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Heritage Science: A Future-Oriented Cross-Disciplinary Field

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For some readers of *Angewandte Chemie* and of this Special Issue, heritage science and what it involves may well be new. Unsurprisingly so, as the term was established as recently as 2006 to denote the cross-disciplinary field of scientific research of cultural heritage. Heritage science should be seen as an umbrella term that encompasses conservation science, archaeological science, and building science: regardless of whether the object of study is an iconic painting, a mummy, or a monumental building, the scientific methods and the approaches to research are often similar.

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Despite this recent development, scientific research of cultural heritage is itself far from recent. Although better known for his electrochemistry and electromagnetism research, Michael Faraday's lecture at the Royal Institution in 1843 explored the chemical degradation of leather as a consequence of indoor air pollution—a typical heritage science topic, studied by a world-leading chemist who had trained as a bookbinder. This research is an excellent early example of cross-disciplinarity.

With this Special Issue, heritage science demonstrates its relevance to, as well as its deep roots in chemistry, and other physical and engineering sciences. To understand the composition or construction of heritage materials and structures, and to infer their provenance or perhaps even time of their creation, that is, to *interpret* heritage, it is essential to know how to ethically apply methods and techniques to heritage. Interpretation of the resulting scientific data in view of our knowledge of historic and artistic techniques and materials requires intensive cross-disciplinary collaboration with arts and humanities, and makes the field both challenging and attractive.

As individuals, and as a society, we value heritage for many reasons, such as aesthetic, emotional, or perhaps simply economic. We inherently desire to preserve cultural heritage, and make it accessible so it can be enjoyed by others, which makes heritage science essentially future-oriented. This requires an excellent understanding of the processes of change, so that the often costly investments into long-term preservation (e.g., energy and CO_2 emissions required to climatise collection storage and display environments for possibly hundreds of years) can be radically rethought. Conversely, more visitor access leads to longer exposure to adverse conditions or more transportation of artworks, and thus more wear and tear. Better acquisition and mining of information and organization, visitors is required. Scientific research is thus needed to *manage* heritage, so it can be sustainably preserved and accessed.

However, heritage science is more than just the study of interpretation and management of the material evidence of the humankind, that is, what it does. We also need to look at how and why. Similar to medical science, it has its own ethical principles: loss of integrity of an object through sampling needs to be balanced by information gained through analysis. The views and values of owners or communities need to be taken into account, especially if religious objects or human remains are studied.

Furthermore, the 2001 UNESCO Declaration on Cultural Diversity includes the right of individuals and communities to cultural heritage and cultural expressions. Cultural heritage has thus been defined as a right and a common good, and communities are a key stakeholder in its interpretation and management, and a key beneficiary of heritage science.

This statement leads to another important aspect of heritage science: one of its main fields of impact is outside the domains of engineering and science. The stewards of cultural heritage are often public or private institutions or individuals, few of

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whom have scientific backgrounds. Research questions in heritage science are often posed by conservators, curators, and managers, and in order for our research to have impact, its outcomes need to be interpreted and communicated appropriately.

With this in mind, what does better interpretation and management of heritage enable apart from the noble goal of its preservation? As a field, heritage science trains researchers with a disciplinary breadth as well as a deep understanding of science and of its importance to users. The complex research questions require the development of technologies and approaches that are valuable to other fields of scientific endeavour.

However, we also need to claim a higher goal. Heritage science enables both society and individuals, as well as future generations, to exercise their right to cultural heritage and contributes to our understanding of who we are and our sense of place. It has a deeply social purpose.

It is thus not surprising that heritage science often attracts significant media and public attention. Our field is an excellent vehicle to engage the public both with science and with heritage, and as one of the publications in this Special Issue demonstrates, this enthusiasm could be transformed into active participation of the general public in scientific research.

How do we integrate historic and human understanding of cultural heritage in our scientific work to enable meaningful interpretation of results?

In a similar manner to environmental science, nascent in the 1960s and 1970s, heritage science is currently developing its philosophical and theoretical canon. With ever more accurate methods and techniques becoming available, how do we integrate historic and human understanding of cultural heritage in our scientific work to enable meaningful interpretation of results? With rapid artistic and technological advancements, what new forms of heritage are being developed that require new scientific approaches involving traditional fields of science, as well as computer and data science, or social science? What are the grand challenges of heritage science?

Hopefully, this Special Issue will take a step towards an integrated definition of the field. The majority of the articles before us explore new methods of characterisation and analysis, leading to entirely new or substantially improved understanding of heritage. Further contributions focus on the development of conservation methods, from cleaning to development of protective films, for a diversity of heritage materials of inhomogeneous composition and unknown environmental and social histories.

Thus, in the realm of physical sciences, two broader scientific challenges appear to be emerging from these contributions and could be phrased as follows:

- Understanding of heritage ecologies: a comprehensive model of the relationships between heritage and its physical and social environments would enable an understanding of how heritage is created, and what (as well as how and for how long) is to be preserved. Significant advances in the knowledge of multimodal material–environment interactions would be required, as well an understanding of how value and benefits are created, exploited, transferred, or lost.
- Developing networked heritage ecosystems: given the diversity and ubiquity of heritage, it will not be possible to comprehensively characterise and monitor it all, with the exception of the most iconic items. It is not even clear what information we need to measure, collect, and how, in order to understand, interpret, and manage heritage. Significant research and technical effort would be required to develop the monitoring tools and data analysis expertise that is required.

The contributions in this Special Issue focus on the chemical aspects of heritage science, however, the authors do reflect on the arts and humanities aspects of their research. It is significant that reviewers recognised the value of cross-disciplinary research and its importance to applied chemical science, especially given how often such research "falls between the cracks" either when considered for publication or for funding. I am hugely grateful and indebted to the authors and the reviewers, as well as the editorial team for having demonstrated the breadth that is necessary for cross-disciplinary research to thrive.

We live in an exceptionally interesting period for heritage science, and hopefully, this Special Issue will have at least two effects: 1) It will demonstrate the intellectual strength and potential of the emerging field; and 2) it will attract even more excellent scientists into our fold. The cutting-edge science that we do today may well become future heritage.

Guest Editorial

M. Strlič* _____ ▮▮▮▮–▮▮▮▮

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