey, adapted.

[11] See also Plin. *NH* 2.158 (*auri argentique . . . et aeris*), 35.9 (*auro argentove, at certe ex aere*); 21.5 (*aerea inaurata aut inargentata*), 33.126 (*quantum auri sit in ea, quantum argenti vel aeris*). Unsurprisingly Pomponius Mela (2.78): *viris equis ferro plumbo aere argento auroque etiam abundans*. The inclusion of *etiam* suggests that the final three items are to be taken as a discrete phrase. See also Cic. *ND* 2.151 (*aeris argenti auri*); Livy 45.33.5 (*ex auro et argento et aere et ebore*); Ov. *Am*. 3.8.37-38 (*aeraque et argentum cumque auro*); Quint. *Inst*. 2.21.9 (*auro argento aere ferro*)*;* Apul. *Met*. 11.10.6 (*aereis et argenteis immo uero aureis etiam)*.

[12] For example, Pliny, *NH* 33.159.3-4: *Tertium genus est pressum, quod alii Scyricum vocant, ex insula Scyro, iam et ex Achaia, quo utuntur ad picturae umbras, pretium in libras HS bini; dupondiis vero detractis quod lucidum vocant, e Gallia veniens* ("The third kind is deep in color, which some call Scyric, coming from the island of Scyros, and today it comes from Achaia too, which they use for the shading in a painting, and the price is two sesterces per pound; there is a discount of two *asses* for the kind they call bright, which comes from Gaul"). The combination

The negative purpose clause *ne*...*pretia detraherentur* makes clear the reason for Tiberius' destruction of the workshop. But the reason is expressed with neither explanation nor motivation, and, as a result, seems oddly disconnected from what has come before: Tiberius has the craftsman's workshop destroyed because he is worried about the effect on precious metals. Yet Tiberius' concern with the value of bronze, silver, and gold is not stated.[13]

But if we knew the context for the anecdote, we might be able to understand the immediate motivation for Tiberius' severe reaction. Of course, we do not know the context: there simply is nothing explicit within the anecdote or in the narrative contexts of its various versions that places it in a specific contemporary event or moment. And yet when searching for such an event or moment, it is tempting to look to the financial crisis of the 33 CE. I should stress that positing the crisis of 33 CE as the context that gave rise to the anecdote is speculative; again, there is no evidence that explicitly sets the anecdote in the context of the crisis. But it may fit (and after all, the anecdotes of the miraculous fuel-efficient cars were likewise born of economic crisis). Moreover, if we do not set the anecdote within the crisis, then

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appears also in Col. *DRR* 8.17.15.10: *Nam nisi piscis domini cibariis saginatur, cum ad piscatorium forum perlatus est, macies indicat eum non esse libero mari captum, sed de custodia elatum, propter quod plurimum pretio detrahitur* ("For unless a fish is fattened with food provided by its owner, when it is brought to the fish-market, its leanness shows that it has not been caught in the open sea but brought out of a place of confinement, and on this account a large sum is knocked off the price"; trans. Forster & Heffner).
Sen. *De Ben.* 4.29.3.1 uses *pretium detrahere* to give economic coloring to a discussion of the exchange of reciprocal gifts or favors: *Quis beneficium dixit quadram panis aut stipem aeris abiecti aut ignis accendendi factam potestatem? Et interdum ista plus prosunt, quam maxima; sed tamen vilitas sua illis, etiam ubi temporis necessitate facta sunt necessaria, detrahit pretium* ("Whoever called a morsel of bread a benefit, or tossing anyone a copper, or enabling him to get a light? And sometimes these are more helpful than very large gifts; yet, for all that, their cheapness detracts from their value even when the necessity of the moment has made them necessities"; trans. Basore).

[13] According to Murphy 2004, 201, "Whether or not the story is true, it reflects the idea of the emperor as the final arbiter of what was permitted to be known. This story is significant because it is so explicit about the dangers that might follow if the emperor failed to control strictly the progress of new knowledge into public... The knowledge which Tiberius restricted...menaced the established order of money and property." Murphy does not connect the story to 33 CE, but instead considers it in the broader context of the emperor as the "centre of knowledge." Crum 1952, 166-67, provides later examples of rulers who purportedly destroyed inventions and/or their creators in order to prevent the spread of knowledge and also as manifestations of their own power. Champlin 2008, 413, tracing stories that portray Tiberius as a wise ruler, takes a different approach, noting that "where Tiberius is merely jealous of the craftsman he executes, the prudent 'Caesar' acts in statesmanlike manner to save the economy of his empire from collapse."

the reference in Pliny's version of the anecdote to gold, silver, and bronze simply does not make sense. So, bear with me for a moment.

According to several ancient sources, the year saw a confluence of severe economic problems, of which Tacitus (*Ann*. 6. 16-17) provides the fullest account.[14] As he records, *magna vis accusatorum in eos inrupit qui pecunias faenore auctitabant adversum legem dictatoris Caesaris* ("a great force of accusers unleashed against those who were in the business of making money, through usury, in contravention of a law of the dictator Caesar"). In response, the emperor offered a grace period within which new and existing loan agreements had to be revised, in accordance with the law. But, as Tacitus tells us, *hinc inopia rei nummariae, commoto simul omnium aere alieno, et quia tot damnatis bonisque eorum divenditis signatum argentum fisco vel aerario attinebatur* ("because of this, there was a shortage of cash, as everyone's debts were called in; and because so many people's property was subject to condemnation or auctioned off, the money realized was held by the imperial or public treasury").

Tacitus continues that the Senate, in response, required lenders to invest two-thirds of their capital in land. This measure had several results: first, lenders called in their debts, leaving borrowers in financial peril, many of whom lost properties; second, the real estate market was flooded with properties, which were bought up by former lenders, whose working capital was thereby redistributed and concentrated among a few purchasers (mostly other lenders and the government), thus reducing the extent of its circulation. Tacitus continues: *eversio rei familiaris dignitatem ac famam praeceps*

[14] Suetonius (*Tib.* 48) has the following brief account:

> *Publice munificentiam bis omnino exhibuit, proposito milies sestertium gratuito in trienni tempus… Quorum alterum magna difficultate nummaria populo auxilium flagitante coactus est facere, cum per senatus consultum sanxisset, ut faeneratores duas patrimonii partes in solo collocarent, debitores totidem aeris alieni statim solverent, nec res expediretur*.
> He demonstrated his generosity to the public twice in all: when one hundred million sesterces were distributed free for a three-year period… He was compelled to do this by the considerable lack of money among the people, who were clamoring for help, since no relief had been brought by a decree of the senate that lenders must invest two-thirds of their capital in land and that debtors must pay off the same proportion of their debts immediately.

There is an account also in Cassius Dio 58.21.4-6.

dabat, donec tulit opem Caesar disposito per mensas milies sestertio factaque mutuandi copia sine usuris per triennium ("The upheaval to assets plunged families' status and reputations downward, until the emperor brought relief by distributing one hundred million sesterces among the banks and by making available three-year, interest-free loans").

Scholarly attempts to explain what exactly was happening during the crisis of 33 CE have been hampered by the nature of our ancient evidence, written as it was by historians, not economists, and by attempts, some of them anachronistic, to fit what little evidence we have into modern economic explanations.[15] Yet most scholars agree, following our ancient sources, that there was a monetary crisis; that liquidity was constrained because too much cash was held in the treasury or by private individuals; and that in an attempt to end the crisis, Tiberius apparently released a large amount of metal currency to be used for loans.[16]

If we situate the anecdote in the context of the financial crisis, we might infer that it imagines Tiberius destroying an unbreakable glass because a rush away from precious metal objects—both coins and luxury items—to an unbreakable glass might cause the value of metals to drop before he had time to draw on his reserves and inject cash into the economy.[17] As a result, he would be unable to solve the crisis.

[15] This is the complaint of Elliott 2015. Key scholarship on the crisis includes Frank 1935, Crawford 1970, Rodewald 1976, Lo Cascio 1981, Duncan-Jones 1994, 23-25, Schartmann 2012, and now especially Elliott 2020, 90-96. Some scholars situate accounts of the crisis in contemporary politics and downplay the notion that there was a monetary crisis, emphasizing instead confiscations of usurers' property and the role of informers. I follow Elliott 2020, who argues that there was a monetary crisis and that Tiberius' response was purposeful.

[16] Duncan-Jones 1994, 25, reports that coin output increased around 33, probably in response to the financial crisis; Butcher and Ponting 2015, 184, are not persuaded.

[17] In theory, as precious metal coins lost their value, people would shun an over-valued metal currency and prefer to buy and sell through barter. Vendors might in turn raise their cash prices and trigger inflation. (Such over-valuation of hard metal currency is similar in effect to its debasement.) On the relationship between coinage supply and value, see the helpful summary in Hitchner 2009, 282-83. With a dearth of hard metal currency in the economy, Tiberius would have felt compelled to draw on his reserves to inject cash, though his reserves would have lost value. Hitchner (p. 284) points out that Tiberius was not offering a loan, but rather "a large private aristocratic injection of cash," a difference that might explain his anger at being potentially undermined.

But is the anecdote realistic? Could an unbreakable glass—if such existed—have had such a significant effect on the value of precious metals? In theory, it could have become hugely popular, perhaps so popular that people might sell their precious metal decorative items, replacing them with unbreakable glass objects; as a result, metal currency would lose value.[18] Yet this outcome is improbable. A loose analogy would be that every car owner in the 1970s replaced their existing cars with new marvelously fuel-efficient models and, in so doing, cut their gas consumption by 90%. That scenario is possible, though unlikely, especially because it would require that a change in cars happened so quickly that the government, oil companies, and other car manufacturers had no time to respond. The outcome that the anecdote has Tiberius fearing was unlikely, and the story as a whole is implausible.

Despite its implausibility, the anecdote continued to be told, for two reasons, I argue. First, because it was entertaining and second because it resonated as an illustration of Tiberius as someone who meddled in technologies and who was paranoid and suspicious. The theme of Tiberius the meddler is emphasized in Petronius' retelling of the anecdote; the emperor's paranoia and suspicion come to the fore in Cassius Dio's version.

Trimalchio's Two Stories

In Petronius' *Satyrica*, Trimalchio, the loutish freedman, has been showing off his wealth. Pointing to a dish, he declares jokingly that he is the only owner of real Corinthian ware: after all, the person who made his dish is called Corinthus. He then (*Sat*. 50) tells everyone the origin of Corinthian ware:

[18] An objection to this possibility is that an unbreakable glass would not necessarily have affected the value of precious metals: if the costs of manufacturing were low, unbreakable glass would compete with clay objects, perhaps bronze too, rather than silver and gold, and it would have little appreciable effect on the macro-economy. Ancient authors—and their various sources—may not have understood this, and besides the anecdote is made more effective if the consequences of an unbreakable glass are exaggerated.

> *Cum Ilium captum est, Hannibal, homo vafer et magnus stelio, omnes statuas aeneas et aureas et argenteas in unum rogum congessit et eas incendit; factae sunt in unum aera miscellanea. Ita ex hac massa fabri sustulerunt et fecerunt catilla et paropsides <et> statuncula. Sic Corinthea nata sunt, ex omnibus in unum, nec hoc nec illud.*
>
> When Troy was captured, Hannibal, that trickster and great rogue, gathered up all the statues—bronze and gold and silver—onto one pyre and set them alight; they were turned into one bronze mix. And so craftsmen drew from that mass and made plates, dessert dishes, and little statues. That's how Corinthian ware was born, from everything turned into one, neither one thing nor the other.

At the fall of Troy, the trickster Hannibal gathered up all the sculptures, *omnes statuas aeneas et aureas et argenteas*, and melted them down; the result was a new metal: Corinthian bronze. Trimalchio then complains that metal smells; he would prefer glass, except that it breaks. His version of the anecdote of unbreakable glass follows (*Sat*. 51):

> *Fuit tamen faber qui fecit phialam vitream, quae non frangebatur. Admissus ergo Caesarem est cum suo munere, deinde fecit reporrigere Caesari et illam in pavimentum proiecit. Caesar non pote valdius quam expavit. At ille sustulit phialam de terra; collisa erat tamquam vasum aeneum. Deinde martiolum de sinu protulit et phialam otio belle correxit. Hoc facto putabat se coleum Iovis tenere, utique postquam illi dixit: 'Numquid alius scit hanc condituram vitreorum?' Vide modo. Postquam negavit, iussit illum Caesar decollari: quia enim, si scitum esset, aurum pro luto haberemus.*
>
> But there was this craftsman who made a shallow glass bowl, which could not be broken. And so he was given an audience with Caesar with his gift; then he made to hand it to Caesar, but threw it onto the ground. Caesar could do nothing but be thoroughly afraid. But the craftsman picked up the bowl from the ground; it had been

> dented as if it were a bronze vase. Then he brought out a little hammer from his cloak and with effort did a good job of correcting it. Having done this, he thought that he had Jupiter by the balls; at any rate the emperor said to him afterwards: "No one else knows about this hardening of glass, do they?" And just look. After he said no, Caesar ordered his head taken off: because, you see, if the invention became known, gold would be worth dirt.[19]

A craftsman has made unbreakable glass; he has an audience with the emperor, and the emperor, horrified at the possibility of an unbreakable glass, has the craftsman executed. Because, you see, gold would be worth dirt.[20]

The story of Corinthian bronze is a double of the story of unbreakable glass. First, there are two tricksters: Hannibal and the craftsman. Inclusion of the tricky craftsman reflects a perception of secrecy around technology and a perception too that craftsmen were secretive, tricky, and sly, seeking to get one over on others, even emperors. The audience between the craftsman and Tiberius does not go as either expects. The craftsman goes to hand his creation, the glass, to Caesar. But then he drops it; then hammers it back into shape; and is pleased with himself. He is trying to trick the emperor, to confuse

[19] Isidore of Seville, *De vitro, Etymologiae* 16, 16.6, and John of Salisbury, *Policraticus* 4.5, both offer expansions of the version told in the *Satyrica*.

[20] The fictional context of Petronius' version has led to literary interpretations of the story: some scholars have interpreted the story as having magical or superstitious elements. Schmeling 2011, 212, for example, claims that the emperor "is terrified at first because breaking the glass bowl will bring bad luck," and references Artemidorus 1.66, who tells us that in dreams a glass cup signals bad luck because of its frangibility, while a cup of metal (or horn) brings good luck because it cannot be broken. It is unclear, however, whether presentation of a glass cup should threaten bad luck outside of a dream. According to Borghini 1990, the story centers on the magical figure of the craftsman who, when he breaks the glass that he offered the emperor, will conjure bad luck for him. When the apparently frangible glass does not break, the craftsman appears to have thwarted bad luck, and is punished by the emperor for his hubris. For Horsfall (1989, 195-96), the story is a "tall tale." Champlin 2008, 411, puts the story into the context of myth-making, specifically the construction of types of myths and their employment as "monarchical stereotypes" (p. 414) in accounts of the life of Tiberius. Šubrt 2017 offers the attractive argument that Petronius uses the story ironically to contrast Trimalchio's economic interests and savvy, despite his lack of education, with the unworldliness of well-educated elites.

him, and he is trying to catch him off-guard. He is overly confident, making the emperor seem inferior, and he is using technology to do it.

Tiberius reacts to the tricky craftsman with fear. He asks him: "No one else knows about your hardening of this glass, do they?" (*Numquid alius scit hanc condituram vitreorum?*). This is not a straight question: the Latin *numquid* is used when a negative answer is expected, or it can suggest to the questionee that the questioner is anticipating a negative answer.[21] When the solicited negative answer comes back from the craftsman, the emperor nevertheless reacts by having him beheaded. The emperor responds to the craftsman's invention—and his superiority too—by having him executed. In this anecdote, technology is a source of fear and disruption.

The two stories are doubles also because they are both impossible. Corinthian bronze was not first discovered at Troy, and Hannibal certainly was not involved. Though even good sober Pliny the Elder does not discount the notion that Corinthian bronze originated in the Roman sack of Corinth in 146 BCE, as gold, silver, and bronze votive objects melted: (*NH* 34.3 and 34.6): *quondam aes confusum auro argentoque miscebatur...Ex illa autem antiqua gloria Corinthium maxime laudatur. hoc casus miscuit Corintho, cum caperetur, incensa* ("At one time, bronze was melted and mixed together with gold and silver...From those bronzes which were famed years ago, the Corinthian is most highly praised. An accident mixed it together at Corinth, when the city was seized and burned").[22] In the early first century, there was genuine confusion about the origins of Corinthian bronze: Petronius has Trimalchio

[21] Pinkster 2015, 328-30.

[22] On the story, see McDermott 1962, 146. The same story appears in Florus (*Epit*. 1.32.6-7 (B.ii.16)):

> *Quantas opes et abstulerit et cremaverit, hinc scias, quod quidquid Corinthii aeris toto orbe laudatur incendio superfuisse comperimus. Nam et aeris notam pretiosiorem ipsa opulentissimae urbis fecit iniuria, quia incendio permixtis plurimis statuis atque simulacris aeris auri argentique venae in commune fluxerunt*.
>
> How great was the wealth which was plundered or burnt may be judged from the fact that we are told that all the Corinthian bronze-work, which enjoys so high a repute throughout the world, was a survival from the conflagration. For the damage inflicted on this rich city in itself caused a higher value to be placed upon Corinthian bronze, because, by the melting together of countless statues and images by the flames, brass, gold and silver ore were fused into one common mass. (Trans. Forster).

get the story "wrong", except that perhaps no one was sure of what the right story was.[23] The reference to Hannibal as a trickster suggests that Petronius doubted the story; notice too "*aeneas*"—his readers must surely have groaned at that pun. The story of a glass that cannot be broken (*non frangebatur*) and that, once dropped and dented, can be mended (*correxit*) by means of a light hammer, just like metal, is also factually inaccurate.[24]

Finally, the stories are doubles of each other because both feature Tiberius' intervention. We will need to do some work to identify his presence in the first, and Suetonius (*Tib*. 34) will help: *Corinthiorum vasorum pretia in immensum exarsisse tresque mullos triginta milibus nummum venisse graviter conquestus, adhibendum supellectili modum censuit annonamque macelli senatus arbitratu quotannis temperandam* ("complaining bitterly that the value of Corinthian-ware vases had skyrocketed and that three mullets had been sold for thirty thousand sesterces, he decided that there should be a limit on household decoration and that market prices should be regulated annually, as the senate should see fit"). Tiberius was concerned at the sky-high prices being charged for Corinthian ware and, as a result, proposed that household decorative items be reined in. Suetonius supplies no additional detail, but his explicit reference to Corinthian ware suggests that Tiberius had let it be known that he was unhappy at the prices being charged for it, and that those prices were the impetus for broader action against high-priced decorative items. Petronius has Trimalchio tell the story of his own Corinthian ware perhaps as an illustration of just the sort of acquisitive passion and boasting that led to the mania that

[23] After all, there was bronze from Corinth, there was Corinthian bronze produced in Corinth, and there was Corinthian bronze from outside of Corinth. All of these were being presented as "*aes Corinthium*." (On the various ancient definitions of Corinthian bronze, see Jacobson and Weitzman 1992.) So why not have one's own version: that is authentic because it is made by a man called Corinthus. Plutarch *Mor*. 395b also has versions of the Corinthian bronze story, though he disbelieves them: only one house destroyed, not the entire city; or craftsman trying to disguise some gold he has, adds an alloy coating.

[24] McDermott 1962, 144-45, explains Petronius' reference to the hammer thus: "Those ignorant of the technique of making glassware apparently believed that, when the glass vases were decorated with figures in relief, they were made by hammering." A hammer can also be used to work heated glass pliant through heating and blowing.

prompted Tiberius' response.[25] The story that follows, of unbreakable glass, sees Tiberius imagined as reacting to another technological innovation, for which high prices might be charged and for which there could even be a similar mania.[26]

Both Pliny and Petronius emphasize the imagined economic significance of an unbreakable glass in order to explain Tiberius' reaction to the craftsman and his invention. The anecdote may perhaps have originated in the crisis of 33 CE and been further inspired by Tiberius' reaction to rising prices for Corinthian bronze.

Cassius Dio and the Disruption of Hierarchy

The theme of technology as a source of fear and disruption is present in Cassius Dio's version, but he emphasizes still further the emperor's paranoia and suspicion.

As was the case with Petronius' version, so Dio's too has a lead up story that provides context. A portico in Rome had begun to lean; an architect or inventor solves the problem. Tiberius is not grateful, but jealous, making sure that the man's name is not made public; the emperor does give him money, but then expels him from the City (57.21.5-6):

[25] Klebs 1893, 665-68, provides an early argument for setting the dramatic action of Trimalchio's dinner in the reign of Tiberius. Yet Petronius may not be historically consistent: Courtney 2001, 7-8, observes that among the performers referred to by name during the dinner, at least one may have been active under Gaius.
Velleius Paterculus, in 30 CE, had also railed against the current craze for Corinthian ware. The date, only three years before the financial crisis, might reveal that the early 30s were a period of economic concerns for Tiberius, though, as Baldwin 1973, 46, notes, Cicero had already commented on the craze in the late Republic.

[26] The collocation of bronze, silver, gold appears in Petronius, altered slightly to bronze, gold, silver, in the story of Corinthian bronze that immediately precedes: *omnes statuas aeneas et aureas et argenteas in unum rogum congessit* ("he gathered up all the statues—bronze and gold and silver—onto one pyre"). Perhaps by means of this displacement of the collocation from the story of unbreakable glass to that of Corinthian bronze, Petronius is connecting the two stories of technological discoveries. After all, in the anecdote, Tiberius is imagined as thwarting unbreakable glass just after its discovery, perhaps—we might posit—for the sake of the economy and to resolve the debt crisis; and Tiberius reins in the prices for Corinthian ware perhaps also for economic reasons, perhaps also to stop indebtedness. Pliny (*NH* 37.49) also uses the collocation in his own version of the Corinthian bronze story: *in Corinthiis aes placet argento auroque mixtum* ("Corinthian ware is made by mixing bronze with silver and gold").

> κατὰ δὲ τὸν χρόνον τοῦτον καὶ στοὰ μεγίστη ἐν τῇ Ῥώμῃ, ἐπειδὴ ἑτεροκλινὴς ἐγένετο, θαυμαστόν δή τινα τρόπον ὠρθώθη. ἀρχιτέκτων γάρ τις, οὗ τὸ ὄνομα οὐδεὶς οἶδε (τῇ γὰρ θαυματοποιίᾳ αὐτοῦ φθονήσας ὁ Τιβέριος οὐκ ἐπέτρεψεν αὐτὸ ἐς τὰ ὑπομνήματα ἐσγραφῆναι), οὗτος οὖν ὅστις ποτὲ ὠνομάζετο, τούς τε θεμελίους αὐτῆς πέριξ κρατύνας ὥστε μὴ συγκινηθῆναι, καὶ τὸ λοιπὸν πᾶν πόκοις τε καὶ ἱματίοις παχέσι περιλαβών, σχοίνοις τε πανταχόθεν αὐτὴν διέδησε, καὶ ἐς τὴν ἀρχαίαν ἕδραν ἀνθρώποις τε πολλοῖς καὶ μηχανήμασιν ὀνευσάμενος ἐπανήγαγε. τότε μὲν οὖν ὁ Τιβέριος καὶ ἐθαύμασεν αὐτὸν καὶ ἐζηλοτύπησε, καὶ διὰ μὲν ἐκεῖνο χρήμασιν ἐτίμησε, διὰ δὲ τοῦτο ἐκ τῆς πόλεως ἐξήλασε.
>
> At about this time, when the largest portico in Rome had begun to lean, it was set upright in a miraculous way. An architect-inventor, whose name no one knows—because Tiberius, jealous of the man's miracle-working, did not give it out to be entered into the public records—that one who was never named shored up the foundations all around it so that they would not collapse completely and, winding wool and fabric wadding around all the rest of the portico, secured it on all sides with ropes; and he pulled it back again into its original position by means of many windlasses and helped by many men. And so at that time, Tiberius both held him in awe and was overly jealous of him; because of the first he honored him with money and yet, again, because of the second he expelled him from the City.

The man later returns and seeks to rehabilitate himself by impressing the emperor with an unbreakable glass (57.21.7):

> μετὰ δὲ ταῦτα προσελθόντος οἱ αὐτοῦ καὶ ἱκετείαν ποιουμένου, κἀν τούτῳ ποτήριόν τι ὑαλοῦν καταβαλόντος τε ἐξεπίτηδες καὶ θλασθέν πως ἢ συντριβὲν ταῖς τε χερσὶ διατρίψαντος καὶ ἄθραυστον παραχρῆμα ἀποφήναντος, ὡς καὶ συγγνώμης διὰ τοῦτο τευξομένου, καὶ ἀπέκτεινεν αὐτόν.

> Sometime later, when the man approached him and begged for forgiveness, he let drop before him, deliberately so, some glass cup, and although it was dented in some way or broken, the man worked at it with his hands and forthwith showed it anew, whole again. Because of this, while he hoped to receive forgiveness, the emperor had him killed.

Dio's two stories—of the architect and the portico, and of the inventor and his unbreakable glass—were presumably originally separate, but became conflated, perhaps by Dio, perhaps by one of his sources, a conflation made possible by the fact that the Greek ἀρχιτέκτων can be rendered not only architect, but also, thanks to its broad semantic range, as inventor, designer or artificer.[27] The two stories are centered on a person solving a technological problem: righting a leaning portico and producing a glass that will not break. Both stories contrast the powerless and good architect-inventor who does good and produces wonderous objects and, on the other, the bad emperor who is jealous, suspicious, and destructive. Tiberius reacts to the man and his two examples of technological prowess with angry jealousy, depriving the man of renown, liberty, and finally his life.

Yet the story is not so straightforward. The man is tricky: he begs for forgiveness, but then brings out the unbreakable glass cup and deliberately throws it down to the ground (καταβαλόντος τε ἐξεπίτηδες). He works at the damaged cup with his hands (ταῖς τε χερσὶ διατρίψαντος) rendering it again unblemished. The application of his hands—Dio keeps his description vague—might suggest some strange wonder-working; at least, that is the impression the man is giving. Then, voilà, he makes the cup whole again. His apparently marvelous abilities render him momentarily the superior of the two men; it is only with his death that power is restored back to the emperor, its rightful holder.

Dio omits any economic justification for Tiberius' response, and indeed his inclusion of the anecdote in the year 23 CE suggests that Dio (or his source) did not associate it or chose not to associate

[27] *LSJ*, s.v. ἀρχιτέκτων, A2.

it with the crisis of 33. His placement of it within the year 23 may suggest that he doubts its veracity: he includes it in a series of anecdotes meant to illustrate Tiberius' cruelty, especially towards senators (57.19.1-23.3), but places it immediately before his claim that Tiberius may not have been involved in the death of Drusus.[28] Dio's version of our anecdote shows Tiberius as paranoid and suspicious, but perhaps helps to rehabilitate him by supplying a justification: the emperor needed to kill the tricky craftsman in order to maintain his own power.

The anecdote, as told by Pliny, Petronius, and Dio, imagines a tricky craftsman and his potentially economically deleterious innovation in glass. Tiberius' destruction of the workshop or execution of the man reinforces characterizations of the emperor as cruel. Yet it might also imagine the emperor as a shrewd ruler who perceives that innovation can be dangerous and a threat to the status quo. Indeed, as Colin Elliott has recently argued, Tiberius' actions in 33 CE were motivated by concern for the economic status quo and also to preserve socio-political order.[29] Indeed, even Tiberius' detractors may have acknowledged that he was financially astute: Suetonius (*Cal*. 37.3) and Dio (59.2.6) report that Tiberius amassed a fortune during his reign, which Gaius subsequently squandered. This astuteness may be reflected in the anecdote.

Stories in Glass

The anecdote may have gained credibility thanks to other stories of unbreakable glass in circulation. Indeed, Pliny's version of the anecdote is followed by his claim (*NH* 36.195) that in the reign of Nero, only a brief time later, glass that people termed hard-as-stone was produced, and it commanded sky-high prices: *Neronis principatu reperta vitri arte, quae modicos calices duos, quos appellabant petrotos,*

[28] Dio 22.3: οὐ μέντοι καὶ πιστὸς ὁ λόγος ("and yet the story is not credible").
[29] Elliott 2020, especially 93.

HS VI venderet ("When Nero was emperor, a type of glass was found which could render two small beakers, which they call hard-as-stone, for sale for six thousand sesterces").[30] During the same period, we learn of Nero's notorious boiled-then-chilled water (Plin. *NH* 31.40): *Neronis principis inventum est decoquere aquam vitroque demissam in nives refrigerare*. ("The emperor Nero made this invention: boiling water and, in a glass, plunging it into snow and cooling it"). Perhaps the collocation *vitroque demissam* implies an unbreakable glass: a regular glass that has been heated to a high temperature and then plunged into cold snow should undergo thermal shock and shatter;[31] we might surmise that in Nero's reign, a type of glass—perhaps akin to a tempered or ceramic glass—was found or, more likely, was claimed to have been found that could withstand a sudden change in temperature.[32] In both cases, Nero is presented as embracing innovation; Tiberius, by contrast, is imagined as quashing it.

[30] Eggert 1991, 290, n. 39, and Hayward 2016, 94, have dismissed the validity of the process. Trowbridge 1930, 166, suggests that *petrotos* may also be interpreted as "a name for certain cups which perhaps looked like rock crystal," though this interpretation undermines the connection between the types of glass said to have been discovered under Tiberius and then Nero, both apparently unusually hard. Freestone 2008, 96-97, points out that, while Pliny may not present his material on glassmaking with the accuracy and precision that we today expect in order to understand a production process, when compared to archaeological evidence (which has been subjected to chemical analysis), Pliny's descriptions seem mostly accurate, or at least not completely wrong.
The passage quoted follows immediately after Pliny's version of the anecdote of Tiberius and the unbreakable glass. The passage is constructed as a rhetorical question introduced with *quid refert* ("what does it matter"), suggesting that Tiberius' destruction of the craftsman's facility was pointless: an unbreakable glass would anyway be produced again; if so, Pliny seems to have been convinced by the possibility of an unbreakable glass. Alternatively, he is dismissing the truth of the Tiberian story as the first example of unbreakable glass and privileges instead the Neronian for reasons unknown.

[31] Plin. *NH* 36. 199 attests to this problem: *est autem caloris inpatiens, ni praecedat frigidus liquor* ("but [glass] cannot tolerate heat, unless a cold liquid goes in first"). Martial, also aware of the problem, recommends earthenware as an alternative (12.74). On the story about Nero's water, see generally Woods 2009.

[32] Martial, in one of his riddling *Apophoreta* (14.94.2), will later refer to glass that can apparently withstand scalding water: *nostra neque ardenti gemma feritur aqua* ("Our stone-hardness is not shattered by scalding water"), concerning which Leary 1996, 155, reminds us that Romans mixed hot water into their wine. Dalby 2001, 76, understands Nero's technique as a development in public health: "Until Nero's time the only safe way to add water to wine was to add it recently boiled, still hot. The Romans knew this, although, unaware of microbes, they had no idea why it was. They liked to add ice to wine, and even carried snow to Rome and stored it there for the purpose, but they knew that it would sometimes make them ill. Nero's great idea was to boil water, to seal it in a jar, and then to embed the jar in the snow. This produced ice-cold water that was more or less sterilized, to add to wine, and I think it will be agreed that it was a significant contribution to human happiness, or at least to the happiness of those in Rome who could afford large quantities of snow in summer."

The anecdote of the craftsman and his unbreakable glass, told in three versions, does a lot of work: it helps us to see how innovations in technology could reflect contemporary society and perhaps even contemporary economics; it also helps us to understand how innovations were (mis)understood and how inventors were viewed by society; and finally it shows that emperors' reported responses to technology could be used to express sentiments about them. Those who heard the anecdote may have gasped at Tiberius' cruelty, but they may also have imagined an emperor who could foresee economic catastrophe in unbreakable glass.

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Of Myths and Machines:
Technology and Traditional Storytelling in Imperial Rome

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Since the 19th century, the development of technology in Antiquity has often been inscribed into the paradigm 'from *mythos* to *logos*', where it was seen as being emancipated from religion to constitute a new and independent, rational discipline.[1] Nowadays, however, critical voices can be heard about the idea proposing that, for most of Antiquity, technology was a procedure about which rational discourse was the rule. Scholars have studied aspects of the intersection between myth and technology mainly in terms of how specific technological themes and topics were formulated and imagined in ancient myths.[2] The present paper will approach the interaction between myth and technology from a different, yet complementary perspective. Indeed, ancient mythology is rich in tales about technological wonders made by divine craftsmen, but what is perhaps more striking is that many historical inventors crafted devices and mechanisms to illustrate or evoke the ancient myths.[3] This paper proposes to examine how such mythic narratives were mediated via such technological inventions and constructions during the time of the High Roman Empire (ca. 1st–2nd c. CE). How were myths meant to serve as familiar reference/anchor points for the intended audience? In what ways were they artistically transformed and conveyed? What were the intentions of the teller in this interaction, the expectations of the audience, the habits of tradition, the demands of context?

Exemplary is Hero of Alexandria's frequent use of mythological themes in his plans and designs of machines which used hydraulics and other mechanisms to make them move in complex and surprising ways.[4] What was the performative function of myth as embodied, live, enacted events conveyed through such technology (situated *behind* the scenes),[5] and how does it relate to the conceptual framework of ancient visual culture more generally (especially the principle of *enargeia*, visual 'vividness')?[6] What are the links with the experience of ancient spectacle and entertainment, in particular the world of ancient dramaturgy and its use of theatrical technologies?[7] What may have been the potential function and use of such machines in the context of scholarly debate (e.g., as a criterion for the plausibility of myths: cf. the technical-scientific strand of exegesis in Ps.-Heraclitus' *Homeric Problems*),[8] or the link with textual recitation and the rhetorical and literary practice of *ecphrasis* ('verbal description of a visual object/artwork')?[9] How do such technological devices relate to ancient cognitive belief

[1] E.g., Vernant 1983, 299, who speaks of a process of 'secularisation' of technical skills.

[2] E.g., Graf 1999, on the development of metallurgy; Lively 2006, on classical cyber myths; Devecka 2013, on mythic *automata* – self-moving machines – as a culture's expressions of utopian desire; Mayor 2018, on robots and artificial lifeforms. Similarly, in ancient natural scientific literature myth and the roles of gods and heroes are not completely rejected, even as rational philosophical accounts of nature are offered: see Taub 2008, 31-78.

[3] E.g., amazing *automata* enacting mythic scenes during religious processions: cf. Athenaeus, *Learned Banqueters* 5.196-203.

[4] Most notably his automatic theatres: e.g., the one that tells the myth of Nauplius in five scenic settings using all kinds of special effects (*On Making Automata* 2.20-30; for matters of source criticism, see Marshall 2003).

[5] See Beacham 2013.

[6] Cf. Kampakoglou – Novokhatko 2018.

[7] Especially the 'deus ex machina' and its many narratological-cum-mechanical manifestations; cf., e.g., Fiorentini 2013.

[8] See Russell – Konstan 2005, xxi-ii. Interestingly, the Greek word *automaton* appears for the very first time in the *Iliad*, where it is used of automatically opening temple doors on Mt Olympus (5.749, giving rise to a literary trope: Bur 2016, 28-32). Hero designed and described precisely such a self-moving device in his *Pneumatica* (1.38-9).

[9] Cf. Webb 2009, Roby 2016, Squire 2018.

systems (e.g., concepts of the supernatural and the overall religious and philosophical framework)?[10]

Answering questions such as these will considerably extend and meaningfully complement recent studies on ancient technology by drawing attention to its literary implications.[11] Exploring the literary significance of ancient technology may ultimately add a new, as yet unexplored, perspective to the controversy regarding the so-called *blocage* of ancient technology.[12] In this regard, the hypothesis that close ties with literary culture may have been more definitional to ancient technology than has been generally recognized so far deserves close consideration.[13]

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[10] Cf. Meineck 2017, Meineck et al. 2019.

[11] Especially those focusing on its philosophical and religious contexts: see Tybjerg 2000, 2003, Berryman 2003, 2009, Wikander 2008, McCourt 2012, Bosak-Schroeder 2016, Bur 2016.

[12] I.e. the idea that something 'blocked' the ancient mind and prevented it from making connections between technology and economy, or technology and wider applications, fiercely debated among historians of technology: see, e.g., Greene 1994, 2000, Cuomo 2007, 3-4, Oleson 2008, 5-6, Devecka 2013.

[13] That storytelling was, indeed, an important facet of ancient 'technology' more generally (not only mechanical technology) is perhaps most clear from Vitruvius' prescription that the well-educated architect "ought to know many stories" (*On Architecture* 1.1.5). Cf. also Ulrich 2008, 53-54, for technical representations of mythological materials more generally.

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