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GalenQt: A New Multispectral Imaging Tool for Recovering Lost Text and Its Use for the Reconstruction of the Lacuna in Galen's *Simple Drugs*, Book 8

The Syriac Galen Palimpsest (henceforth SGP) is, as its name suggests, a palimpsest that contains a Syriac version of one of Galen's writings—namely, books 2–9 out of the eleven books of *On Simple Drugs*.¹ The challenge is to read the erased text, which in the case of the SGP is a very variable task. On some pages, the undertext is visible to the naked eye, and indeed this is how the palimpsest was initially identified.² In other parts, however, there is no visible undertext whatsoever. Multi-spectral imaging and image analysis have traditionally been powerful tools used to read erased texts in palimpsests, as the example of the Archimedes palimpsest amply illustrates.³ Yet until today, scholars have generally had to rely on looking at sets of raw images and images processed by imaging experts when studying the SGP and other palimpsests, because a dynamic and user-friendly multi-spectral image analysis tool has been lacking. We had set ourselves the task of developing such a tool during a project funded by the Arts and Humanities Research Council which aims at deciphering the SGP.⁴

Over the course of the last three years, we have developed such a new tool, GalenQt, which enables humanities researchers with no technical computing expertise to manipulate sets of multi-spectral images in novel ways. We launched the new tool during the Vienna conference on 27 April 2018, and have subsequently made numerous improvements.⁵ The present paper describes this new tool and offers a concrete example of how it helps to read the erased undertext. We shall first briefly give some background information on how SGP was imaged and analysed, then explain our own design goals for GalenQt and how we endeavoured to meet them. In particular, we explain how to use the new software tool by looking at a concrete example.

This example is taken from book 8 of Galen's *On Simple Drugs*, and notably the section dealing with drugs beginning with the letters *phi* and *chi*.⁶ We chose this particular passage of the manuscript because the parallel witness for the Syriac translation by Sergius of Rēš 'Aynā of books 6–8—namely London, British Library, MS Add. 14,661 (henceforth BL)—contains a lacuna here. This lacuna corresponds to three folios in SGP,

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¹ On Galen's *Simple Drugs* in Greek, see Petit, *La tradition manuscrite*; Petit, *Théorie et pratique*.

² Hiersemann, *Katalog 500*, no. 20. Since 2010, there has been considerable scholarly activity in working on this palimpsest; see Bhayro *et al.*, *Collaborative Research*; Bhayro and Brock, *The Syriac Galen Palimpsest*; Bhayro *et al.*, *The Syriac Galen Palimpsest*; Bhayro *et al.*, *Imaging the Syriac Galen Palimpsest*; Bhayro and Hawley, *La littérature botanique et pharmaceutique*; Hawley, *More Identifications*; Kessel, *Membra disjecta sinaitica I*. In particular, see the special issue of *Manuscript Studies* 3.1 (2018), guest edited by William Noel and Ralph M. Rosen, which is devoted solely to this topic.

³ Netz *et al.*, *The Archimedes Palimpsest*.

⁴ The Syriac Galen Palimpsest: Galen's *On Simple Drugs* and the Recovery of Lost Texts through Sophisticated Imaging Techniques (September 2015 to February 2020).

⁵ Both the original and the latest release can be found on <https://github.com/wol101/GalenQt> (accessed 01.07.2023).

⁶ 12.150–154 Kühn (chapters 21.5–22.6).

the second of which is particularly hard to read and will be the focus of the present contribution.⁷ The poor readability of the selected passage renders the reconstruction of the Syriac much more difficult and therefore presents a true challenge to demonstrate the capabilities of GalenQt. We also employed a new methodology of digital philology that relies on a bilingual digital corpus capable of being searched in innovative ways. We have previously described this methodology in an article reconstructing the beginning of the lacuna and will not dwell on this topic here.⁸ Let us therefore return to imaging and image analysis, and begin by outlining what had been done prior to our project.

IMAGING BACKGROUND

In order better to read the undertext, the whole manuscript was photographed at a resolution of 7216 by 5412 pixels with a multi-spectral imaging camera using 13 different illumination wavelengths from 365 nm to 940 nm, thus covering the complete visible spectrum and extending into the infrared and ultraviolet ranges. Extra images were taken using a selection of filters and raking light options such that 23 separate images were taken for each page. The entire collection of images has been made available to the research community via the OPenn digital repository of the University of Pennsylvania Libraries as Free Cultural Works, and it is this image collection that is the starting point for this project. In their raw state, the images created using ultraviolet illumination generally show the undertext the most strongly. Unfortunately, this alone is rarely enough to make the text readable. The images on the web site⁹ have been processed to some extent from the original images. They have been contrast-adjusted and down sampled from the original 16 bit images to 8 bits, and various image enhancements have been tried, including creating pseudo-coloured composites from multiple greyscale images. However, the approaches taken are largely automated and it is clear that further improvements in legibility could be made by using different multi-spectral algorithms.

The challenge of improving the legibility of the undertext is primarily one of maximising the contrast between the undertext and the other elements within the images: the parchment, the overtext, and other markings on the manuscript, such as rubrics. This problem has been addressed in many fields of science since multi-spectral imaging (and indeed its extension, hyper-spectral imaging) is commonly used in remote sensing applications and there is considerable interest in maximising the information content in the images obtained.¹⁰ There are two main goals for multi-spectral image processing. The first is to allow a human to see as much as possible in the image, and the second is to automatically identify what is in the image. In our context this would be the difference between making the palimpsest legible to a scholar, and automatically reading the manuscript.

This paper will concentrate on the first of these options, since training a machine to read even perfectly legible Syriac would be a very challenging prospect. In terms of making images more legible, what we are looking for are ways of combining the multiple images recorded and presenting them to the user such that the details of interest are enhanced. This is essentially a problem of dimensional reduction. In the SGP, each folio has been photographed 23 times, and so for each pixel we have 23 different grey levels of information; the dimensionality of the source data is therefore 23. A grey scale image has a single dimension of information, and a colour image has three dimensions of information: its red, green, and blue intensities equating to the colour sensitivities of the three different cell types in the human eye. Therefore a dimension reduction algorithm should be a good way of presenting the information contained in the original 23 images in a smaller number of images and these should demonstrate better contrast between information containing aspects and background.

Dimension reduction techniques, although originally developed as statistical tools, are now often considered part of machine learning.¹¹ There are many different approaches, but in the context of machine learning we can usefully divide them into supervised and unsupervised approaches. Unsupervised approaches are fully

⁷ SGP, f. 166r+171v (chapter 21.5 and the beginning of chapter 21.6), f. 214r+221v (chapters 21.6–22.6) and f. 214v+221r (the end of chapter 22.6).

⁸ ‘On *phlómos*’ (chapter 21.5, 12.150 Kühn); Afif *et al.*, *Analyzing Images, Editing Texts*.

⁹ <http://www.digitalgalen.net> (accessed 01.07.2023).

¹⁰ For a review see Ose *et al.*, *Multispectral Satellite Image Processing*.

¹¹ See for example, Marsland, *Machine Learning*.

automated and do not require any training data and are thus very easy to use. However, whether an unsupervised technique is able to enhance a specific aspect of a multi-spectral image is not guaranteed, since it is up to the algorithm to identify what might be considered interesting aspects of the image, and not the user. Supervised approaches require some training by the user. This, of course, takes longer, since for some approaches the training data set needs to be extensive, and it requires that the user can identify some areas of interest in the original images to create the training data set. On the plus side, though, because the user has explicitly identified *a priori* those parts of the image that are interesting, the success rate of supervised dimensional reduction techniques is likely to be higher. A combination that can work well is the use of an unsupervised technique initially to help locate areas of the image that contain undertext. Once identified, these areas can be used for training a supervised algorithm which will then lead to an optimal image separation.

Probably the most common unsupervised dimensional reduction technique used for multi-spectral imaging is principle component analysis (PCA). This technique is available as a plug-in for the popular free image manipulation software ImageJ and is often used as a first step in processing multi-spectral images.¹² The idea behind PCA is that the algorithm finds the direction within the high dimensional data that shows the most variation. This is the first principle component axis. It then finds the direction orthogonal to this axis that encompasses the largest proportion of the remaining variation. This process is repeated until all dimensions have been used up. We can then generate a rotation matrix that converts the original data (i.e. the pixel grey values) into this new principle component space. We still have (in the case of SGP) 23 images, but the first image is guaranteed to contain most of the variation of pixel intensities, and each subsequent image will contain progressively less variation. If we are lucky, one of these new images (or perhaps a combination of several of them) will show good separation between the features we are interested in and the background. There are, however, a very large number of other techniques. Some of these are variations on principle components, such as kernel principle components, and others are completely different approaches, such as locally linear embedding and isomaps.¹³

Similarly there are a very large number of supervised techniques. Almost all the classic machine learning algorithms can act in a dimension reduction capacity such as artificial neural networks and support vector machines. We have had very good success using linear discriminant analysis (LDA), which is very easy to train and works very rapidly on large images that can otherwise be slow to process.¹⁴ LDA is a process of finding the linear combination of the input dimensions that maximises the separation between the training classes whilst at the same time minimising the spread of the data within the classes. It also reduces the dimensionality of the input data to the number of individual categories minus 1. LDA in this context is identical to canonical variates analysis (CVA) and is a more commonly encountered name in the imaging field. Our previous implementation used the commercial package Matlab (<https://www.mathworks.com/>) and the training data was generated by selecting points within ImageJ and exporting them as comma separated text values containing the coordinates of pixels that had been classified into the various text and background categories for the SGP. This approach is both complex and unnecessarily time consuming. As far as we are aware, there are no freely-available integrated tools for both training and applying supervised dimension reduction techniques to multi-spectral images.

DESIGN GOALS

We therefore set ourselves the task of producing such an integrated tool to allow the easy application of supervised and unsupervised techniques to multi-spectral images. Ease of use is key because we strongly believe that the most important requirement is to put the image-processing power into the hands of the scholars who will actually be interpreting the documents. These experts will have their own working preferences, will spend many hours looking at the images in great detail, and will therefore want to customise their working environments, and be able to make flexible choices about how multi-spectral images are combined and displayed. We also wanted our tool to run on a range of different platforms. Most multi-spectral image acquisition systems are tied to particular hardware (commonly Microsoft Windows), and there are specific philological software

¹² <https://imagej.nih.gov/ij/> (accessed 01.07.2023).

¹³ For a detailed review see Van der Maaten *et al.*, *Dimensionality Reduction*.

¹⁴ Afif *et al.*, *Analyzing Images, Editing Texts*.

packages that again are limited to specific operating systems (commonly Apple Macs), and so we predicted that users would want to run our software on at least these two platforms. We initially considered producing a plug-in for ImageJ, because this software already exists for a range of hardware and provides a great deal of useful functionality. ImageJ, however, is a general purpose imaging tool with a very large number of functions that are not useful for enhancing the readability of manuscripts. This generality means that the interface is unnecessarily complicated and finding the useful functions is much harder and more confusing than it would be in a dedicated tool. Instead we decided to create a tool from scratch that concentrated on performing a limited range of functions well. We then had to decide on a minimum specification for what we wanted the tool to do. The functions that we envisaged the tool would provide are the following:

1. Organising multiple images associated with a folio, allowing rapid selection and display so that the user can find interesting features quickly.
2. Real time update for essential viewing controls such as brightness, contrast, and gamma so that the user can customise the appearance of the image.
3. Straightforward interface to allow the user to create pseudo-colour images by applying individual grey scale images to the red, green, and blue colour channels.
4. Interactive method for generating training sets for supervised dimensional reduction algorithms.
5. Interface for choosing images, training sets, and applying a range of multi-spectral supervised and unsupervised learning techniques.

The requirement for real time update meant that we needed to take advantage of the processing power of the graphics card directly, and we made the design decision that the program should be primarily aimed at high-end computers with larger amounts of memory, and that speed was the primary goal. This being the case, we decided against using either a scripting language such as Python or a language that runs on a virtual machine such as Java. The requirement for cross-platform compatibility, however, meant that we could not simply use the native interface for a particular computing system and therefore had to choose one of the available free-to-use cross platform widget sets. The main choices are wxWidgets (<https://www.wxwidgets.org/>) and Qt (<https://www.qt.io/>), and we chose the latter because it has better support for GPU programming. Qt requires the underlying code to be written in C++, which in general works well for imaging applications, because it provides high speed, low level access to the underlying data, and also because there are a large number of support libraries for image and numerical processing that can be easily incorporated.

There are some particular challenges when working with images in a multi-spectral context. First, pixel intensities are generally handled computationally as unsigned integer values, commonly with 8, 16, or 32 binary bits depending on the source. However, dimension reduction techniques are almost always floating point processes. The most time-efficient way of handling this is to treat the image as a floating point entity throughout. Unfortunately the Qt image compositing system cannot handle floating point images and converting the image back to an 8 bit value before display is relatively time consuming. Fortunately, recent OpenGL implementations can cope easily with floating point textures, and by using custom shaders we can leave the resultant images in floating point format and at the same time allow the contrast, brightness, and gamma calculations to be performed directly on the graphics card, which allows for very rapid update and also means that we can use the graphics hardware directly for scrolling and rotation.

The second issue is that by their very nature multi-spectral imaging techniques tend to produce large numbers of images. The raw SGP data consists of 23 TIFF images per folio. When performing processes such as PCA or LDA we tend to generate further images and we might want to save particular composite images for publication or for use with other software. At the same time each of these images has associated metadata. For SGP this is contained in separate text files with some additional information encapsulated within the TIFF files. Our solution to handling this is to create a single XML project file that keeps track of all the images associated with a particular folio. This file contains the locations of the images and also the training data categories and point locations. The file does not duplicate the image data and so this approach, whilst space efficient and easily extensible, is somewhat fragile since it relies on the relative locations of the image files to remain constant. Currently we do not have a good solution to this issue but in future versions of the software we hope to incorporate repair functions so that missing or orphaned images can be tracked down.

THE NEW SOFTWARE

Our current software, GalenQt, is available to download from GitHub (<https://github.com/wol101/GalenQt>). There are compiled releases for MacOS and Windows, with full source code for compilation on Linux. This release covers the basic functional requirements, but we are planning to extend a number of areas in the near future. The process of enhancing an SGP folio can be broken down into the following steps.

1. The first step is to decide on the layout of the local copy of the images. In general, we recommend that each folio has its own folder that contains the project XML file that specifies the locations of the images and the training data. Within that folder we create a subfolder that contains the 23 raw, 16 bit images for that folio. Any images generated by the dimension reduction algorithms can be stored in other subfolders. In this way, as long as the whole folder and subfolders are always copied as a single unit, the image links saved in the project XML file will remain intact.
2. Once the folder structure has been decided we are ready to create a new project file using the File/New menu item.
3. Once the project file has been created we can add images to it using the File/Import Images... menu item. The project file can be saved and opened as normal and, as long as the images have not been moved relative to the project file, they will all be found again.
4. Imported images will be loaded into memory and the Image List on the right hand side will be populated with their names. With SGP each 16 bit grey scale image is 76 MB and these will double in size when converted to 32 bit floating point format internally, so just displaying these images will take up 4 GB of RAM. Processing these images is likely to double or triple the space requirement so it is not recommended to use a computer with less than 16 GB of RAM; 32 GB is likely to perform better. It is also recommended that the graphics card has as much memory as possible since then the images can be cached on the card and performance will be much faster.
5. The raw images are automatically mapped so that their lowest value is displayed as zero brightness and their highest value is displayed as maximum brightness. Each image can be assigned to the red, green, or blue channels and an image can be mapped to more than one channel. Double clicking on the image name in Image List will automatically assign the image to all three channels and it will appear in grey scale.
6. The currently selected image will show its brightness distribution in the Histogram panel. This panel shows the original brightness distribution and the brightness distribution after the minimum, maximum, gamma, and zebra values are set. These values can be set numerically using the spin boxes or using the sliders on the left hand side. The brightness displayed is governed by equation 1.

$$y = \text{mod}(\text{clamp}\left(\frac{x - x_{\min}}{x_{\max} - x_{\min}}, 0, 0.99999\right) \times \text{zebra}, 1)^{\gamma}$$

Where y is the output intensity scaled between 0 and 1, x is the input intensity, $x_{\min}$ and $x_{\max}$ are the range settings, zebra is the zebra setting, and γ is the display gamma.

7. The image view can be changed using fairly standard mouse interactions. Clicking on the image enables drag based panning, the central scroll wheel of a mouse zooms, and there are scroll bars, zoom buttons and 90° rotation buttons.
8. Unsupervised routines (currently only PCA is implemented) require that the source images are selected. Once more than one image is selected the Process/PCA can be chosen and this will pop up the PCA dialogue. Here the output folder needs to be selected because this is where the newly generated PCA images will be saved. There are then a number of options which affect the way the PCA is calculated. During this process memory usage will increase since both the source and destination images are held in memory. Once the PCA images are generated they are automatically loaded and made available in the project file. Generated TIFF images are floating point format which may cause difficulties when reading them into some other software. Adobe Photoshop is perfectly happy but programs like Microsoft Word will not read them. If the image is in view and exported using the File/Export Image option then an 8 bit colour TIFF image using the currently selected scaling options will be created, and this image can be easily used elsewhere.

9. Supervised routines require a training set. This is generated by manually selecting points on the image and assigning the point to a particular category. This is handled by right clicking into the panel below the image list. There will then be the option to create a new points folder. This is not created on disk but within the project file itself since all the training data is held in the project file. Once a points folder is created, right clicking on the points folder will allow point lists to be created. For the SGP we typically train on parchment, overtext, and undertext, with perhaps rubrics or decorations as additional categories. On folios with water damage these might need to be further subdivided, since the intensities in the water-damaged areas are different from the intensities elsewhere. Once a point list has been created it can be made current and points can then be added by shift left clicking on the image. Right click also allows points to be deleted if they are erroneously placed. The number of points required for training depends on the supervised method and the amount of variation in the intensities. Typically 50 or more points for each category seems to work quite well.
10. Supervised routines (currently only LDA is available) become available once at least 2 point lists have been selected and at least two images. The source images can be the results of previous processing or they can be the raw images in any combination. Once the LDA dialog is displayed you have the option to select the output folder where the new images will be created, and you can specify the maximum number of images. In general, it is useful to have all the images (which is the number of classes minus one). After the LDA has completed, the program displays a clustergram illustrating how well the different classes have been separated. Once the initial LDA has been performed it is usually possible to see the undertext much more clearly than before and this new image can be used to improve the training set.

USING GALENQT WITH THE SYRIAC GALEN PALIMPSEST

Figure 1 illustrates how GalenQt has helped us read specific folios in the SGP. Panel A shows a portion of f. 214r+221v as illuminated under white light. The overtext is clearly visible but there is almost no indication of undertext in this area of the page. Panel B shows the page viewed under UV light (365 nm) and here we can start to see some of the undertext showing through, but the contrast is relatively poor and it is almost impossible to read the undertext in this image. Panel C shows the image that best reveals the undertext after the set of

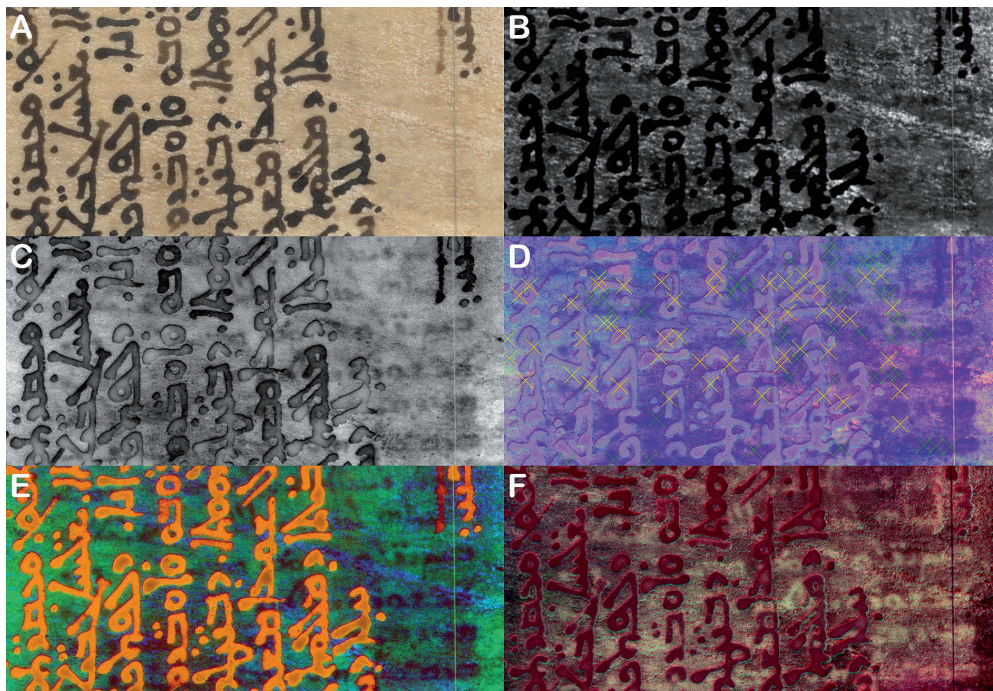


Fig. 1: portion of f. 214r+221v under white light (A); UV light (B); processed by PCA (C); marked up for LDA (D); and initial (E) and final (F) LDA result (© Owner of the Syriac Galen Palimpsest and the University of Manchester, Creative Commons Attribution 3.0 Unported Access Rights)

images have been processed by PCA. In this particular case, the 4th principle component demonstrates reasonable separation of the undertext, illustrating the value of this method as an initial screening tool. To improve the legibility of the image further we need to produce a training set where the scholar identifies the particular points on the image that correspond to different features. Panel D shows this process within GalenQt where areas containing undertext are marked on a pseudocoloured image created by applying individual greyscale images to each of the red, green, and blue channels, and adjusting the individual brightness and contrast values. Once this manual identification step has been completed, we can use LDA on the image. A single pass through is shown in Panel E, but we can then use this improved image to identify more undertext-bearing areas and that provides a better training set that more completely captures the variation within the undertext. We can also use different processing options. Panel F shows the final result of using three passes of LDA. The separation is about as good as can be achieved using this approach.

THE RECONSTRUCTION OF THE LACUNA IN BOOK 8

The transcription and reconstruction were performed using our established methodology, which consists mostly of a cross-search within the parallel Graeco-Syriac corpus of books 6–8 of Galen's *Simple Drugs* on the Sketch Engine platform. We used different query functions including search within a context and regular expressions search (CQL). The common vocabulary within books 6–8 allowed us to reconstruct substantial parts of all eleven entries with the exception of those lines (particularly, in chapters 21.6, 21.7, and 22.5) which belong to the gutter area of the secondary bifolio, where the parchment is damaged and the folio torn apart.

Our reconstruction of the following entries from the SGP is mainly based on the edition of the Greek text by Kühn and the Greek manuscript Vatican Urbinas gr. 67 (henceforth U).¹⁵ In most cases, the *pínax* in BL enabled us to reconstruct the rubric titles that are invisible on the multi-spectral and processed images. To this end, we considered both the space in the *pínax* and in the rubrics of SGP. In addition, we used some parallel texts which enabled us to reconstruct the relevant portions of the text in book 8. Thus, we considered the concise Arabic version of Galen's *Simple Drugs* preserved in the manuscript Paris, Bibliothèque nationale de France, arabe 2857 (henceforth P) containing chapters 21.6 (ff. 114v–115r) and 22.4 (f. 115r–v).¹⁶

We also relied on three indirect Syriac sources. The first is the Syriac medical handbook (*kunnāšā*) compiled by ʾĪšōʿ bar ʾAlī (9th century) preserved in Damascus, Syrian Orthodox Patriarchate, MS 238 (henceforth D). The first book (*mēmra*) of this seven-part handbook deals with simple drugs and constitutes an abridgement of books 6–8 of Galen's *Simple Drugs*.¹⁷ The second source is quotations from the Syriac version of Galen's *On Simple Drugs* contained in Ḥunayn ibn Ishāq's own work *On the Properties of Foodstuffs*.¹⁸ For this compilation, three manuscript witnesses are available, including the manuscript Mingana Syr. 661 (henceforth M), which was available for us to consult. Although both sources include a Syriac translation of the Galenic passages that differ from that by Sergius of Reš ʾAynā, they still employ a medical vocabulary that is very close or similar to the latter. MS D, f. 64r–v offers evidence for chapters 21.6, 21.8, 21.11, 22.1 and 22.2, whereas Ḥunayn's *Properties of Foodstuffs* includes two entries attributed to Galen related to the date-palm (cf. chapter 21.6). One deals with dates, palm spathes and palm pith, while the other treats palm spathes and palm pith only (MS M, ff. 118v–120r).

The third source is Bar Bahlūl's *Lexicon* (10th century). We were able to establish that in some cases it includes verbatim quotations from Sergius' translation of *Simple Drugs* (see for example chapter 22.1). Sergius' translation, at least of book 8, was therefore available to Bar Bahlūl and served as one of the sources for his *Lexicon*. The edition of the texts below illustrates the significance of this material for restoring the lacuna in book 8, which covers the missing folios in BL.

¹⁵ About this manuscript's relationship to the Syriac transmission of *Simple Drugs* see Martelli, Galeno grammatico; Afif *et al.*, On Digamma and the Armenian Earth.

¹⁶ About this manuscript, see Ullmann, *Wörterbuch*, 27.

¹⁷ Kessel, A Syriac Medical *Kunnāšā*.

¹⁸ Hawley, Preliminary Notes. See also Bhayro *et al.*, The Syriac Galen Palimpsest, 139–143.

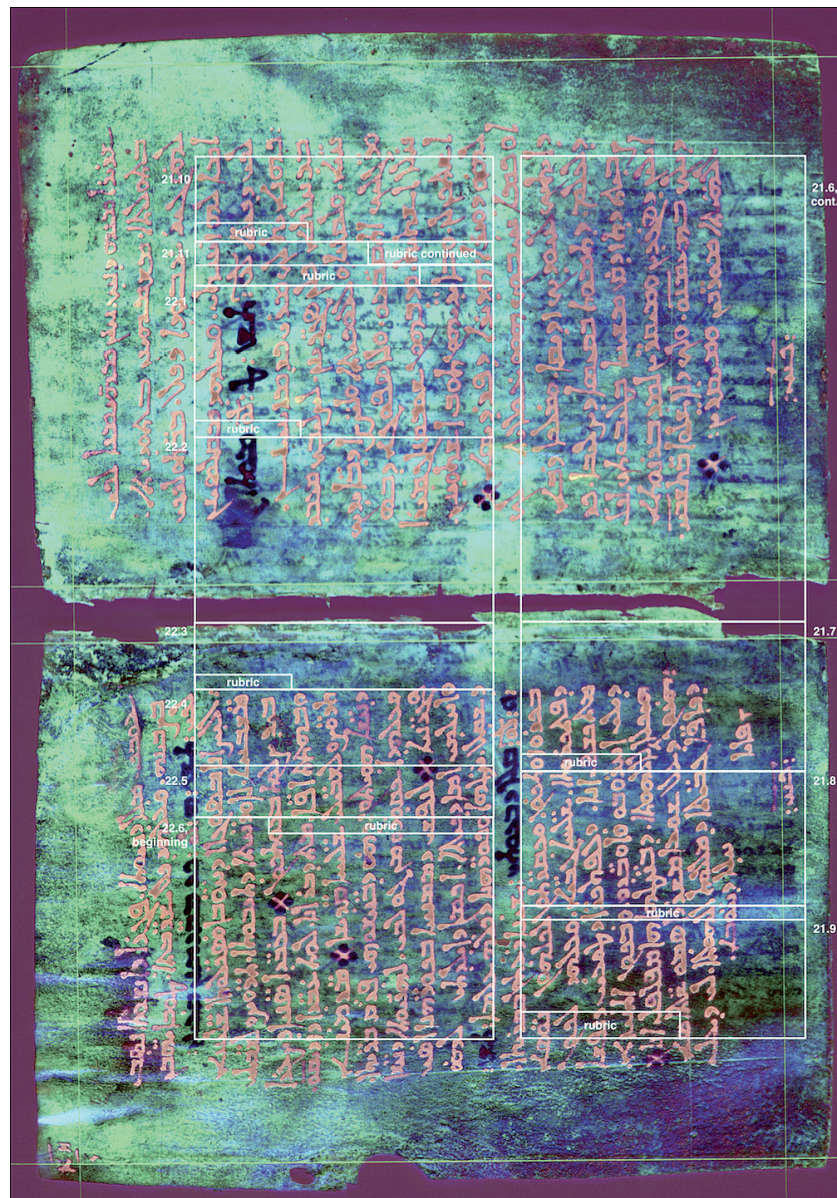


Fig. 2: a mark-up map of f. 214r+221v, LDA-processed (© Owner of the Syriac Galen Palimpsest and the University of Manchester, Creative Commons Attribution 3.0 Unported Access Rights)

[Chapter 21.6]

[12.151 Kühn] [ζ'. Περὶ φοίνικος.] Φοῖνιξ τὸ δένδρον στυπτικῆς μετέχει δυνάμεως ἐν ᾧ πασι τοῖς ἑαυτοῦ μέρεσιν. ὁ μὲν οὖν τῶν κλάδων χυλὸς αὐστηρὸς ἐστὶν ἐξ ὑδατώδους οὐσίας χλιαρᾶς καὶ γεώδους ψυχρᾶς συγκείμενος. ὁμοίᾳς δὲ τούτου· φύσεώς ἐστι καὶ ὁ καλούμενος ἐγκέφαλος ἐδώδιμος ὑπάρχων. ὁ δὲ καρπὸς αὐτοῦ καὶ μάλισθ' ὁ γλυκὺς οὐκ ὀλίγης μετεῖληφε θερμότητος. ἐδώδιμος δ' ὢν εἰς πολλὴν ἔρχεται χρῆσιν, οὐ μόνον ἔξωθεν ἐπιτιθέμενος, ἵνα τονῶσαι τι καὶ ξηρᾶναι καὶ συναγαγεῖν καὶ πιλῆσαι καὶ πυκνῶσαι χρήζομεν, ἀλλὰ καὶ ὡς σιτίον λαμβανόμενος ἅμα τε τοῖς ἄλλοις καὶ αὐτὸς καθ' ἑαυτόν. ὁ δὲ καλοῦσιν ἐλάτην, τὸ ἀπαλὸν ἐκβλάστημα τοῦ φοίνικος, τὴν αὐτὴν τῷ κατ' αὐτὴν ἐγκεφάλῳ δύναμιν ἔχει. τὸ δ' οἶον ἀμφίεσμα αὐτοῦ στυπτικὴν μὲν καὶ αὐτὸ κέκτηται ποιότητα, ξηραίνει δ' ἐπὶ πλέον ἀπάντων τῶν εἰρημένων, ὥς ἂν καὶ τῇ τῆς οὐσίας συστάσει ξηρότερον αὐτῶν ὑπάρχον καὶ ἥκιστα μετέχον ὑγρότητος, ὥστε δεόντως ἐπὶ τῶν σηπεδονωδῶν ἐλκῶν αὐτῷ χρῶνται. καὶ τοῖς συνάγουσι τὰ κεχαλασμένα τῶν ἄρθρων φαρμάκοις μιγνύουσι καὶ ταῖς [12.152 Kühn] ἥπατικαῖς τε καὶ στομαχικαῖς δυνάμεσιν, ἔξωθεν τε καὶ ἔσωθεν. ἔστι δὲ καὶ ἡ ῥίζα τοῦ φυτοῦ ξηραντικῆς ἀδήκτως δυνάμεως, ἔχουσα τι καὶ αὐτὴ στυψέως.

On the date-palm.

The date-palm tree has astringent power in all its parts. The juice of its branches is bitter,¹⁹ because it combines a warm watery substance with the cool earthly one. Of similar nature to it (the juice) is the so-called pith, which is edible. Its fruit, and especially the sweet one, has considerable warmth. Since it is edible, it has many uses.²⁰ It is not just applied externally, when we use it for tightening, drying, closing, compressing, and firming up. It is also taken as a food, either with other things or by itself. The tender sprout of the date palm, called ‘spathe (*elātē*)’²¹ has the same power as its pith. Its membrane-like thing²² also has an astringent quality and dries more than all the other [parts] just mentioned. For it is both drier in the composition of its substance and has extremely little moisture²³, so one necessarily uses it²⁴ on septic wounds. One also mixes it with the medicines applied to limbs to fight paralysis and with drugs for liver and stomach disorders, the latter being used both externally and internally.²⁵ The root of the plant also has the drying power whilst not being pungent, and also some astringency.

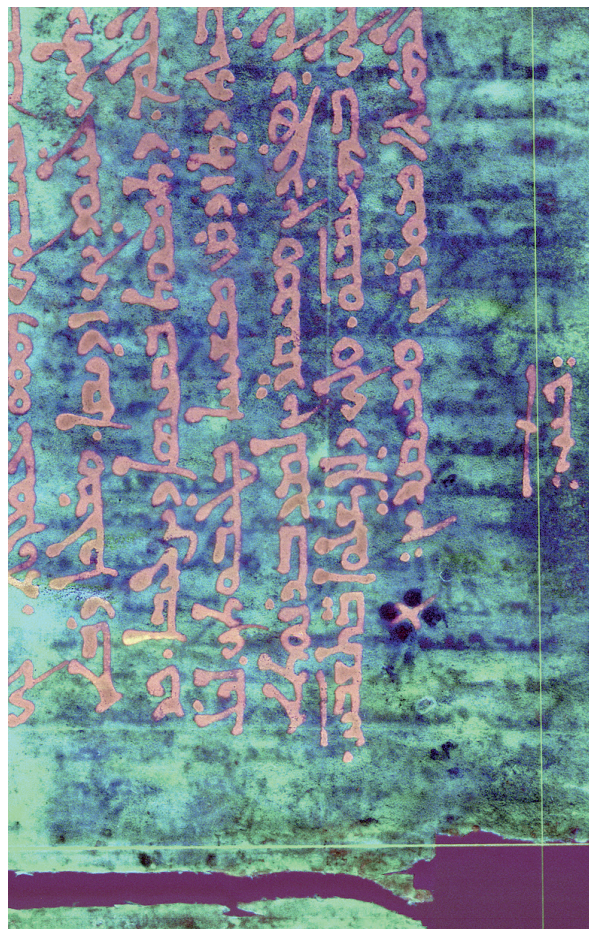


Fig. 3: portion of f. 214r+221vA, chapter 21.6 (continued). Undertext in black (© Owner of the Syriac Galen Palimpsest and the University of Manchester, Creative Commons Attribution 3.0 Unported Access Rights)

¹⁹ SGP: ‘very bitter’.

²⁰ ἐδώδιμος δ’ ὄν εἰς πολλὴν ἔρχεται χρῆσιν: not in U; SGP: ‘it is edible and fulfils the great need/use’.

²¹ SGP: ‘Their spathe that is called *elātē* [...] the tender sprout of the date-palms’.

²² SGP: ‘the membrane-like of this blossom’.

²³ SGP: ‘it does not have very much moisture’.

²⁴ SGP: ‘we use it’.

²⁵ SGP: ‘and they are [applied] externally and taken [internally]’.

within the head’, ‘the brain’) with the secondary meaning ‘pith’. It is used twice in chapter 21.6 ‘On date-palm’ (12.151–152 Kühn) and in both cases its Syriac equivalent is not clearly readable in the SGP—it is either covered by the overtext (f. 166r+171v, col. B, line 34) or thoroughly washed off (f. 214r+221v, col. A, line 6), with the exception of the clearly readable first letter *mīm*. The only other case of the use of the expression ὁ τοῦ φοίνικος ἐγκέφαλος can be found in book 4, where the Syriac translation has ܠܬܝܬܝܢ ܠܬܝܬܝܢ (lit. ‘the flower of the date-palm’) with the word ܠܬܝܬܝܢ being used instead of the more generic term ܠܬܝܬܝܢ (‘palm’) in book 8.⁴⁶ In the Syriac treatise *On the Properties of Foodstuffs*, the term used to render palm pith is ܠܬܝܬܝܢ.⁴⁷ Bar Bahlūl describes it as ܠܬܝܬܝܢ ܠܬܝܬܝܢ (‘the heart of the palm trees’) and ܠܬܝܬܝܢ (‘the pulp of the palm tree’).⁴⁸ However, several clues allow us to give ܠܬܝܬܝܢ as an equivalent of ἐγκέφαλος. First, ܠܬܝܬܝܢ means among other things ‘brain’ and ‘marrow’, i. e. ܠܬܝܬܝܢ ܠܬܝܬܝܢ (‘the marrow of kernels’) or here ܠܬܝܬܝܢ ܠܬܝܬܝܢ (‘the marrow of the tree’). Second, in the *Syriac Book of Medicines*, ἐγκέφαλος is specifically rendered by ܠܬܝܬܝܢ.⁴⁹ Third, in the *Syriac Geoponica*, the term ܠܬܝܬܝܢ (‘the brain of the head’) is used to translate the same word.⁵⁰ Fourth, Galen in his treatise *Properties of Foodstuffs* explains the word ἐγκέφαλος as follows: ‘The spinal marrow is similar to the brain and should not be called “marrow” (Ὁ νωτιαῖος μυελὸς ὁμογενὴς μὲν ἐστὶν ἐγκεφάλῳ, κακῶς δ’ ὀνομάζεται μυελός).’⁵¹ For ἐγκέφαλος, the Arabic translation gives the generic word *موخ* which shares the same root as the Syriac ܠܬܝܬܝܢ.⁵²

In the second instance, Galen explains the meaning of the word ἐλάτη: ὁ δὲ καλοῦσιν ἐλάτην, τὸ ἀπαλὸν ἐκβλάστημα τοῦ φοίνικος (‘the tender sprout of the date-palm, called spathe (*elátē*)’). The Syriac has ܠܬܝܬܝܢ ܠܬܝܬܝܢ ܠܬܝܬܝܢ ܠܬܝܬܝܢ ܠܬܝܬܝܢ ܠܬܝܬܝܢ ܠܬܝܬܝܢ (‘their spathe which is called *elátē* is the tender sprout of the palm trees’). The word ܠܬܝܬܝܢ (‘spathe’) was recovered by using the regular expression function of Sedra IV on the ground of three hardly visible letters (ܠܬܝܬܝܢ). The same term is used in Hunayn’s *Properties of Foodstuffs* in the chapters on the date-palm according to Galen and in MS D. Moreover, Bar Bahlūl gives *الطلع* as a counterpart for ܠܬܝܬܝܢ which is also present in the concise Arabic version of *Simple Drugs*.

In the third example, Galen explains how to use the spathe and the pith of the date-palm against liver and stomach disorders: ἔξωθεν τε καὶ ἔσωθεν (‘externally and internally’). Here, we fill out the erased Syriac text as follows: ܠܬܝܬܝܢ ܠܬܝܬܝܢ ܠܬܝܬܝܢ ܠܬܝܬܝܢ (‘and they [are placed] externally and taken [internally]’). On the one hand, the adverb ἔξωθεν comes generally with the verb ἐπιτίθημι (ܠܬܝܬܝܢ) in the passive form within books 6–8. Although there is no verb in the Greek text, the Arabic version gives *فيما يوضع* (‘where they are placed’). We therefore suggest reading ܠܬܝܬܝܢ in the SGP. On the other hand, the only other occurrence of ἔσωθεν (‘internally’) in the bilingual corpus of books 6–8 is translated by ܠܬܝܬܝܢ that also renders εἶσω (twice). MS D, which abridges the passage, does not have any verb but gives the adverb in a similar way. It then offers further support to fill the gap with ܠܬܝܬܝܢ (‘and internally’).

⁴⁶ About those two words and their related semantic fields, see Löw, *Aramäische Pflanzennamen*, 109–125. The word ܠܬܝܬܝܢ is also used in SGP, f. 144r+145v (book 4): ܠܬܝܬܝܢ ܠܬܝܬܝܢ ܠܬܝܬܝܢ (‘the fruit of the palm trees and the wines’) for ὁ τῆς φοίνικος καρπὸς καὶ τῶν οἴνων (11.648 Kühn).

⁴⁷ Cf. Hawley, Preliminary Notes, 93. MS D has ܠܬܝܬܝܢ (‘heart’).

⁴⁸ Cf. Duval, *Lexicon Syriacum*, col. 1750, lines 1–2. MS P has the identical Arabic word.

⁴⁹ Cf. Bhayro, *The Reception of Galen’s Art of Medicine*, 135.

⁵⁰ Cf. Payne Smith, *Thesaurus*, col. 2033.

⁵¹ *On the Properties of Foodstuffs* 3.10 (6.678 Kühn).

⁵² The Arabic translator also makes a further distinction between *موخ الرأس* (‘brain of the head’) and *موخ الصلب* (‘marrow of the spine’), cf. Ullmann, *Wörterbuch*, 216.

[Chapter 21.9]

[θ'. Περὶ φύκου.] Φῦκος ὑγρὸν ἔτι καὶ χλωρὸν ἐξαιρούμενον τῆς θαλάττης, καὶ ψύχει καὶ ξηραίνει κατὰ τὴν δευτέραν τάξιν, ἔχει γάρ τι καὶ στρυφνὸν μετρίως.

On seaweed.

When seaweed is taken out of the sea whilst it is still wet and green, then it cools and dries in the second degree, for it also has some moderate astringency.

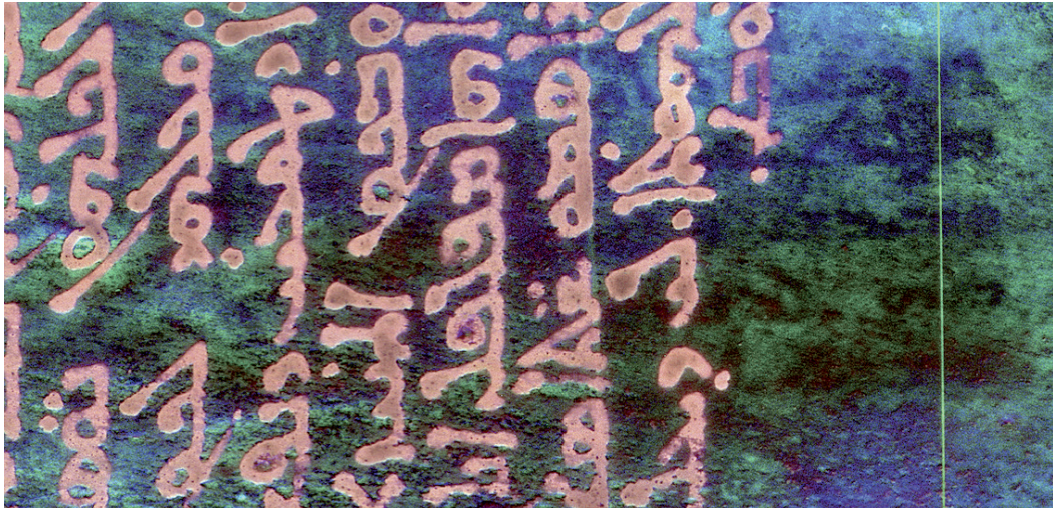


Fig. 6: portion of f. 214r+221vA, chapter 21.9. Undertext in black (© Owner of the Syriac Galen Palimpsest and the University of Manchester, Creative Commons Attribution 3.0 Unported Access Rights)

[ܘܠܟܝܢ ܕܡܪܝܬܐ ܘܠܟܝܢ ܕܠܚܝܬܐ]
 ܠܟܝܢ ܕܡܪܝܬܐ [ܠܟܝܢ ܕܠܚܝܬܐ] [ܠܟܝܢ ܕܡܪܝܬܐ] [ܠܟܝܢ ܕܠܚܝܬܐ] [ܠܟܝܢ ܕܡܪܝܬܐ] [ܠܟܝܢ ܕܠܚܝܬܐ]
 ܠܟܝܢ ܕܡܪܝܬܐ ܠܟܝܢ ܕܠܚܝܬܐ ܠܟܝܢ ܕܡܪܝܬܐ ܠܟܝܢ ܕܠܚܝܬܐ ܠܟܝܢ ܕܡܪܝܬܐ ܠܟܝܢ ܕܠܚܝܬܐ

The entry on seaweed is present in MS D (f. 64r); however, it differs considerably from Sergius' translation. The title was reconstructed from the *pínax* (BL, f. 56v), taking into account one full line of unreadable rubric in the SGP (approx. 18–20 characters). It is not particularly clear which sort of seaweed is discussed in this entry. The Syriac transcription ܘܠܟܝܢ is recorded in Bar Bahlūl's *Lexicon* (variant: ܘܠܟܝܢ ܕܡܪܝܬܐ) as a form used by Sergius for the Syriac ܠܟܝܢ (literally 'redness'; variant: ܠܟܝܢ).⁶² Indeed, the latter is not present in Sergius' translation of books 6–8; furthermore, while pointing to the red colour of the seaweed, the word itself contradicts Galen's description. This may be the reason why Sergius has chosen to repeat the transcription of the Greek word as the second component in the title, where we would expect to see the existing Syriac equivalent.

⁶² Duval, *Lexicon Syriacum*, col. 1521, lines 14–16; Payne Smith, *Thesaurus*, col. 3070.

[illegible]

Χαλβάνη is a West Semitic loanword in Greek, cf. Hebrew חלבנה in Ex 30:34 being a derivative of 'חלב' (milk).⁶⁹ The Aramaic form חלבניתא (Syriac ܠܚܒܢܝܬܐ) is obviously of the same origin, pointing out the milky nature of the juice (or resin) of the root of the fennel plant.⁷⁰ Interestingly, the entry ܠܚܒܢܝܬܐ in Bar Bahlūl's *Lexicon* quotes the first phrase of Sergius' translation verbatim, which allowed us to restore parts of the poorly-readable text in SGP.⁷¹ In Bar Bahlūl's description, the first word following the title reads 'ܠܚܒܢܝܬܐ (and the sort [of the plant])', which does not reflect the Greek 'ὀρός (resin)'. The latter is quite commonly used in books 6–8 and rendered as either 'ܠܚܒܢܝܬܐ (juice)' or 'ܠܚܒܢܝܬܐ (milk)'. Therefore in this case we did not follow Bar Bahlūl in our reconstruction, although otherwise the title and the first sentence fully accord with the entry in his *Lexicon*. The Galenic chapter on galbanum is related to the description of fennel (νάρθηξ), also in book 8 (12.85 Kühn), where the Syriac equivalent of the plant name ܠܚܒܢܝܬܐ can be found in the title (BL, f. 57v; SGP, f. 192v+193r, col. B). The entry is also present in MS D (f. 64v), albeit in an abridged form, and mentions the powers of the substance but omits the degrees to which they are changed.

[Chapter 22.2]

[β'. Περὶ χαμαίδρυος.] Χαμαίδρυς ἐπικρατοῦσαν ἔχει τὴν πικρὰν ποιότητα, ἔστι δὲ καὶ δριμεῖα πῶς. ἔξ ὧν δηλονότι δεόντως σπλῆνα τήκει καὶ οὖρα καὶ καταμήνια κινεῖ καὶ πάχος χυμῶν τέμνει, καὶ τὰς ἐν τοῖς σπλάγχχοις ἐμφράξεις ἐκκαθαίρει. καὶ θεῖη ἂν τις αὐτὴν ἐν τῇ τρίτῃ τάξει κατὰ τὸ ξηραίνειν καὶ θερμαίνειν, καὶ πλέον γε κατὰ τὸ ξηραίνειν ἢ θερμαίνειν.

On true germander

True germander has an overpowering bitter quality, and also is somewhat pungent. Therefore it clearly melts the spleen, stimulates urine and menses, cuts the thickness of humours, and also cleanses blockages in the intestines. One could say that it dries and warms in the third degree, although it dries more than it warms.

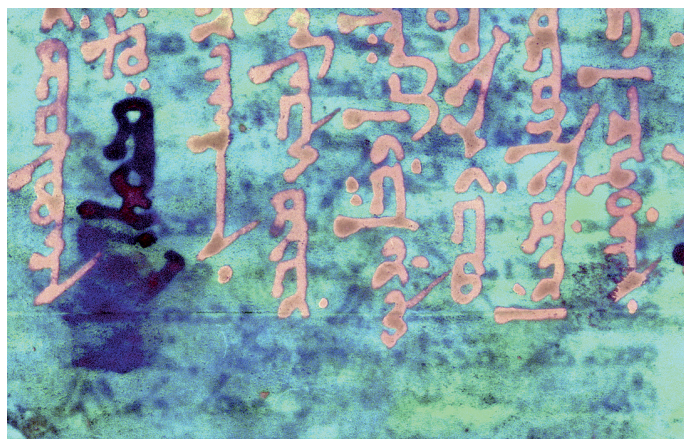


Fig. 10: portion of f. 214r+221vB, chapter 22.2. Undertext in black (© Owner of the Syriac Galen Palimpsest and the University of Manchester, Creative Commons Attribution 3.0 Unported Access Rights)

⁶⁸ Cf. ܠܚܝܬܐ: Duval, *Lexicon Syriacum*, col. 894, line 15.

⁶⁹ Masson, *Recherches*, 60; Beekes, *Etymological dictionary*, 1609; Chantraine, *Dictionnaire étymologique*, 1242; Brown *et al.*, *A Hebrew and English Dictionary*, 317.

⁷⁰ Löw, *Aramäische Pflanzennamen*, 163; Payne Smith, *Thesaurus*, col. 1275.

⁷¹ Duval, *Lexicon Syriacum*, col. 894, lines 15–16.

[Chapter 22.4]

[δ'. Περὶ χαμελαίας.] Χαμελαίας τὴν πικρὰν ἐπικρατοῦσαν ἔχει ποιότητα. διὸ καὶ τὰ ῥυπαρὰ λίαν ἔλκη καὶ ὅσα μεγίστας ἐσχάρας ἔχει, μετὰ μέλιτος ἀνακαθαίρειν δύνатаι.

On spurge-olive

Spurge-olive has a sharp quality that dominates. Therefore, with honey it can clean very dirty wounds and those with extremely large scabs.

⁷⁵[ܠܐ ܕܥܝܢܐ]

(poor readability)

⁷⁸.ܠܐ [ܕܝܢܐ] [traces circa 2 lines] ⁷⁷ܠܐ [ܕܝܢܐ] ⁷⁶.ܠܐ [ܕܝܢܐ] [... ..]

The *pínax* includes the full title, ܠܐ ܕܥܝܢܐ ܕܥܝܢܐ. In SGP, however, the rubric space is limited to approximately 8 characters, therefore only the first element in the title was restored in the edition. This entry is attested in the Arabic version of *On Simple Drugs* (P, f. 115r–v), where the Arabic equivalent of the plant name is مازريون. In both Bar 'Alī's *Syriac-Arabic Glosses* and Bar Bahlūl's *Lexicon*, the Arabic term corresponds to ܠܐ ܕܥܝܢܐ ('wild olive'), as in the BL *pínax*.⁷⁹ There is, however, a certain confusion around this term. Bar 'Alī relates it also to ܠܐ ܕܥܝܢܐ (literally 'Egyptian cyclamen'),⁸⁰ which corresponds to 'chameleon' (χαμαιλέον; 12.152 Kühn) in Sergius' translation (see chapter 22.6 below). Bar Bahlūl, in turn, also equates ܠܐ ܕܥܝܢܐ with ܠܐ ܕܥܝܢܐ ('chameleon').⁸¹

In the SGP only a few words are decipherable, mostly with the help of the Arabic text. For instance, the verb ἐπικρατέω is often rendered by a personal pronoun prefixed by ܐ with the adverb or the adjective ܕܥܝܢܐ. The same construction is used in the Arabic translation (في هذا ... كثير).

[Chapter 22.5]

[ε'. Περὶ χαμαιλεύκης.] Χαμαιλεύκη θερμὴ τὴν δυνάμιν ἐστὶ κατὰ τὴν τρίτην που τάξιν καὶ ξηρὰ κατὰ τὴν πρώτην.

On colt's-foot.

Colt's-foot has a warming power roughly in the third degree and drying in the first.

[ܠܐ ܕܥܝܢܐ]

(poor readability)

[traces circa 3 lines] ܠܐ

Owing to the poor state of preservation, the text of this entry is not readable in SGP. It is not included in MS D either, but is present in Bar Bahlūl's *Lexicon* under the title ܠܐ ܕܥܝܢܐ (variant: ܠܐ ܕܥܝܢܐ).⁸² The latter includes a Syriac translation of Dioscorides' chapter dealing with this plant (*On Medicinal Substances* 1.124; 25.610 Kühn, here: χαμαιπεύκη). R. Payne Smith suggested that Bar Bahlūl himself may have translated the Greek passage into Syriac.⁸³ It is, however, more likely that the lexicographer used an existing translation, probably made or transmitted by Ḥunayn, as follows from Bar Bahlūl's reference to 'the teacher'.⁸⁴

⁷⁵ Cf. ܠܐ ܕܥܝܢܐ : Duval, *Lexicon Syriacum*, col. 860, line 5; ܠܐ ܕܥܝܢܐ (variant: ܠܐ ܕܥܝܢܐ) : Duval, *Lexicon Syriacum*, col. 904, lines 6–7

⁷⁶ P: في هذا من الجر مقدار كثير

⁷⁷ Cf. διὸ καὶ... δύνатаι; P: فهو لذلك ممّا يمكن.

⁷⁸ Cf. μεγίστας; P: العظيمة.

⁷⁹ Duval, *Lexicon Syriacum*, col. 688, lines 5–6; Payne Smith, *Thesaurus*, col. 1119; Löw, *Aramäische Pflanzennamen*, 136.

⁸⁰ Payne Smith, *Thesaurus*, col. 956; Löw, *Aramäische Pflanzennamen*, 127–128.

⁸¹ Duval, *Lexicon Syriacum*, col. 904, lines 6–7.

⁸² Duval, *Lexicon Syriacum*, col. 860, lines 11–14.

⁸³ Payne Smith, *Thesaurus*, col. 1661.

⁸⁴ On Bar Bahlūl's use of existing Syriac translations of Greek authors and his *ad hoc* Arabic translations, see Pormann, *The Oriental Tradition*, 14–20.

[Chapter 22.6]

[στ'. Περὶ χαμαιλέοντος.] Χαμαιλέοντος ἡ ρίζα τοῦ μὲν μέλανος, ἔχει τι δηλητήριον, ὅθεν ἔξωθεν ἢ χρήσις αὐτοῦ πρὸς ψώρας καὶ λειχήνας καὶ ἀλφουὺς καὶ ὅλως ὅσα ῥύψεως δεῖται καὶ τοῖς μαλακτικοῖς καὶ διαφορητικοῖς μίγνυται φαρμάκοις. καὶ τὰ φαγεδαινικὰ τῶν ἐλκῶν ἰᾶται καταπλασθεῖσα. ἔστι γὰρ ξηρὰ κατὰ τὴν τρίτην ἤδη πού τάξιν. ἐν δὲ τῷ θερμαίνειν ἐκ τῆς δευτέρας συμπληρουμένης. ἡ δὲ τοῦ λευκοῦ χαμαιλέοντος ρίζα πρὸς ἔλμινθας πλατείας δίδοται πλῆθος ὀξυβάφου μετ' οἴνου αὐστηροῦ. προσφέρουσι δ' αὐτὴν καὶ τοῖς ὑδερικοῖς παραπλησίαν οὖσαν καὶ αὐτὴν τῇ κράσει τῇ τοῦ μέλανος ρίζῃ, πλὴν ὅσα πικρότερα ἐκείνης ἐστίν.

On chameleon

The root of the black chameleon⁸⁵ has some noxious property. Therefore, it is used externally for scabs, lichens, dull-white leprosy, and in general for conditions requiring cleansing with⁸⁶ softening and sweat-inducing drugs. It also cures cancerous wounds when applied as a poultice. For it is dry, perhaps even in the third degree, and warming in the end of the second degree. The root of the white⁸⁷ chameleon is given⁸⁸ against the broad intestinal worms in the quantity of one *oxýbaphon*⁸⁹ [ca. 30ml], with dry wine. One also offers it to patients suffering from dropsy, because it is similar to the mixture of the root of black chameleon, except that the former is sharper than the latter.⁹⁰



Fig. 12: portion of f. 214r+221vB, chapter 22.6 (beginning). Undertext in black (© Owner of the Syriac Galen Palimpsest and the University of Manchester, Creative Commons Attribution 3.0 Unported Access Rights)

⁸⁵ SGP: 'the root of this if [...] black'.

⁸⁶ SGP: 'for all the pains requiring cleansing; it is mingled with'.

⁸⁷ SGP: 'other'.

⁸⁸ SGP: 'is taken'.

⁸⁹ SGP: 'handful/a measure'.

⁹⁰ SGP: 'of the root of the other, unless it is sharper'.

¹⁰⁰ Duval, *Lexicon Syriacum*, col. 596 line 24.

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