

DELTOS

Vol 33, No 51 (2023)

Deltos

DELTAOS JOURNAL FOR THE HISTORY OF MEDICINE
Athens • June 2023 • Volume 33 • Issue 51 • ISSN 2945-1205



Δελτος

Deltos ΠΕΡΙΟΔΙΚΟ ΤΗΣ ΙΣΤΟΡΙΑΣ ΤΗΣ ΙΑΤΡΙΚΗΣ
Αθήναι • Ιούνιος 2023 • Τόμος 33 • Τεύχος 51

Waxing lyrical: ancient medical authors on wax and wax tablets

Laurence Totelin

doi: [10.12681/dj.38106](https://doi.org/10.12681/dj.38106)

Copyright © 2024, Laurence Totelin



This work is licensed under a [Creative Commons Attribution-NonCommercial 4.0](https://creativecommons.org/licenses/by-nc/4.0/).

Waxing lyrical: ancient medical authors on wax and wax tablets

Laurence Totelin¹



Figure 1. Stone palette to mix ointments and two copper-alloy cylindrical medicine containers. The container on the right is made of four compartments, one of which was found to have contained a wax like the Punic wax. London, British Museum, 1968,0626.37. Licensed under a Creative Commons Attribution 4.0 licence.

Abstract

This short survey discusses some of the uses of wax in ancient medicine: it was a key pharmacological ingredient; it served to create models of surgical tools; and it was a support for the writing of ancient recipes. Physicians distinguished between different types of wax, some of which were considered more efficacious than others. Wax could be consumed orally, but most commonly entered in the production of salves (cerates).

Key Words: wax; writing tablets; surgical instruments; cerates

Introduction

The relaunch of *Deltos* invites us to reflect on the uses in ancient medicine of *deltoi*, writing tablets, and the wax with which they were filled. For wax was a key substance in ancient medicine, one that entered the composition of numerous remedies, especially of cerates.

Writing tablets and other *deltoi* in ancient medicine

In his *Commentary to the Sixth book of the Epidemics*, Galen described the way in which he thought some of the books of Hippocratic *Epidemics* had been compiled by Thessalus, Hippocrates' son:

τὰ γὰρ ἐν διφθέραις ἢ χάρταις ἢ δέλτοις ὑφ' Ἱπποκρά-

¹Cardiff University, School of History, Archaeology and Religion, Cardiff University, CF10 3EU

τους γεγραμμένα τὸν υἱὸν αὐτοῦ Θεσσαλὸν ἀθροίσαντά φασι ταυτὶ τὰ δύο βιβλία συνθεῖναι, τὸ τε δεύτερον καὶ τὸ ἕκτον, ἔνιοι δὲ καὶ τὸ τέταρτόν φασι.

They say that Thessalus, Hippocrates' son, collected what his father had written on leather sheets, or rolls of papyrus, or tablets, and composed two books, the second and the sixth books [of the Epidemics]; some also add the fourth (Galen, Commentary to the Sixth Book of the Epidemics 2.15¹).

Galen imagined that the *Epidemics*, and possibly other Hippocratic texts, had been written in short instalments, which would fit on supports that could accommodate a short amount of text². The wax tablet, the *deltos*, was one of these possible supports^{3,4}. It was made of wood that had been carved out to pour in wax; several tablets could be bound together by means of leather threads⁵. Archaeology has uncovered examples of such writing tablets, for instance recently at the Bloomberg site in London, as well as examples of styli, the implement used to write in the wax (Fig. 2)⁶. However, no medical example to date has been discovered. That is not to say that this was not a frequent support for medical writing. Indeed, its portability and relative ease of use would have made it an excellent support for taking notes in a clinical context.

In a medical context, the word *deltos* might also have referred to a pharmacological box. Indeed, the theologian Basil of Caesarea (fourth century CE) mentioned *deltoi* divided in many compartments (*polyptychos*) that contained numerous remedies (*Homilies*, edited in⁷). Such boxes are also well known archaeologically. They are rectangular, lidded boxes, divided into compartments, which could accommodate various types of medicinal preparations. They are variously made of copper alloy, silver, ivory or bone, and measure between 10 and 12cm in length, 6 and 7cm in breadth, and 2 and 3cm in height. The lid is either

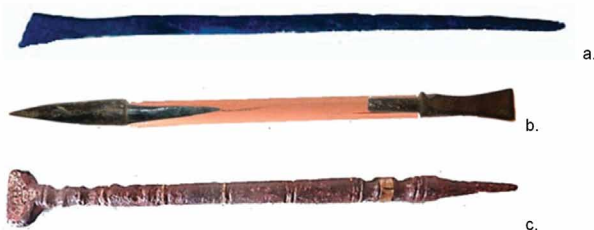


Figure 2. (a) Roman bronze stylus found in the River Fleet; (b) Roman stylus with a separate greenstone writing point and bronze eraser (the wooden shaft is modern); (c) a Roman bronze stylus with five gold bands found in the Roman Senate in the mid-19th century. Photos courtesy of the Museum of Writing Research Collection, University of London.

sliding or hinged⁸ (Fig. 3). The diminutive *deltarion* also appears to have designated such a pharmacological box or a medical instrument box^{9,10}. There are several representations of these boxes as medical toolboxes, including one on the sarcophagus of a physician from Ostia, who died in the early fourth century CE (New York, Metropolitan Museum of Art, 48.76.1) (Fig. 4). The toolbox rests opened atop a cupboard. It contains scalpels and other surgical tools. Pharmacological and surgical boxes were probably named *deltoi* because of their similarity to the writing tablets with which physicians were familiar.

Moulding instruments

Not only were medical cases called *deltoi* by analogy with wax tablets, but wax also served an important purpose in the creating of new surgical instruments according to a unique testimony from Galen:

θαυμάζειν οὐχ ὅτι καὶ ἀργυρίου καὶ χρυσοῦ καὶ ἀργυρωμάτων καὶ συμβολαίων πο<λ>λῶν ἀποκειμένων ἃ διεφθάρη κατὰ τὴν πυρκαϊάν ἀλύτως ὠφθη<ν> φέρων ἀλλ' ὅτι πλῆθος ἄλλο τῶν ὑπ' ἐμοῦ σε<σ>ω<ρ>ε<υ>μένων αὐτοῦ, φάρμακα δὲ παντοῖα πάμπο<λ>λα, τὰ μὲν ἀπλᾶ, τὰ δὲ συγκείμενα, καὶ ἄρμενα παντοδαπά, τὰ μὲν εἰς τὰς ἰατρικὰς ἐπιτήδεια



Figure 3. Brass pharmacological box divided into four compartments. Copy of a Roman original in the Naples Museum. London, Science Museum, A622298. Licensed under a Creative Commons Attribution 4.0 licence.



Figure 4. Roman sarcophagus from Ostia, ca. 300 CE, showing a physician reading a scroll, sat on a chair, next to a cupboard on top of which is an open box of surgical instruments. New York, Metropolitan Museum of Art, 48.76.1. Open Access.

χρείας ≤ά≥ μὲν οὖν ἔφην ἀπολέσας ἄλλα κτήσασθαι ἔτι ἐλπίζει≤ν>, τὰ δὲ ὑπ' ἐμοῦ [χρήματα] προσευρημένα [τῶν ἀρμένων] ὧν τὰ ὑποδείγματα πλάτ≤τ>ων αὐτὸς ἐκ κηροῦ τοῖς χαλκεῦσιν ἐδίδουν, ὡς οὐκ ἔτ' οἶόν τε σχεῖν ἄνευ χρόνου πο≤λ>λοῦ καὶ ἀσχολίας μεγάλης.

You were amazed that I was seen to bear without grief the destruction in the fire of my silver, gold, silverware, and many contracts that had been deposited there, but also of the further many things that I had stored there, namely numerous remedies of all sorts, some simple and some compound, and many kinds of instruments. Some instruments, useful for medical practice, I said that I had lost but I hoped to reacquire, but other instruments, which I had created myself, moulding models of wax myself before giving them to the bronze smiths, I cannot recover without much time and effort (Galen, Avoiding Distress 1.4-5, edited in¹¹).

Galen was here talking about the losses that he had endured in a great fire at Rome, when many of his possessions, left in storage near the Via Sacra, were burnt down¹². Among his losses were surgical tools that he had invented himself and brought in existence using the *cire perdue* (lost wax process) (11, Nutton¹³). Galen moulded models (*hypodeigmata*) of his tools, which he passed on to bronze smiths. The smiths then placed the wax model in clay, which they heated to harden the clay and melt the wax, which escaped through a hole and was therefore lost, hence the name of the technique. They then poured copper alloy in the mould to make the surgical tool. This technique could create complex, but unique tools, since the original wax model and the clay mould were lost in the process¹⁴. The creation of instruments (*organa*) was one of the categories in the medical contests held in Ephesus during the Great Asclepeia, known through a series of second-century CE inscriptions^{15,16}. While Galen's description of making medical tools by means of the *cire perdue* method was unique, it is likely that other physicians employed it in antiquity.

Wax in ancient pharmacology

Wax was a key ingredient in ancient pharmacology¹⁷. All medical authors who described simples, that is, single medical substances, devoted chapters to beeswax. These included Dioscorides (*On Materia Medica* 2.83, edited in¹⁸), Pliny the Elder (*Natural History* 21.83-85, edited in¹⁹); Galen (*On the Properties of Simple Medicines* 7.10.23, edited in²⁰), Oribasius (*Medical Collection* 15.1.10.15, edited in²¹), Aetius

(1.198, edited in²²), and Paul of Aegina (7.3.10, edited in²³). In their chapters devoted to wax, Pliny and Dioscorides, who often relied on the same sources, singled out specific types of wax as excellent: Cretan (Κρητικὸς) and Pontic (Ποντικὸς) for Dioscorides; Punic (*Punica*), Cretan (*Cretica*), Pontic (*Pontica*), and Corsican (*Corsica*) for Pliny. In other parts of his work, Dioscorides also mentioned Tyrrhenian wax (e.g. *On Materia Medica* 2.76.6 and 14, edited in¹⁸). Pontic and Tyrrhenian waxes appear very frequently as ingredients in ancient medical recipes – Cretan, Corsican, and Punic waxes do not. That is not to say that these waxes were not commonly employed in medicine, but rather that medical writers did not stress their use. Further, geographical epithets, such as Cretan, Pontic, or Tyrrhenian, attached to medical ingredients were not always an indication of their actual geographical origins, but could refer to a particular standard of quality or a method of production²⁴. Both Pliny and Dioscorides described a method to cleanse wax with sea water to make an excellent quality wax. Pliny specified that it was this process that led to the creation of Punic wax, which was particularly useful in medicine:

Punica fit hoc modo: ventilatur sub diu saepius cera fulva, dein fervet in aqua marina ex alto petita addito nitro. inde lingulis hauriunt florem, id est candidissima quaeque, transfunduntque in vas quod exiguum frigidae habeat, et rursus marina decocunt separatim, dein vas ipsum aqua refrigerant. et cum hoc ter fecere, iunceae crate sub diu siccant sole lunaque. haec enim candorem facit, sol siccatur, et ne liquefaciat, protegunt tenui linteo. candidissima vero fit post insolationem etiamnum recocta. Punica medicinis utilissima.

Punic [wax] is made in this way: yellow wax is exposed to the air in the open several times, then it is boiled in sea water taken from the deep sea, and to which soda is added. Then, with a skimmer, they collect the 'flower', namely, the whitest parts, and they transfer it to a vessel which contains a little bit of cold water. Then, they boil it [the flower] again on its own in sea water, after which they cool down the vessel itself with water. When they have done this three times, they dry the wax in the open, on rush mats, under the light of the moon. For the moon makes it white, while the sun dries it; and in order for it not to melt, they cover it with a thin linen cloth. To obtain the whitest wax, after the exposure to the sun, it should be boiled once again. Punic [wax] is the most useful for medicine. (Pliny the Elder, Natural History 21.84)

The addition of soda would have created a partially

saponified wax^{25,26}. The Roman architect Vitruvius, for his part, noted that Punic wax, mixed with oil, served as a coating for wall paintings, so that they would keep their colour (*On Architecture* 7.9.3-4, edited in²⁷). This has prompted art historians and conservationists to investigate whether traces of Punic waxes can be found in ancient artefacts, such as the so-called Fayum portraits²⁸⁻³¹. Similar analyses (by gas chromatography–mass spectrometry) were carried out on residues from medicine containers from the British Museum, showing that a compartment in a four-compartment bronze cylindrical medicine box (1968, 0626.37) (fig. 1) had held wax that could have been prepared following the Punic wax process³².

Dioscorides described the properties of beeswax as follows:

δύναμιν δὲ ἔχει πᾶς κηρὸς θερμαντικὴν, μαλακτικὴν, πληρωτικὴν τε μετρίως, μείγνυται δὲ καὶ ῥοφήμασιν ἐπὶ τῶν δυσεντερικῶν, καταπινόμενος δὲ μεγέθη κεγχριαῖα δέκα οὐκ ἔᾶ τυροῦσθαι ἐπὶ τῶν τιθηνουσῶν τὸ γάλα.

Every wax has a quality that is warming, emollient, and moderately filling. It is also mixed with gruels for people suffering from dysentery and, when drunk in the amount of ten grains of millet, it prevents the milk of nurses from curdling. (On Materia Medica 2.83.3).

The final assertion, concerning the power of wax to prevent breast milk, is perhaps surprising. It is repeated by Oribasius (*Synopsis for Eustathius* 9.9.11, edited in³³) and Aetius (16.38, edited in³⁴). The Greeks and Romans believed that breast milk could turn into cheese in the breast, making it unsuitable for an infant's consumption, as they could choke on the lumpy milk (Soranus, *Gynaecology* 2.18.1-3, edited in³⁵). Dioscorides also appears to be alone among our preserved sources to recommend wax in a gruel for people suffering from dysentery. Indeed, wax was more often applied than consumed by mouth. It entered in the composition of many pessaries, suppositories, poultices, and salves.

Salves containing wax were known as cerates (κηρωτή in Greek). Numerous recipes for cerates are preserved in ancient medical writings. Perhaps the most famous was the *tetrapharmakos*, a salve, which as its name indicated, contained four (*tetra*) ingredients: wax, bull suet, resin, and pitch (see e.g. Celsus, *On Medicine* 5.19.9, edited in³⁶). A reference to the *tetrapharmakos* is also found on a papyrus letter dated to 59 CE, from a certain Chaeras to the physician Dionysius (*P. Mert.* 1.12, line 24, edited in³⁷). Most of the time, ancient medical writers did not elaborate on the methods involved in making cerates, probably because they were very familiar with them. Aetius, however, sometimes gave more detail, as in this recipe for a cerate to apply to the belly, when people suffer from fevers:

σκεύαζε δὲ οὕτως τὴν κηρωτήν· κηροῦ <ς ῥοδίνου <δ. τῆκε τὸν κηρὸν μετ' ὀλίγου ῥοδίνου ἐπὶ διπλώματος καὶ ἐπίχεε εἰς ὕδωρ ψυχρὸν καὶ ψυγέοντα ἄρας τῆκε πάλιν καὶ ἐπίχεε καὶ μάλασσε ταῖς χερσὶν ἀποπλύνων τὸν κηρὸν τῷ ὕδατι καὶ πάλιν τὸ τρίτον τῆκε καὶ ἐπιχέας πλῦνε, εἶτα ἐπιβάλλων τὸ λοιπὸν τοῦ ῥοδίνου τῆκε καὶ ἄρας κινῶν ψῦχε καὶ ἐπίχεε ἐν θυίᾳ καὶ λείου ἐπιστάζων ὕδωρ ὅσον ἐπιδέχεται καὶ ἀνελόμενος ἀπόθου εἰς ψυχρὸν ὕδωρ ἀλλάσσω.

Prepare the cerate in this way: 6 ounces of wax; 4 ounces of rose oil. Melt the wax with some rose oil in a double pot (diplōma) and pour over cold water. While it is cooling take it, melt it again, pour over water and soften with the hands, washing the wax with the water. And again, melt for a third time and wash having poured over water. Then add the remainder of the rose oil; melt; stir; cool down and pour into a mortar. Crush it, letting the water fall in drops, as much as can be taken. Remove from the mortar and put away (Aetius 1.113, edited in 22).

This four-stage process, when recreated in a simple kitchen context, led to the creation of a thick salve that could easily be applied as a poultice to the body³⁸. Cerates were not difficult to make, but they required time and some specialist equipment in the form of a double boiler.

ΠΕΡΙΛΗΨΗ

Ενθουσιώδεις αναφορές στο κεριό και στις κηρωμένες δέλτους από τους αρχαίους ιατρικούς συγγραφείς

Laurence Totelin

Αυτή η σύντομη έρευνα εξετάζει μερικές από τις χρήσεις του κεριού στην αρχαία ιατρική: Αυτό αποτελούσε βασικό φαρμακολογικό συστατικό, χρησιμοποιείτο για τη δημιουργία μοντέλων χειρουργικών εργαλείων, ενώ εχρησιμοποιείτο

και για τη συγγραφή συνταγών. Οι ιατροί διέκριναν μεταξύ διαφορετικών τύπων κεριού, μερικοί από τους οποίους θεωρούνταν πιο αποτελεσματικοί από άλλους. Το κεριό σε κάποιες περιπτώσεις λαμβανόταν από του στόματος, αλλά συνήθως χρησιμοποιείτο στην παραγωγή κηραλοιφών.

Λέξεις Κλειδιά: κεριό, ξύλινες επιφάνειες γραφής, χειρουργικά εργαλεία, κηραλοιφές

REFERENCES

1. Wenkebach E, Pfaff F, Galeni In Hippocratis Epidemiarum librum VI commentaria I-VI. Edidit E. Wenkebach; commentaria VI-VIII, in Germanicam linguam transtulit F. Pfaff, editio altera lucis ope expressa. CMG V 10,2,2. Berlin: Akademie Verlag; 1956.
2. Langholf V, Structure and Genesis of some Hippocratic Treatises. In: Horstmanshoff HFJ, Stol M, editors. Magic and Rationality in Ancient Near Eastern and Graeco-Roman Medicine. Leiden: Brill; 2004. p. 219-75.
3. Marganne M-H, Le médecin, la trousse et le livre dans le monde gréco-romain. Papyrologica Lupiensia. 2003;12:115-30.
4. Marganne M-H, Le livre médical dans le monde gréco-romain. Liège 2004.
5. Lalou É, Les tablettes à écrire de l'antiquité à l'époque moderne. Turnhout: Brepols; 1992.
6. Pearce J, Roman London's First Voices: Writing Tablets from the Bloomberg Excavations, 2010–2014, By Roger S.O. Archaeological Journal. 2018;175(2):401-3.
7. Migne J-P, Patrologiae cursus completus (series Graeca). Vol. 31. Paris: Garnier; 1885.
8. Sobel H, Römische Arzneikästchen. Saalburg-Jahrbuch. 1991;46:121–47.
9. Fischer K-D, Was ist das deltarion in POxy LIX 4001? In: Andorlini I, editor. 'Specimina' per il corpus dei papiri greci di medicina Atti dell'Incontro di studio, Firenze, 28-29 marzo 1996. Florence: G. Vitelli; 1997. p. 109–13.
10. Gitton-Ripoll V, Le sens de ΔΕΛΤΟΣ, ΔΕΛΤΑΡΙΟΝ comme instrument médical. In: Boehm I, Rousseau N, editors. L'expressivité du lexique médical en Grèce et à Rome: Hommages à Françoise Skoda. Paris: Presses de l'université Paris-Sorbonne; 2014. p. 205–16.
11. Boudon-Millot V, Jouanna J, Pietrobelli A, Galien. Tome IV. Ne pas se chagriner. Texte établi et traduit par V. Boudon-Millot et J. Jouanna avec la collaboration de A. Pietrobelli. Paris: Les Belles Lettres; 2010.
12. Tucci PL, Galen's Storeroom, Rome's Libraries, and the Fire of AD 192. Journal of Roman Archaeology. 2008;21:133-49.
13. Singer PN, Nutton V, Davies D, Tassinari P, Galen: Psychological Writings. Translated with Introduction and Notes by V. Nutton, D. Davies and P.N. Singer, with the Collaboration of P. Tassinari. Cambridge: Cambridge University Press; 2013.
14. Hunt L, The Long History of Lost Wax Casting: Over Five Thousand Years of Art and Craftsmanship. Gold Bulletin. 1980;13(2):63-79.
15. Nutton V, The Medical Meeting Place. In: van der Eijk PJ, Horstmanshoff HFJ, Schrijvers PH, editors. Ancient Medicine in Its Socio-Cultural Context. Papers Read at the Congress Held at Leiden University, 13–15 April 1992. Amsterdam: Rodopi; 1995. p. 3-25.
16. Zimonyi Á, The Context of Medical Competitions in Ephesus. Acta Antiqua Academiae Scientiarum Hungaricae. 2014;54(4):355-70.
17. Chouliara-Raios H, L'abeille et le miel en Egypte d'après les papyrus grecs: Philosophikē Scholē Panepistēmiou Iōanninōn; 1989.
18. Wellmann M, Pedanii Dioscuridis Anazarbei De materia medica libri quinque. Edidit M. Wellmann. Volumen I. Quo continentur libri I et II. Berlin: Weidmann; 1907.
19. Jones WHS, Pliny. Natural History. Volume VI. Books 20–23. Translated by W. H. S. Jones. Cambridge, MA: Harvard University Press; 1951.
20. Kühn KG, Claudii Galenii opera omnia. Editionem curavit D. Carolus Gottlob Kühn. Tomus XII. Leipzig: Car. Knoblochius; 1826.
21. Raeder J, Oribasii Collectionum medicarum reliquiae, libri IX-XVI, edidit J. Raeder, CMG VI 1,2 Leipzig and Berlin: Teubner; 1929.
22. Olivieri A, Aetii Amideni Libri medicinales I-IV, edidit A. Olivieri, CMG VIII 1. Leipzig and Berlin: Teubner; 1935.
23. Heiberg JL, Paulus Aegineta, Libri V–VII, edidit J. L. Heiberg, CMG IX 2. Leipzig: Teubner; 1924.
24. Totelin L, The World in a Pill: Local Specialties and Global Remedies in the Graeco-Roman World. In: Kennedy RE, Jones-Lewis M, editors. The Routledge Handbook of Identity and the Environment in the Classical and Medieval World. London: Routledge; 2016. p. 151-70.
25. Colinart S, Grappin-Wsevoljy S, La cire punique: étude critique des recettes antiques et de leur interprétation: application aux portraits du Fayoum 1. In: Colinart S, Grappin-Wsevoljy S, Matray C, Bridgland J, editors. 12th triennial meeting, Lyon, 29 August-3 September 1999: preprints ICOM (Committee for Conservation). London: James & James; 1999. p. 213-20.
26. Rinaldi S, Ancient Formulas for Punic Wax. In: Omarini S, editor. Encausto: Storia, tecnica e ricerca. Encaustic: History, Technique and Research. Florence: Nardini editore; 2012. p. 90-4.
27. Granger F, Vitruvius. On Architecture, Volume II: Books 6-10. Translated by Frank Granger. Cambridge, MA: Harvard University Press; 1934.
28. Kühn H, Detection and Identification of Waxes, Including Punic Wax, by Infra-Red Spectrography. Studies in Conservation. 1960;5(2):71-81.

29. White R, The Application of Gas-Chromotography to the Identification of Waxes. *Studies in Conservation*. 1978;23:57-68.
30. Freccero A, Wax Paint and Punic Wax: Research and Experiments. In: Omarini S, editor. *Encausto: Storia, tecniche e ricerche*. Encaustic: History, Technique and Research. Florence: Nardini editore; 2012. p. 105-13.
31. Botticelli G, Freccero A, Matteini M, Reproduction of Pictorial Techniques using Beeswax, Punic Wax, Encaustic and other. In: Omarini S, editor. *Encausto: Storia, tecniche e ricerche*. Encaustic: History, Technique and Research. Florence: Nardini editore; 2012. p. 141-51.
32. Stacey RJ, The Composition of some Roman Medicines: Evidence for Pliny's Punic Wax? *Analytical and Bioanalytical Chemistry*. 2011;401:1749-59.
33. Raeder J, *Oribasii Synopsis ad Eustathium, Libri ad Euphrasium*, edidit J. Raeder, CMG VI 3. Leipzig and Berlin: Teubner; 1926.
34. Zervos S, *Gynaekologie des Aëtios*. Leipzig: Fock; 1901.
35. Ilberg J, *Sorani Gynaeciorum libri IV, De signis fracturarum, De fasciis, Vita Hippocratis secundum Soranum*, edidit J. Ilberg. Leipzig and Berlin: Teubner; 1927.
36. Spencer WG, *Celsus. On Medicine, Volume II: Books 5-6*. Translated by W. G. Spencer. Cambridge, MA: Harvard University Press; 1938.
37. Idris Bell H, Roberts CH, Letter to a Physician. In: Idris Bell H, Roberts CH, editors. *A Descriptive Catalogue of the Greek Papyri in the Collection of Wilfred Merton Volume I*. London: E. Walker; 1948. p. 50-4.
38. Totelin L, *Cerative Focus*. *ConcoctingHistory* [Internet]. Totelin L, editor. <https://ancientrecipes.wordpress.com/2013/05/02/cerative-focus/2013>. [cited 2023].

Corresponding author:

Laurence Totelin
e-mail: totelinlm@cardiff.ac.uk