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The psychedelic world of textile dyes in Spitalfields – the V&A Leman silk

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In 2016 the Victoria and Albert Museum acquired a panel of brocaded silk dress fabric in immaculate condition woven from one of the few surviving patterns drawn by James Leman, a leading 18th-century silk designer and master weaver in Spitalfields, London. The acquisition offered an illuminating view into a particular aspect of the cosmopolitan manufacturing world in which Leman operated.

The silk appears as pristine now as when it came off the loom in around 1709, spending most of the following 300 years unused. Its dyes, still exceptionally vibrant, provided us with the rare opportunity to investigate their composition unaffected by the usual ravages of time.

Loose thread ends from the reverse of the brocade, one sample per shade of colour, were analysed, and traditional dyes were identified: indigo for the blues, cochineal and annatto for the crimson, safflower for the pinks, weld (with or without annatto) for the yellows, and a mixture of indigo and weld for the greens. The presence of annatto and safflower suggests that the silk should only be exposed to light in a controlled manner, to avoid fading. Research is planned on additional textiles not deteriorated through over-use and display, to get a better understanding of the brilliant palette popular in the 18th century, towards compiling an open-access database.

Overall, the results of the dye analysis reveal the trade links London, and in particular the dye works which provided coloured silk yarns to the weavers of Spitalfields, had with the rest of the world: weld was likely cultivated in Europe, indigo could have originated from both Asia and South America, cochineal was from South America and safflower was originally from the near East. The cultivation of annatto, originally from South America, had already spread to Southern Europe well before Leman was active.

Indigo in 18th century tapestries – Dyeing, use and degradation

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At the end of the 17th century, Colbert, Minister of Finance of Louis XIV, reorganized the French Manufactures. The three Tapestry workshops of Gobelins, Beauvais and Aubusson were given the title of Royal Manufacture, [1] leading to the establishment of many rules allowing the manufacture of tapestries called "Grand Teint" of very high quality. Among these rules, a list of "solid" dyes imposed was established including indigo to dye blues, greens and some purples.

To enable the study of these dye, a project containing several steps was set up. The first of which consisted in the creation of a color chart of 18th century recipes varying parameters in the indigo tank and the hue. [2-4] In a second step, reference spectra of these samples were recorded with several non-invasive analytical methods from ultraviolet to near-infrared range (HSI-VIS-NIR, FORS, LEDµSF…) [5,6] in order to create a reference spectral database which was then compared to the data obtained on tapestries.

Indigo has already been studied extensively. Indeed, its signal obtained through non-invasive methods is well known [7,8] and it is recognized as one of the dyes that degrades the least. [9] However our observations on tapestries have allowed us to observe other phenomena. This study proposes to show the spectral variations generated by the different recipes but also the different states of degradation of the dye according to the textile, wool or silk. Finally, a comparative study carried out between the different Manufactures of the time will allow the observation of different dyeing habits as well as aesthetic choices.

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Dyehouse notes from the Crutchley Archive: 'grain' dyeing practices with alum and tin 'spirits' for red woollen cloth, 1716 to 1728.

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In early eighteenth-century London, the Crutchley family were amongst many dyers in the business of creating 'beautiful cullers' for fashionable textiles. The Crutchleys' speciality was to dye woollen cloths in scarlet, crimson and other red shades at their dyehouses in Southwark near the River Thames. Nine of their dyers' books with hundreds of colourful dyed textile 'patterns' and handwritten dyeing instructions have survived and are now part of the UNESCO-registered Crutchley Archive in Southwark Archives' collection. [1]

All the instructions in the Crutchley books are for 'in grain' and 'out of grain' dyeing involving cochineal, madder and occasionally stick lac with alum and tin mordants and permitted additions of brazilwood, logwood and other dyes to create tonal shades and tints. The three oldest books, dated 1716 to 1728, also hold detailed records of dyehouse operations: pre- and post-dyeing treatments of the cloths; preparing fresh and recycled baths of mordants and dyes; making tin 'spirits' (a nitrate solution) with aqua fortis (nitric acid); and selecting dyeing equipment, timings and water sources. The Crutchleys' battle to prevent 'white spot' spoilage of scarlet cloths, a known risk from aqua fortis in tin spirits, highlights the advantages of their dyehouses being near river and well water sources and tenter-fields.

In our presentation we share and discuss these Early Modern dyeing practices in the context of the colours produced, and the daily manual labour and sensory skills involved in physical acts that come alive in these masterly notes from experienced dyers. For dye history, these intimate accounts give a rare opportunity of actual dye work practices to compare with published information of the period and surviving material evidence from red wool dyeing contemporaries of the Crutchley family to inform modern perspectives of historical dyeing. [2]

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The treasure chest of colours: dyes of the eighteenth-century West African textiles from the Thomas Clarkson's chest

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The paper presents the results of dye analysis of eighteenth-century West African textiles from the wooden chest of the English abolitionist Thomas Clarkson, currently in the collection of the Wisbech and Fenland Museum, UK. At the end of the 1700s, Thomas Clarkson travelled across England giving lectures to mobilise public opinion in support of his campaign to end the slave trade. As a visual aid in these lectures, he used a chest with natural resources and artefacts to highlight the cultured nature of Africans and the inhumanity of the slave trade, and to demonstrate economic alternatives. The chest also played a pivotal role in the 1788–1789 Privy Council enquiry into the slave trade. He collected these African products and specimens from sailors of ships in the main ports of Britain, like Bristol and Liverpool, which were involved in the African trade. These textiles are among the earliest surviving fabrics from West Africa and are therefore of great importance for our understanding of the historical development of local weaving and dyeing traditions, yet little is known about their provenance.

This research was carried out as part of a broader project aimed at establishing, for the first time, a much more detailed understanding of the origins of 32 West African textiles and textile-related materials in the collection through technological characterisation (textile analysis; fibre identification; dye analysis) and contextual research. Ten textiles were selected for dye analysis using HPLC, which was carried out on 26 samples. The dye sources identified include indigo/woad and a luteolin/apigenin containing yellow colourant. Furthermore, bright reds were obtained with Mexican cochineal applied on tin mordanted fibres. This new research adds important new data to our understanding of 18C West African textile production and to scholarly debates of cultural exchanges in textiles in the Early Modern Period, where the role and development of West African coastal manufacturing is significantly understudied.

An optimised small-scale sample preparation workflow for historical dye analysis applied to Scottish and English Renaissance embroidery using UHPLC-PDA

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The sample preparation step for micro-invasive dye analytical techniques such as UHPLC-PDA and LC-MS is vital for reliable results. However, the focus of many dye analysis method papers in recent years has been on the extraction solvent and its impact on various dyestuffs and their markers, [1-4] few studies have focused on the sample preparation workflow itself. Here, an optimised sample preparation workflow based on a 96 well plate and filtration by centrifugation together with a shorter UHPLC method using CORTECS C18 1.6 µm technology, is presented. It allows the use of an extraction volume of 50 µl and makes the analysis of samples as small as 0.01 ± 0.001 mg possible. The bulk approach employed, where up to 96 samples can be prepared simultaneously, reduces the random error introduced and increases the analytical efficiency, leading to more reliable results overall. Combined with the decrease in analytical time from the developed UHPLC method, the production of larger data sets and the use of modern chemometric approaches, which currently only a few dye analysis studies have utilised, [5-7] is facilitated. The workflow gives consistently high percentage recoveries (> 85 %) over a range of seven concentrations (0.1 – 20 µg ml^{-1}). It has been successfully applied to 17 reference dyed textiles encompassing mordant, direct and vat dyes on both wool and silk with standard deviations of < 5.1 % (n = 5), showing its reliability regardless of dye class and fibre. The new method was used to analyse historical samples from a collection of English and Scottish Renaissance embroideries in the National Museums Scotland (NMS) collection. Multiple dye sources were confidently identified in the historical objects, including weld, cochineal, madder, indigo and safflower. Overall, the developed workflow increases the reliability and efficiency of dye analysis investigations using UHPLC-PDA and LC-MS.

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Development of a new mild extraction method for the analysis of natural dyes in Cultural Heritage textiles by LC-DAD-MS

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It is well known that identification of dyes provide significant information about the biological sources used and can thus trace geographical provenience and historical period of museum textiles. Acid hydrolysis was the standard method for dyes extraction from fibres since its first application in 1985 [1] while mild extraction methods have been increasingly used after their first development in 2005. [2] The latter brings significant benefits, as giving notably more information regarding the original dye source. The main problem with flavonoid dyes when it comes to the classical extraction using acid hydrolysis is the decomposition of the glycosidic components to aglycons, resulting in loss of information regarding their biological source. Lately, natural dyes extraction techniques have progressively developed towards milder chemical and physical conditions, in order to preserve the yarn and the chromophores. [3]

In this present study a new mild extraction procedure with rapid sample preparation and short chromatographic method will be presented, developed in order to preserve glycosides' information and the fibre itself. Aiming to evaluate the versatility of the extraction procedure, this approach was tested on protein materials like silk and wool fibres, dyed with flavones, anthraquinones and indigo. Dyes' characterization and comparison with the acidic extraction was performed using HPLC (High Performance Liquid Chromatography) with diode array (DAD) and MS detection. Advantages and limits of this new method will be presented as well as its application in the identification of dyes in samples from historical textiles in Romanian collections.

It was concluded that extraction of dyes from textiles by using this new method would be a promising alternative, as it can reveal more information about the original dye source as compared to the harsh extraction which uses a strong acid, as it preserves the glycoside linkages. By using it with LC-DAD-MS analysis it has the advantage of being shorter, as compared to other mild extraction methods.

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A new on-gel sampling system for identification of lake-pigments in polychromies

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The identification of organic materials in pictorial art objects represents a complex issue, especially in the presence of inorganic materials, which can produce a signal that strongly interfere with those of organic compounds during non-invasive and on-site analyses. Several approaches are available for the sensitive detection of these analytes in the laboratory, nonetheless, to sample is a delicate matter. Moving from recent works which exploited the application of silver-loaded gels for SERS detection of dyes from artworks, [1–4] this study explores the potential of an analytical procedure which takes advantage of gel substrates versatility to conduct multi-analytical identification: through Agar-gel substrates, [5] organic compounds are directly sampled from pictorial films in order to be analysed by means of spectroscopic techniques, and successively re-extracted for chromatographic analyses. [6]

The methodology was tested on madder lake pigments in three binders: egg yolk, Arabic gum, and beeswax, to consider its suitability for pictorial materials recurring in archaeological matrices. Several protocols were tested by varying Agar-gel concentration and application time on mock-ups, to discriminate between mechanical and chemical extraction. For the extraction of dyes, the novel ammonia-based extraction protocol was selected. [7] The protocol is efficient in preserving the sensitive but informative glycosyl moieties of dyes. Optical non-invasiveness of the procedure was measured by means of optical microscopy and colorimetry. Preliminary characterization of extracted dyes on gel was performed through multi-spectroscopic approach (UV-Vis-NIR spectroscopy, Surface Enhanced Raman Scattering spectroscopy) and, for a deeper characterization, re-extraction was carried out from gel substrates combined to a clean-up procedure for HPLC-MS analyses. The procedure is going to be tested also on pigments derived from brazilwood and indigo, in complex paint systems and in the presence of inorganic components.

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Calico-printing in Mulhouse from 1750 to 1914: unpublished dyers' books

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In 1833, a group of textile manufacturers based in Mulhouse formed an Industrial Society known as the "Societé Industrielle". [1] In order to inspire artists and designers of the time by introducing them to different patterns and styles, they decided to collect designs from their own production as well as from other countries, including from earlier times. This collection grew in importance to become what is today one of the most important collections of printed textiles in the world, housed in an impressive museum built in 1880, titled "Musée de l'Impression sur Etoffes".

Apart from the printed textiles collection, industrialists gave to the museum library dyes books, sample books and archives dating from 1750 to the First World War. Most of the dyes and recipe books are related to calico printing techniques and chemistry, since Mulhouse Industrial Society also founded a school of chemistry during the first half of the 19th century. This collection of around 150 dye books, mostly unpublished, [2] is currently being studied by the National Institute of Art History within a database which has just been created with the National Archives. This database is an inventory of technical sources of dyeing, from the Renaissance to the beginning of the twentieth century, kept in French public collections: archives, libraries and museums. It takes into account manuscript dyeing treatises, dyers' handbooks and any handwritten document dealing with at least one dyeing process.

At DHA 40, we would like to introduce the database, which will be launched at the beginning of 2022, focusing on the example given by Mulhouse Industrial Society dyeing archives.

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Vordan Karmir: An attempt to unravel the mystery of Armenian cochineal recipes for paints and inks used in manuscripts

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Vivid reds and purples in 17th-century Armenian manuscript illuminations from miniature schools of Constantinople, New Julfa and Crimea, led us for the search of lost Armenian cochineal recipes. This scale insect has been used for centuries in textile dyeing and painting. Before the availability of American *Dactylopius coccus*, the Old World cochineal species (*Porphyrophora hamelii*, *Porphyrophora polonica, Kermes vermilio*) were the source of precious dyes. We focused our study on Armenian cochineal (*Porphyrophora hamelii)* and its historical use, to understand better the ancient technology and its transmission through centuries.

Our research enabled us to trace several new cochineal recipes, registered mostly in 17-19th-century Armenian texts preserved in the Matenadaran collection (Yerevan). To the best of our knowledge, these recipes have specificities related to the use of ingredients and extraction processes different from those described in other European texts for the preparation of paints and inks based on this type of insect. The processing of cochineal in the Armenian practice shows some parallels with textile dyeing, when the fibers are being degreased and cleaned prior to mordanting, such as the use of saponin-containing plants by dyers. [1] *Saponaria officinalis* was always used in these Armenian cochineal recipes.

To understand the formulations within Armenian cochineal recipes, our team gathering experts in chemistry, biology, history, linguistics, and conservation science, went in search of the local ingredients, including *Porphyrophora hamelii* or the Ararat cochineal, and then began by preparing historically accurate reconstructions combined with chemical characterization. These new data will be presented in this communication, discussing the role of each added ingredient. [2] The paints and inks that have been reproduced will build a base for further characterization of organic colourants in our case studies, the Armenian manuscripts of Gulbenkian collection (Lisbon). [3]

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Unravelling the origins, technical history and sciences behind the colouring of textiles, Conste des ververs, a Flemish dyeing manuscript from Leuven, 1619-1623

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Conste des Ververs is a unique Flemish dyers manuscript kept in the Archives of Leuven, in Belgium. The manuscript is dated from 1619-1623 and was written by Henricus Coghen, a dyer who lived and worked in Leuven. The manuscript mostly mentions recipes to dye stockings for dyeing and sometimes specific materials are referenced, such as wool, silk, linen - and feathers. Various ingredients such as several red woods, indigo, weld, safflower, mordants and minerals such as massicot, orpiment, arsenic, cinnabar are cited to achieve a wide range of colours.

This presentation reports on our experiments and reconstructions of recipes, as well as the study of the manuscript in comparison with other European historical sources. Colorimetric measurements of the resulting samples were obtained to give a scientific nomination for each colour, and thereby making the historical colour terminology (incarnate, feuillemorte, terneyt, etc.) more accurate and visually understandable.

This research intends to investigate the origin, the process of making, and the partly forgotten sources of the dyeing techniques and ingredients from the early seventeenth century. By unravelling and deciphering the 167 historical recipes from Conste des Ververs and reconstructing them, we aim to provide a better understanding of those partly forgotten source materials and processes and provide workable recipes for scholars and artists.

Traditional dyeing technologies in Latvia and Estonia

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The aim of the paper is to give insight into local dyeing methods and technologies that were practiced in the rural areas in the North-East Baltic in the 19th and the first half of the 20th century. The study is based on both unpublished and published written sources. [1-6] Dyeing technologies used in farmsteads more or less differed from the ones practiced by professional dyers. Dyeing was integrated into everyday life, for example heating of dyebaths was often done in bread ovens after breads were baked. In the countryside coloration of textile materials was carried out both by direct dyeing and by using a mordant. The most popular mordant, the same as in dyers' workshops, was alum ($KAl(SO_4)_2{\cdot}12H_2O$). Additionally copper sulfate ($CuSO_4{\cdot}5H_2O$) or 'blue alum' and ferrous sulfate ($FeSO_4{\cdot}7H_2O$) or copperas were used. However, iron mordant also was used in its natural form as iron-rich water or mud from a bog. In Latvia textile material was mostly mordanted in the dyeing process. The material was placed in a dye solution where the mordant was added. This was not the case in Estonia, where mostly premordanting with alum was used. Both copper and iron mordants were used post-dyeing. Very old dyeing techniques, such as fermentation, continued to be practiced on the farmstead. In Estonia alder buckthorn (*Rhamnus frangula*) bark was processed first by fermentation and then modified with wood ash lye to get red. Wood ash lye was also used as a modifier for making yellows dyed with tannin-containing dyeplants darker. Water was mainly used for making the dyebaths except when dyeing red with northern bedstraw (*Galium boreale*) roots. Then homemade beer was commonly used.

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Uncovering the secret recipe of Ajuda Songbook's pink

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Ajuda Songbook (Cancioneiro da Ajuda) is a monument to Galician-Portuguese medieval lyric containing an exceptional series of illuminations; however, its provenance and date of production are still unknown. [1] In our first study of this manuscript, a complex brazilwood colour was discovered, different from any other that we have found in other illuminations of manuscripts from Portuguese collections. [1] Because dye recipes and paint formulations can be very characteristic of each scriptorium and workshop, these materials have great potential in provenance and dating studies, thus this pink colour became one of our main clues for the study of the Ajuda Songbook. [2,3] Although we were able to fully characterize the paint formulation (I.e. binder, additives, etc.) we were not able to find any match in our extensive database of historical references and reconstructions from medieval treatises and recipe books. [2-4]

Therefore, we have expanded this research to brazilwood recipes from five Iberian and two Italian treatises, encompassing the 11th-17th centuries. In this poster, we will be exploring their differences in extraction and other production processes, alongside their characterization through the microscope, colorimetry, Fiber Optics Reflectance Spectroscopy (FORS), portable Raman, Infrared, and microspectrofluorimetry. From our research we found three types of recipes: in the first type the result is the precipitated pigment; in the second type the binder is added to the precipitate during the process resulting in paint, and in the third type paint is also obtained, but the binder (glair) is used in the extraction process. This last type, found in three recipes of the treatises *De Arte Iluminandi* and *Sloane*, resulted in the reconstructions that demonstrated the colorimetry values closer to Ajuda Songbook's pink. The use of egg white in the extraction might be a fundamental clue to find out where the Ajuda Songbook was produced.

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Baltic Sea blue - experiments with woad and lichens

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The prevailing shade of colour in the Finnish and Estonian textiles during the Late Iron Age was dark, blackish blue. According to dye analysis (UHPLC) the archaeological woollen textiles contained colourants from woad (*Isatis tinctoria*) and local lichens (such as *Lasallia pustulata*). [1-4] These colourants often appeared together.

There might be many explanations for the blue woad colourants and purplish lichen colourants in one textile. For example, the colours may be a result of two separate dyeings. Alternatively, they might indicate contamination caused by the migrated dyes in the burial context. However, this inspired us to test if combining these two dye sources and dye with them in the same vat is possible. Namely, woad and rock tripe need an alkaline dye vat, and it would be time and energy efficient to dye with them both simultaneously.

We prepared a woad vat from fresh leaves, human urine and wood ash lye in our experiments in summer 2020. That was combined with a 3-year-old lichen vat containing rock tripe and human urine. In addition, some honey and sourdough starter were added. The vat was kept at 30 degrees for a week. After that, test yarns were lifted out from the vat and oxidated. Their green shade of colour rapidly turned to dark blue with a grey-purplish tint.

The UV light tolerance was tested on a sunny window for four months, and in visual assessment there seemed to be only minimal changes. The experiments will be remade in summer 2021 to measure the changes in the pH values more carefully and to evaluate the role of other lichen species in the final colour shades.

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Bark of alder species as a source of natural dyes

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Throughout centuries textiles have been dyed using plants, insects and fungi. Knowledge and skills of natural dyeing are part of the intangible cultural heritage. Craftsmen and peasants from the territory of present-day Latvia used different parts (roots, leaves, berries, barks) of local plants to obtain dyes. The popular dye trees of Latvia summarized in the listing of plant dyes are: black alder (*Alnus glutinosa*), grey alder (*Alnus* incana), silver birch (*Betula pendula*), juniper (*Juniperus communis*), alder buckthorn (*Frangula alnus*), pedunculate oak (*Quercus robur*), bird cherry (*Padus avium*), aspen (*Populus tremula*), European crab apple (*Malus sylvestris*), ash (*Fraxinus excelsior*). [1, 2]

The first publications about plant dyestuffs, including alders, appeared in the Latvian press at the end of 19th century. The alder tree barks and mordants create a wide colour range from yellow to brown, reddish, grey and black. [2-5]

Practical dyeing experiments provide the necessary reference materials. This study will present results of the chemical analysis of dyestuff extracts, evaluate the chemical content of pigments in barks dyeing solutions of black alder, grey alder and in the dyed woollen yarn. Our aim was to supplement in-house database of pigments from the widely used dye trees – black and grey alder.

In the present study, extracts were analysed by ultra high performance liquid chromatography coupled with diode array detector and mass spectrometry (UHPLC-DAD-MS). Woollen yarn was treated with potassium aluminium sulphate mordant and dyed with barks of black and grey alder. Samples were prepared in compliance with the method described by Wouters and Verhecken (1989) with some modifications for UHPLC-DAD-MS. [6]

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Investigation of Shellfish Purple in 20th-century Traditional *Enredo* from Oaxaca, Mexico by Means of Hyperspectral Imaging and MA-XRF

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In artistic and archaeological contexts, *purpura* is often associated with Tyrian purple, a reddish-purple dye produced by several species of sea snails from the Muricidae family. Publications report the production and use of shellfish purple as a dye, mainly describing Mediterranean snail species *Murex tronculus* as its source. [1-4] Despite many studies focusing on *M. tronculus*, mollusks from other parts of the world were also used to produce the valuable colorant. This is the case for *Purpura pansa*, another shellfish species found off the rocky shores of western America. [5] Comparably to the purple dye produced using *M. tronculus*, the main constituent of the colorant derived from *Purpura pansa* is dibromoindigo; with bromine being easily detectable by XRF. [6] Furthermore, *purpura* is also identifiable in artworks by means of reflectance spectroscopy, [7] making these two techniques a combination of choice for non-invasive study of the colorant.

Due to the high production cost, the extinction of many of the mollusk species and the development of modern synthetic dyes, the use of shellfish purple has decreased exponentially to the point of often being associated with pre-16th century artistic productions. [4] However, in this study, two modern traditional Mexican skirts in the permanent collection of the National Museum of Mexican Art were investigated for the first time using a combination of reflectance imaging spectroscopy (RIS) and MA-XRF to highlight the use of shellfish purple. These techniques allowed for the identification of indigo, cochineal, and shellfish purple, along with the elemental distribution of materials associated with mordants, but more invasive techniques are used to further distinguish between the Mediterranean and Pacific sources of mollusk used to produce the dye. This study highlights the significance of shellfish purple dye in modern day Mexico and represents one of the first applications of RIS for the study of dyes in textiles.

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Maya Blue: Painting from the Past in the Present

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This paper presents ongoing research carried out between the British Museum and two artists in the Yucatan peninsula, Lorena Ancona and Luis May. Ancona and May have been experimenting with the production of the complex pre-Colombian to early colonial pigment, Maya Blue, using scientific knowledge supplemented with Indigenous methodologies and artistic sensibilities. [1] This project will analyse the molecular composition of contemporary Maya Blue pigment, alongside traces of the pigment on British Museum collections to compare Maya Blue pigments made using current Indigenous methods with those made in the past or recreated in a laboratory. Preliminary ethnographic research has also shown that añil (indigo), from sources other than *indigofera spp.,* such as those extracted from *lonchocarpus spp*., may have also been employed to produce Maya Blue. Scientific analysis in conjunction with ethnographic work may additionally identify and help elucidate, the botanical sources and production of other blue colourants in this region. According to the historical references, [1] besides indigo, other organic dyes from plant sources were used as blue pigments, such as the extracts of muicle/mohuitli (*Justicia spicigera*) or matlalítztic/matlalxóchitl (*Commelina spp.*). The latter has recently been found used as a "hybrid blue colourant" on Mesoamerican codices. [2]

Crucially, this research project also moves beyond traditional ethno-archaeologies in which the present is mined to explain the past, and eschews more recent research narratives which claim that Indigenous knowledge, or the past, can hold answers for the future of a more sustainable globalised world. Instead, it aims to acknowledge the multi-temporality of heritage – alongside the importance of emphasising Indigenous cultural continuity. More broadly, this project seeks to reveal the cognitive insights of post-disciplinary research through the juxtaposition of scientific, Indigenous, artistic and ethnographic methodologies. Not only will this politically engaged process elucidate aspects of the pre-Colombian pigment that have been ignored by scientists working in laboratories, it will also champion multivocal and local methodologies.

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Evidence of the use of a dye chemically related to commelinin in Mesoamerican codices

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While the ancient Mesoamerican codices preserved memories, stories, and religious information, they also implicitly passed down the key that allows us to disclose the technology of pigments manufacture of pre-Hispanic indigenous people. Over the years, thanks to the use of a range of non-invasive and portable analytical techniques, an extensive characterization of their painting materials has been achieved. [1-6] The in situ analytical campaigns have put in evidence mainly the use of organic materials extracted from indigenous plants. Furthermore, also the presence of hybrid pigments (composed of organic dyes supported on inorganic substrates, such as clays and/or other types of silicates) has been pointed out, highlighting a peculiar technology typical of Mesoamerica. [7] The experimental evidence of a paint different from Maya blue in some blue areas of the codices prompted us to enquire the historical references on the lookout for other types of organic dyes from plant sources and hybrid pigments where a similar technology to make blue was applied. This evidence has been detected on three different codices, namely Codex Bodley and Codex Selden from the Bodleian Library collection in Oxford, and Codex Borbonicus at the Bibliothèque de l'Assemblée Nationale in Paris. [5, 6] The first, is a pre-Hispanic codex while the others are dated to the period after the arrival of the Spaniards in Mesoamerica.

Here we aim at presenting the non-invasive study of the blue dye extracted from *Commelina communis* and its hybrid pigments. A comparison between the analytical data collected on specifically conceived paint models and on the codices will be reported, providing indication of the spectral markers that can be exploited for the non-invasive characterization of the dye and addressing the issue of its photochemical stability both as pure dye and hybrid.

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An insight into cultural and technical choices behind dyes and pigments found in the 17th century polychromed wooden ceiling of Santa Rosa de Lima (Nueva Vizcaya, Mexico)

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The Royal Mine of Cuishuiriachi in Nueva Vizcaya (today the Mexican state of Chihuahua) was established briefly after the discovery of silver, copper and other minerals mine in 1687. By that time, the Society of Jesus had established two missions few miles away from Cusihuiriachi (Cusi) and more than thirty in the region. [1,2] Jesuits' interest and ability to adapt themselves to local influences to build and decorate their churches has been studied in depth. [3,4] The technical studies (XRF, FORS, ATR-FTIR, LM, RAMAN, GC-MS) carried out in the polychrome wooden ceilings located at Cusihuiriachi Spanish colonial church, Santa Rosa de Lima and other six Jesuit mission churches have confirmed this ability. Results evidenced that Jesuits merged their European artistic canons styles and techniques with those from Mesoamericans and local populations. [5]

The *palette* in Cusi polychrome ceilings (yellow, red, pink, blue, green and black) has been documented in a previous study, with special attention to red-pink and blue colors. Results revealed that indigo (*Indigofera species*) and cochineal (*Dactylopius coccus*) were some of the main sources for their production respectively. [6] That indigo was used instead of local azurite was an extraordinary finding, since there was no evidence until now of the use of these dyes by Mogollon pre-Hispanic groups [7] or by Tarahumara Indians [8,9] to decorate wood and ceramic craft objects. In addition, the yellow color from the ceiling was also identified as a dye (and not as an inorganic yellow earth, which can be easily found in varied yellow color tones a couple miles away from the church even nowadays). Furthermore, results revealed the possible mixture of malachite and indigo to obtain the green used in the central wooden panels of the ceiling, while green and yellow earth were added to produce a darker green to decorate the edge panels.

In this research, local organic and inorganic material resources around Cusihuiriachi region were collected and analyzed (LM, FTIR) and were used for comparative purposes in the characterization of Cusi polychrome ceiling structure and decoration. In the present article the characterization of the yellow and green color will be presented and the reasons behind the choice of dyes over pigments will be discussed.

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Colour names on lead tags from a Roman cesspit in Carnuntum, Austria

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In 2011, a Roman cesspit was excavated in the civil town of Carnuntum, the provincial capital of Upper Pannonia in Roman times. Coin finds indicate that the latrine was in use between the reigns of the Roman emperors Traianus (98-117 CE) and Marcus Aurelius (161-176 CE). The cesspit contained household and food waste, human faeces, pottery shards, pollen, lime for disinfection, amber pieces and 145 lead tags. Archaeozoological, archaeobotanical, palynological and parasitological investigations provided insight into flora, fauna, eating habits and state of health of the Carnuntum population in the 2nd century CE. [1]

The lead tags (ca. 3 x 4 cm) show a correlation to textiles. The fronts and backsides have been inscribed with letters in Latin cursive writing (ca. 2 to 4 mm). X-ray images and CT-scans made it possible to read the letters on the severely corroded tags. The abbreviations of terms concern personal names, prices, names of textiles and colour names. The terms were compared to those on 1123 tags from the Pannonian city Siscia (Croatia) dated to the same period. [2] The Carnuntum tags were attached to clothing in a dyeing workshop or a laundry, but not in a warehouse because of the low prices indicated on the tags. Terms are related to cleaning (*remundare, pundare, putare*), restoring *(recurare*), repairing (*sarcire*), fulling (fullonicare) and dyeing (*cociliare*). Abbreviations on the tags point to cloaks (*abolla, banata, casula, gausapa, lacerna, mantus, paenula, palla, palliolum, pallium, sagum*), clothes (*tunica*), wool (*lana*), cloths and blankets (*lodix, pallium, pannus*), socks or slippers (*udones*), and a money bag (*sacculus*).

The abbreviations indicating colours are related to blue (*caeruleus*), red (*haematinus*, *cusculium*, *coccinus, nitelinus, purpureus, ruber, sanguineus*), yellow (*fulvus, galbinus, sulfureus*), brown (*corticeus, fuscus, myrteus*), black (*piperinus*) and green (*myrteus, viridis*). It will be discussed which dyeing materials could have served to obtain the colours mentioned on the tags.

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Textile wrappings of Egyptian votive animal mummies: A multi-scalar investigation of the colouring materials

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Animal mummies are extraordinary witnesses of ancient Egyptian beliefs and religious practices. [1] Commonly exhibited in museum galleries, they attract the curiosity of visitors, while bringing a unique historical/cultural perspective. The textile wrappings encasing the mummified body of the animals are usually patterned using undyed and coloured (mostly red, brown and black) linen strips.

In this study, 20 animal mummies, including cats, ibises, crocodiles, calves and birds of prey from the collections of the British Museum (London, UK) and the Museo Egizio (Turin, Italy), were investigated with the main aim of identifying the colourants used in the textile wrappings.

Broadband multispectral imaging was initially carried out to obtain preliminary information at the macro scale on the distribution and chemical nature of the colouring agents. Fibre optic reflectance spectroscopy was then used to survey several coloured areas of the mummies. Safflower (*Carthamus tinctorius*) and red ochre were identified non-invasively. Representative samples were then taken and observed using optical microscopy and scanning electron microscopy, in order to obtain information at the micro scale on the distribution of the colouring agents on the fibres, as well as the presence of other materials, including those from environmental contamination. Energy dispersive X-ray spectrometry revealed the elemental composition of particles and clear areas of the fibres, whereas high performance liquid chromatography tandem mass spectrometry provided the identification of the organic dyes at a molecular level.

Hydrolysable and condensed tannins, in combination with iron as a mordant, were found to be used in the very dark shades, which generally corresponded to the textiles in the worst state of preservation. Other aspects, such as fibre processing, fungal attack and presence of coating materials, also appeared to play a role when assessing the conservation state of these textiles.

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The Color Purple in the Andes

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The presence of purple in Andean textiles- from Precolumbian times to the present day evokes complex visual and cultural questions. [1] Looking at the history of its use and creation, whether directly from shellfish sources impressed onto the surface of cotton cloth from the south coast of Peru ca. 400-300 b.c.e., [2] to 12th century garments using mordanted cochineal manipulated to a purple hue, [3] to yarns spun from red and blue dyed fiber used in an early 16th century colonial Inca-style tunic or bi-color yarns in Bolivian Aymara heritage cloths from the 18th-19th centuries, the transitory and liminal aspect of the color contributes to its relatively rare use in the long trajectory of Andean textile traditions, and one that is primarily found in textiles of cultural significance. [4] The paper will present the archaeological and historical use of various methods to produce purple color from the perspective of dyes and their sources, as well as through creative technical features of Andean textile traditions, by spinning, warping and weaving that developed in the region from ancient traditions through the 19th century, to produce the color, or the effect of, the color purple.

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Dyes on archaeological and historical contexts from the Atacama Desert (South America). A synthesis overview along time.

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We present for the first time a synthesis of all the organic dyes identified to date in the Atacama Desert (South America) from the analysis of archaeological and historical materials. Based on a bibliographic review and unpublished own results, this work allows us to explore in a global approach the use of dyes over time. Recognized in textiles associated with archaeological contexts from before the beginning of our era and in mural paintings of the 17th century, we offer a general review on the consumption of dyes for almost 2,000 years. The set of analytical techniques used in the different studies and their results are evaluated, highlighting the advantages and limits of each one. The variability of the dyes, obtained from plants and insects, in time and space between different regions of this vast desert territory is discussed. In summary, despite the advances made in recent decades, these are still insufficient to understand the similarities and differences evidenced. Additionally, the existing interpretations on the obtaining and possible origin of the colorants are reviewed, rescuing the need to expand the analysis and characterization of dye references. Finally, we propose the possibility of a local origin of the dyeing practices and not as the influence of foreign cultural groups or traditions from the Central Andes area or other neighboring regions.

Ingenious Crafts: Tricks, Tips and Techniques for Dyeing Wool in ancient Mesopotamia (c. 2000-500 BCE)

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Some of the earliest written evidence describing people's experiences with natural dyes and their efforts to imprint vivid colors onto fabrics comes from ancient Mesopotamia (modern Iraq and its periphery). In cuneiform tablets, some dating as far back as 4,000 years ago, Assyriologists have access to a vast and diverse "clay trail" that has enabled them to understand the ancient textile industry of this region in great detail, despite the paucity of archaeological evidence. The work orders, sale receipts, lists of materials and even recipes for dyeing left behind are eloquent witnesses to how Assyrian and Babylonian craftsmen exploited vegetal, mineral and animal substances to answer to a wide range of economic, environmental, aesthetic and technical demands in the production of colorful textiles.

One of the difficulties that hinders our interpretation of texts is the highly technical, often abbreviated language used by scribes, especially in recounting chemical procedures. In the following paper, I will describe some Mesopotamian practices related to dyeing that highlight these difficulties and show how experimental archaeology and comparative data from neighboring Egypt, Anatolia and the Levant can help shed new light on them. The topics I will explore include Babylonian recipes for dyeing wool in diverse shades of red, blue and purple in the Iron Age; techniques for ensuring the durability and brilliance of colour; and methods used to imitate the colors of costly, imported dyes with locally available alternatives.

Widening the South American dyes database: flavonoid and lichen dyes from Antúnez de Mayolo reference collection and case studies from the Bryn Mawr College collection (Pennsylvania, US)

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The determination of the dye source responsible for the hue of archaeological textiles is generally challenging, even more so when dye plants are amongst the most photo-sensitive, as in the case of yellow South American dyes. Obtaining this information allows for access to historical and anthropological information related to trade routes, ancient technologies, and practices. Difficulties are exacerbated whenever little information on the raw materials is available, including knowledge of plants of the geographical area, and on the traditional recipes and technologies adopted by ancient civilizations. To fill this gap, the molecular characterization of South American raw dyeing materials, of reference textiles subjected to artificial ageing, [1] and a comparison with a relevant number of case studies was done. [2]

This study will present the results of a survey based on chromatographic, spectroscopic, and mass spectrometric techniques (HPLC-DAD-FD, HPLC-ESI-Q-ToF, and DART-ToF-MS) of some yellow and orange dyes from the Antúnez de Mayolo reference collection (formerly known as Saltzman collection) of reference Peruvian dyestuffs, including both yellow flavonoid dyes and orange lichen dyes. [3] The collection is enriched by reference wool yarns dyed with *Cosmos sulphureous*, a yellow Mexican and South American dye recently identified in Paracas textiles. [2] All specimens were also subjected to artificial photo-ageing. Selected case studies of yellow samples from archaeological Peruvian textiles sampled from the Bryn Mawr College collection (Pennsylvania, USA) will also be presented. [4]

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Early Iron Age textile dyes from an inhumation burial from North Brabant

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In 2010 an exceptionally rich Early Iron Age inhumation burial was excavated in the southern Netherlands. It was located in a previously excavated urnfield in the nature reserve known as 'Slabroekse Heide'. The inhumation grave yielded the remains of an individual, sometimes called the 'Princess of Slabroek'. The body was richly adorned with elaborate ornaments and toiletry items. Exceptionally, the excavators discovered extraordinary and well-preserved textile fragments preserved in the corrosion of the deceased's bronze bracelets and anklets – leading them to block lift these and have them 'excavated' and conserved in the restoration lab. [1]

Technical examination of the textile fragments revealed the presence of two different weaves: a coarse twill (2/2) located directly on both bracelets and anklets, and a finer twill (2/2) located on top of the coarse twill on the bracelets. Exceptionally, a blocked pattern made up of two colors could be identified on the coarser weave. The distribution of these textile fragments led them to be interpreted as a long-sleeved garment that reached to the ankles. While the other weave is interpreted as a shroud or veil of some sort based on the microstratigraphy and locations of the different textiles. [2-4]

In 2019, technical imaging of the weaved patterns was done, and a micro invasive sampling plan was carried out. Specific samples were analyzed first by means of Scanning Electron Microscopy with Energy Dispersive X-ray spectroscopy to evaluate the conservation state of the fibers and to identify the presence of a mordant. Other samples were analyzed with an Ultra high performance liquid chromatography with photo diode array detection attached to a high-resolution mass spectrometer to identify any remaining organic colorants.

Analyses of the color patterns shows three different organic sources two of which could be identified. One is identified as indigo and one as Polish cochineal (*Porphyrophora polonica* L.), a third flavonoid like colorant remains unidentified.

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Using GC-C-IRMS to investigate biological sources of organic colourants in art through compound-specific carbon and nitrogen stable isotope analysis

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Gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS), a technique used to investigate lipids in archaeology, [1] has considerable potential for the study of organic materials in paintings. One possible application is for the investigation of biological sources of organic colourants, in particular cochineal lake and indigo. American and European cochineal insects, the two main sources of cochineal lake, [2] feed on plants which are expected to fix atmospheric CO_2 through different photosynthetic routes which exhibit varying degrees of isotopic fractionation. *Dactylopius* (American cochineal) feed on cacti, which fix carbon through the CAM (Crassulacean acid metabolism) mechanism, while the plants that *Porphyrophora* (European cochineal) feed on are C3 plants (Calvin-Hack cycle). The secondary metabolites produced by insects feeding on the different classes of plants are thus expected to have distinct $\delta^{13}C$ values. By using GC-C-IRMS to determine the $\delta^{13}C$ values of the carminic acid originating from the two geni, it should be possible to differentiate between the two sources. Similarly, the main two sources of indigo (*Indigofera tinctoria* and *Isatis tinctoria*) might have differing $\delta^{13}C$ values due to the first (Indian indigo) being a tropical plant and the second (woad) growing in more temperate climates. These two plants also have the potential of being distinguishable through their $\delta^{15}N$ values since plants from the Leguminosae family (to which *Indigofera t.* belongs to), unlike other plants, are able to fix N_2 from the atmosphere. [3] By undertaking GC-C-IRMS analysis of derivatised carminic acid and indigotin obtained from, respectively, cochineal and indigo from different geographical locations it will be possible to obtain a range for $\delta^{13}C/\delta^{15}N$ values which will reflect the different types of plants. Preliminary results will be presented, highlighting the feasibility of this approach for the identification of the source of organic colourants in art materials.

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Advances in analytical methodologies through the application of Dispersive Liquid-Liquid MicroExtraction to characterize dyes in ancient textiles

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The potential of chemistry applied to cultural heritage is still to be defined; moreover, the answers it can provide us have enormous historical and cultural importance, also from a scientific point of view, due to the complexity of the matrix and the analytical sensitivity required. Analysis of natural dyes perfectly fits into this matter, due to the complex mixture of the color and the very small samples available. Many papers have developed new extraction methods, with the aim of maximizing the information obtained, reducing the quantity of materials. [1-2]

From this point, this research presents a novel approach for the extraction of natural dyes from historical, archaeological, and artistic matrices developed by Sapienza Group. The approach utilizes the recent extraction protocol with ammonia-EDTA [3,4] and employs an innovative Dispersive Liquid-Liquid Microextraction (DLLME) method for clean-up and analyte enrichment. [5] The research builds upon the recently discovered benefits of the ammonia-based protocol for efficient extraction and preservation of the sensitive glycosyl moieties. [3] However, the current method employs a traditional liquid-liquid extraction and is therefore not well-suited to the smallest samples, where it could involve lower recoveries. On the contrary, the combination with a DLLME clean-up step represents a significant improvement: the DLLME, widely used in forensic science and in food analysis [6, 7], offers a highly controllable method for the preconcentration and purification of natural dyes. By combining the ammonia-based mild extraction method with the novel DLLME protocol, analyzing through high performance liquid chromatography coupled with mass spectrometry (HPLC-MS), the recovery of dye analytes achievable is very much higher than observed with the traditional LLE. Furthermore, the DLLME protocol resulted much more precise and efficient for its simultaneous application on several samples, confirming the great potential of this typology of extraction to solve the major issues in Cultural Heritage analytics.

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Bright orange and scarlet red – disclosing the composition and degradation mechanisms of "combined lake" formulations

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In the late 19th century, it was common to combine several synthetic dyes when manufacturing a lake pigment, thus achieving a wide variety of new shades. This facilitated the production of lakes with specific properties as required by the customer. Two or even more dyes of similar or very different chemical nature could either be precipitated together or in several precipitation steps. [1] In contrast to lakes from a single synthetic dye, combined lakes have not been studied yet. It is unclear how the dyes interact, if their fading behaviour differs and how the precipitating agents affect the stability of the dyes. Another crucial aspect is if such a combined lake pigment could be positively identified or whether it would be mistaken as a mixture of two pigments.

To tackle these questions, several orange-red lakes (containing Orange II and /or Ponceau R and /or Fuchsin) were reproduced following 19th century recipes, naturally and artificially aged, and analysed. [2] A multi-analytical approach was chosen to extensively characterize the various materials contained in the reference pigments, and in paint layers before and after ageing. Infrared spectroscopy (FT-IR) and Gas Chromatography Mass Spectrometry (GC-MS) were used to characterize the organic dyes, substrates and additives in the lakes. Fading of the paint replicas was monitored by colorimetric measurements, while High Performance Liquid Chromatography with Diode Array and Fluorescence Detector(HPLC-DAD-FD) and High Resolution Mass Spectrometry (LC-HRMS) were applied to assess and quantify the chemical changes occurred in the lake composition.

While a preliminary poster presentation at DHA 39 discussed a few aspects of this complex analytical problem, this presentation will give more detailed insights on the relative stability of the formulations, providing the kinetics of fading, and disclose the cross-influence of the presence of more than one dye on the reciprocal ageing process.

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Discovering the new colours of the XX century: a combined Raman and HPLCHRMS study of ACNA dyes

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Since the fortunate mauveine discovery by British chemist Henry William Perkin, [1] both the manufacturing industry and, consequently, the art world entered a new phase of experimentation, where synthetic chemistry played a major role. Related objects from this period ahead are hence very useful in the study of the history of industrial manufacture, fashion, and contemporary art. Cultural heritage studies focusing on synthetic dyes represent a relatively new area of study due to their modernity, and research into synthetic textile dyes is becoming more and more important. [2–4] The characterization of synthetic dyes in artistic and historical matrices represents a breakthrough and a challenge in research for the conservation of Cultural Heritage, because the knowledge of the early production of synthetic dyes and related applications can help to shape our understanding of these crucial periods of change for society.

In this work, a full collection of synthetic dyes, held by the Museum of Chemistry of Sapienza University of Rome, is the object of a diagnostic campaign, providing insight into the composition of dyes produced by the *Azienda Coloranti Nazionali e Affini* (ACNA) in the first decades of XXth Century. A multidisciplinary protocol, exploiting the combination of Raman spectroscopy and High Performance Liquid Chromatography coupled to High Resolution Mass Spectrometry, was applied for the complete characterization of the dyes. In order to maximise the recovery of extracted dyes, a clean-up procedure, adopted from food analytics, [5] was adapted and designed for the characterization of the colorants in textile matrices.

Through this study, the opportunity to understand the synthetic procedures of a company, active throughout the entirety of the 20th century, is exploited. The results of this work constitute an insight into the internal testing and motivations related to the market choices and a synthetic dye database useful for further studies.

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Bordering on Asian paintings: Dye analysis of textile borders and mountings to complement research on Asian pictorial art

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Textile borders and mountings represent important elements of Asian paintings. However, they are often side-lined or not considered an integral part of the original piece, as they may be later additions or may have been replaced during historic conservation or mounting interventions.

Nevertheless, evidence is sometimes present that these textile borders are contemporaneous to the production of the paintings they frame or, in the case of paintings found in archaeological contexts, to the time of deposition. Even when not contemporaneous with the paintings, the mount textiles are often of significant historic interest in themselves, showing a range of complex textile techniques and materials, and highlighting the re-use of fabrics. In all these cases, the study and reconstruction of the original colours of the borders enables further understanding of the holistic visual impact originally intended for the composition, as well as of the role of colour itself, which was used to emphasise, complement or contrast important pictorial themes or motifs in the paintings. Furthermore, the identification of dyes and dyeing techniques has the potential to support the production date and provenance of the paintings.

In this study the textile borders of six paintings from the Library Cave, Mogao Grottoes, Dunhuang, China (late 9th-10th century CE), one Korean painting dated 1789 CE, and two Tibetan thangkas (18th century) were investigated with the aim to identify the dyes present. Fibre optic reflectance spectroscopy (FORS) was used to obtain information non-invasively and, when sampling was possible, high performance liquid chromatography tandem mass spectrometry (HPLC-MS/MS) was used to obtain molecular identification of the dyestuffs employed in their production.

Typical Asian dyes, such as gromwell (*Lithospermum erythrorhizon*), sappanwood (*Biancaea sappan*), safflower (*Carthamus tinctorius*), turmeric (*Curcuma longa*) and pagoda tree flower buds (*Sophora japonica*), were identified. Some of the dyeing techniques were commensurate with the geographical and temporal provenance assigned to these pieces. Considerations about fading and discolouration of the dyes enabled valuable additional information to be obtained that complements the evidence gleaned from the study of the paintings and informs conservators and curators on best practices in the preservation and display of these precious and delicate artworks.

Characterization of Congo Red derivatives on historical pH paper and textile and their significance in dye history and conservation.

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A silk knotted pile carpet fragment in the collection of the Cleveland Museum of Art (1988.243) purportedly derived from 15th century Iran was reviewed for its authenticity. Koechlin and Migeon of the French National Museums wrote in 1928 that the stylistically archaic design indicated that the fragment was from antiquity. However, in 1947, a curator from the Metropolitan Museum of Art disagreed and thought that the textile was modern. In order to aid the dating effort, and as a precursor to radiocarbon dating, dye analysis was performed on three yarn samples from the carpet. Combined data from raman spectroscopy and liquid chromatography with detection by diode array and mass spectrometry showed the presence of synthetic dyes, thus supporting a late 19th or early 20th century creation: the green yarn (indigo top dyed with yellow) contained metanil yellow, the blue had indigo and the red dyed by congo red [1]. In the red sample, two additional compounds A and B were detected in similar amounts as congo red, which were 12 and 24 mass units larger, with A showing an absorption spectrum similar to that of congo red but B having no absorption in the visible range. Here we show that initial hypothesis of A and B being synthetic byproducts were not supported by the analytical results of several dye samples from 1920s being found to be homogeneous in congo red. However, in a group of congo red pH paper presumed to be manufactured prior to 1950s the same A and B were detected. These have now been characterized by high resolution mass spectrometry and 2D-NMR spectroscopy, on which basis structure of A and B can now be proposed and will be presented along with their possible chemical origin as well as their significance in textile history and conservation.

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Scientific investigation into the transition from Madder to Alizarin dyes in French uniforms (pantalon garance)

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Beginning in the 1980s, few French studies on 19th and 20th centuries textiles have investigated dyes, leaving a large research field still to investigate. Gathering academic researchers and museums scientific staffs, the INHA launched in 2017 a research program dedicated to the transition process in dyeing between 1850 and 1914, in association with several museums as well as the Laboratoire de Recherche des Monuments Historiques (LRMH). The main aim of this program is indeed to produce specific textile data regarding precise dates at which the early synthetic dyes have been eventually used, confronted to the dates of the patents. The research also gives new insights about practices in dyers' workshops using both natural and synthetic dyes.

The first part of a case study dedicated to the French madder trousers, common among French uniforms from 1829 to 1915, has been presented at DHA 37. [1] It was based upon research including unpublished archives and close examination of textile samples in different museums.

Since then, our research has been supplemented by microscopic, chemical and colorimetric investigations.

High Performance Liquid Chromatography (HPLC) was used to identify the dyes extracted from madder uniforms and specify their origin (natural / synthetic), which allowed us to draw up a chronological frieze of the arrival of synthetic dyes in the French industrial landscape. This approach was correlated with a colorimetric study in the CIELAB color space, which highlighted the weaknesses of these « new » dyes at the end of the 19th century and the beginning of the 20th century. More than 30 textile items were selected precisely to carry out this study and find out stimulating conclusions.

1. Sarda Marie-Anne, « Madder or (synthetic) alizarin: which dye for the French *pantalon garance* from 1850 to 1914 ? », DHA 37, Lisbon, 26/10/2018.

Investigation on dyeing technology of Qing dynasty longevity lamp streamers preserved in the Palace Museum

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Longevity lamp is an important high lighting and decorative lamp to celebrate the Chinese New Year in the early and middle Qing Dynasty. Some colored streamers hanging on it are used to express the good meaning and praise the emperors' political and military achievements. [1] Till now, most of the studies focused on the history, [2,3] scientific studies were seldom reported. To reveal the source of the dyes and the dyeing technology, dyes of the threads of different colors in three different sizes of the long-life lamp streamers preserved in the Palace Museum were analyzed. Totally twenty-three samples, including different red, pink, orange, yellow and blue colors, were analyzed by ultra-high performance liquid chromatography-quadrupole time-of-flight mass spectrometry (UPLC-QTOF-MS). Based on the identification of specific compositions, the dyes were revealed. The results showed that the blues were dyed either by indigo or indigo combined with cork tree; the red, pink and orange colors were all dyed by safflower and cork tree; the yellow samples were dyed by the combination of pagoda bud and cork tree. In addition, comparing the chromatograms of the red samples with the corresponding faded red part, the major composition of safflower-carthamin decreased, and other peaks, probably the degradation products increased. This study provides a scientific basis for understanding the technology of longevity lamp streamers and shows popular dyeing techniques in the palace in Qing dynasty, which will contribute to the following protection and restoration scheme.

1. Desheng Hu. Sky Lantern · Longevity Lantern [J]. Forbidden City, 1993(3): 39-41.
2. Shu Lin. Sky Lantern and Longevity Lantern in Front of Huangji Hall [J]. Palace Museum History of the Ming and Qing Dynasties Research Center-the First International Symposium, 2012(6): 143-151.
3. Wanping Ren. The Reappearance of the Splendid Age, The "Resurrection" of the Sky Lantern and the Longevity Lantern in the Palace of Heavenly Purity [J]. Forbidden City, 2019 (1) : 15-21.

Dyes in traditional Saxon and Romanian costume

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Romanian traditional costume, as well as clothing and garments representative for the minorities living in Romania, have been the subject of several publications [1-3]. However, no dedicated study was made with references to materials, as for example dyes, although most of the objects preserved are dated from the 19-th and 20-th centuries and the switch from natural to synthetic dyes in different communities would be helpful to document their enthusiasm to accept the new, with its social and economic aspects.

The Saxon costume is characterized by a constant stylistic approach over time but it is not clear if this feature is also maintained with reference to the materials used. In order to answer this question, the Saxon coat and the decorative embroidery made in the Saxon house were chosen for study. Apart from robustness, the Saxon coats is remarked through the association of different materials: white sheep fur embroidered with precious floral elements, with coloured silk threads and metal wires.

In the present study, representative Saxon coats, manufactured in workshops and dated between 1892 and 1908 (years embroidered on objects) were selected, as well as embroideries made in Saxon households from a similar period. Apart from making a comparison between dye analysis results obtained on the two groups and trace (for the dated objects) the evolution of materials during the twenty years, the resulted data will be correlated with that obtained on samples from Romanian shirt decorations in objects from the same period. These shirts, also handmade in households, were acquired in the first decades of the 20-th century by a Romanian woman of noble rank, as it was in fashion at that time for women of high status to dress in the traditional costume [4]. Finally, all the results will be correlated to those obtained in previous studies [5].

Dye analysis were performed by LC-DAD-MS. The biological sources discussed include dyer's broom, weld, sawwort, emodine based dyes, madder, Mexican cochineal, indigoid dyes as well as early synthetic dyes such as fuchsin, synthetic alizarin and indigo carmine.

1. L. Fulga, G. Chiru (2018) Discursul ritual si costumul traditional din sud estul Transilvaniei, Brasov
2. H. Klush (2014) Siebenburgisch-Sachsische Trachtenlandschaften Honterus, Sibiu.
3. Ișfășoiu D., Popoiu P. Costumul românesc de patrimoniu din colecțiile Muzeului Național al Satului „Dimitrie Gusti" ed. Direct-to-Plate București 2008
4. https://artsandculture.google.com/exhibit/queen-maria-and-the-outstanding-romanian-traditional-costumes/_gJiBRcjBVNfIA (accessed May 31st, 2021)
5. Petroviciu I., Teodorescu I., Albu F., Virgolici M, Nagoda E., Medvedovici A., Dyes and biological sources in nineteenth to twentieth century ethnographic textiles from Transylvania, Romania, Heritage Science Journal, 2019, 7-15

Trends in Dyes in History and Archaeology

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In this presentation I will highlight some trends I observed in the last two decades, based on what has been presented at the previous DHA meetings. Although it will be difficult to judge if and how these trends will develop in future, and taking into account it will most likely not complete, the aim of this presentation is to stimulate discussion about future perspectives and to bring people, interested in the same topics, together. This debate could lead to further (joint?) research.

A short part of the presentation will be about the developments of analytical methods, including sample preparation, however this requires a separate review and will not be discussed great in detail. The large variety of colorants investigated nowadays, and the different research questions formulated will be discussed. This includes natural and synthetic dyes and organic pigments, from pre-historic times up till present although one could argue that these very modern colorants do not belong to our history yet! These colorants are found in a large variety of objects, researched for different purposes.

Next to characterization of these dyes, several groups try to understand their (fading) behaviour on the long term, on one hand to understand their original colour and on other hand to predict how they will develop in future. Somewhat beyond the scope of this meeting series is the application of natural dyes for new purposes. An interesting development is the in-depth study of sample books, for which I call for a wider, interdisciplinary and internationally approach.

This interdisciplinarity is applicable for most topics presented in the last decades. It remains the aim of the DHA meetings to bring together scholars from different background to discuss about a very colourful subject.