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EDITORIAL

Editorial

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The conservation–restoration of cultural heritage is undoubtedly a field of interdisciplinary collaboration among professionals with different educational backgrounds and professional experience. To this purpose, a mutual understanding among conservator–restorers, archaeologists, art historians, architects, conservation scientists—and chemists in particular—is needed for a proper safeguarding of cultural properties. Indeed, recent decades have seen the involvement of an increasing number of chemists because of the importance of diagnostic studies and research into conservation materials and treatments. I am pretty much convinced that the vast array of works of art representing the highest forms of human production provides important occasion for knowledge advancement, promoting close interactions among disciplines seemingly far removed from each other, such as chemistry and art history or archaeology.

Cultural heritage, one of the higher expressions of human activities, makes use of a variety of materials that have yet to be identified, and this is why every single work of art systematically involves issues that typically belong to chemistry. This happens from the very moment of the creation of a work of art, and continues towards the period in which chemistry determines the rate of transformation, ageing, degradation and sometimes the complete disappearance of the artefact. It was therefore predictable that chemistry and the other scientific disciplines would be asked to be involved in the safeguarding of cultural heritage.

To this end, chemists apply examination of works of art using both advanced analytical methods and conservation science, which is concerned with the

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physical/material aspects of works of art, their deterioration and conservation. Scientific examination and conservation science both rely on measurements central to analytical chemistry for cultural heritage, that branch of chemistry concerned with determining the qualitative and quantitative identity of heritage materials.

Today, analytical chemistry plays a key role in the characterization of the nature of heritage materials, the study of ancient production techniques, the understanding of causes and mechanisms of degradation, and the development and performance evaluation of restoration materials and methods. It also supports archaeological and historical interpretations through archaeometric studies aimed at characterizing ancient materials, the way in which they were produced, and their provenance, authenticity and dating.

Unfortunately, the systematic involvement of science in general, and chemistry and analytical chemistry in particular, dates back only four decades. In fact, even though the first contributions of science to the study of works of art occurred at the beginning of the last century, it was a cautious entry, independent of the efforts and capacities of the first pioneers, who were few in number and with very limited resources available. However, starting in the 1950s, the application of science, and particularly chemistry, to conservation became increasingly systematic, although poorly coordinated if compared with the extent and complexity of the problems raised by the conservation of cultural heritage.

Nowadays, analytical chemistry as applied to cultural heritage is a recognized discipline that covers many advanced and complex aspects of chemical research, as highlighted by the publication of peer-reviewed journal special issues such as those on characterization of paintings [1], analytical chemistry in cultural heritage [2], advanced techniques in art conservation [3] and a recently published critical review on analytical chemistry in the field of cultural heritage [4].

While offering as broad a view as possible, a panorama of the most advanced analytical methodologies and procedures applied to the characterization, origin and mechanisms of heritage materials decay, this collection of *Topics in Current Chemistry* cannot be comprehensive, but I'm convinced it demonstrates their key role in conservation research.

An innovative contribution to this topical collection deals with synchrotron-based techniques. In fact, although photon-based speciation has been applicable mainly to inorganic materials, novel developments based on scanning transmission X-ray microscopy (STXM) and deep UV photoluminescence bring new opportunities to study speciation in organic and hybrid materials at a sub-micrometre spatial resolution.

Moreover, in the context of the characterization of pigments subject to natural degradation, synchrotron facilities are able to elucidate the chemical transformation that has taken place. In particular, the combination of micro X-ray fluorescence (μ-XRF) with related methods such as micro X-ray absorption spectroscopy (μ-XAS), micro X-ray diffraction (μ-XRD), Fourier transform infrared microscopy (μ-FTIR) and/or Raman microscopy have proven themselves quite suitable for such studies. Since microscopic investigation of a relatively limited number of minute paint samples may not yield information representative of the entire work of art, new methods for macroscopic imaging, such as those based on X-ray fluorescence scanning and full-field hyperspectral imaging, have been developed and are presented and discussed.

The challenge of analysing works of art in situ by means of portable non-invasive analytical techniques including XRF, mid- and near-FTIR, UV–Vis and Raman spectroscopy, as well as XRD, are discussed in detail, along with their impact on our understanding of painting materials and execution techniques. Readers will find successful applications for both point analyses and hyperspectral imaging approaches. More challenging applications, such as the identification of organic pigments, where the synergistic use of FTIR, UV–Vis and Raman spectroscopy can lead to satisfactory results, are also presented and discussed.

Notwithstanding the utility of non-invasive analytical techniques and their use in situ, they cannot provide a detailed stratigraphic characterization of the materials constituting works of art. This is particularly true when organic-based components must be identified and spatially located. In this regard, the most recent decades have seen the development and use of advanced micro-invasive analytical techniques. It is worth mentioning the progress achieved by high-performance liquid chromatography (HPLC) in the detection of dyestuffs, enzyme-linked immunosorbent assay (ELISA), immunofluorescence microscopy (IFM) and immunochemical imaging techniques for protein-based materials, and gas chromatography mass spectrometry (GC/MS) in the detection of organic materials in ancient as well as modern and contemporary works of art. In fact, all these analytical techniques have been substantially improved in terms of both new sample preparation procedures, which allow a greater number of heritage materials to be examined, and interpretation of results, thanks to the great support provided by chemometric multivariate analyses.

The field of Raman and FTIR spectroscopy in art and archaeology has experienced massive, vital growth since its first application to heritage materials. Despite the many reviews available in the literature, this is the first time that extensive coverage has been devoted to advanced spectral processing and the contributions of chemometrics to the furtherance of spectroscopic studies of works of art. Raman spectroscopy is also increasingly being used to uncover structure–property relationships of artistic and archaeological materials at the microscale and to reconstruct ancient technologies. Surface-enhanced Raman spectroscopy (SERS) is now an established tool in the analytical chemist's toolkit, while new developments in spatially offset Raman spectroscopy (SORS) and widefield imaging are expected. At the same time, a new and very promising field is the development of enhanced FTIR methods for detecting trace components in micro extracts, allowing the detection of extractable organic compounds from about 0.1 mg of sample such as natural and synthetic dyes.

Despite initial scepticism, radiocarbon dating has gained considerable importance over the last decades. In fact, art objects made of textile, ivory, stucco, paper or parchment and polychrome statues can now be dated. To this end, the introduction of accelerator mass spectrometry (AMS), which enables the amount of sample to be confined in 1 mg of carbon and reduces counting time to 50 min, has proven to be revolutionary, particularly when applied to the dating of precious art objects.

Another important research issue, which is well presented in this topical collection, concerns DNA sequencing as applied to anthropology, archaeozoology, molecular evolution and population genetics. A dramatic improvement in DNA methodologies has occurred in recent years, yielding to a revolution that has allowed the recovery of even complete genomes from highly degraded samples, with the possibility of going back in time 400,000 to 700,000 years. The application to individual identification of famous personalities such as King Richard III confers to paleogenetics an important role in cultural heritage studies.

It can certainly be said that analytical chemistry has had and will continue to have an impact on all aspects of cultural heritage knowledge, from historical studies, material degradation and characterization, to conservation and fruition.

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