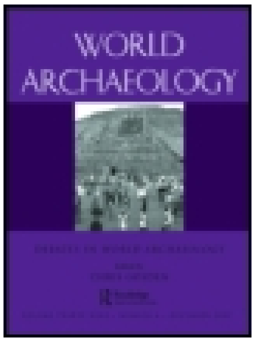

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The organics revolution: new narratives and how we can achieve them

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ABSTRACT

Organic remains from excavated sites include a wide range of materials, from distinct organisms ('ecofacts') to biomolecules. Biomolecules provide a variety of new research avenues, while ecofacts with longer histories of study are now being re-harnessed in unexpected ways. These resources are unlocking research potential, transcending what was previously imagined possible. However, this 'organics revolution' comes with a salutary corollary: our approaches to recovering and curating organics, and making accessible research data, are not developing as quickly as we need. In this paper, we review retention guidelines for institutions in Britain and Ireland, setting this against the backdrop of a 'curation crisis' that is affecting museums throughout Europe, and beyond. We suggest key themes, including the state of existing documentation and considerations of intrinsic and allied research potential, that should be used to open a discussion about the development of more comprehensive and standardised approaches to archiving in the future. Engaging in this conversation is the only way that we can hope to ensure the long-term retention and preservation of organics, while safeguarding associated research data. These changes are needed to ensure future global research collaborations across the academic, curatorial and professional archaeological sectors.

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Introduction: we need to debate archives, storage and ecofacts

Archived archaeological materials are a powerful resource; they allow researchers to test theories, re-analyse materials in new ways to advance knowledge, and create opportunities for access to archaeological data for everyone (Oniszczuk et al. 2021, 7). Globally, over the last four decades, activity in the archaeological and heritage sector, including compliance-driven excavation, has generated millions of records and artefacts that are routinely archived (Kersel 2015, 44). The financial cost of producing these archaeological archives and materials is vast. However, the storage space for archived material is not unlimited, and there is an imbalance between investment in the continued recovery of archaeological materials by the professional archaeology sector (variously termed

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'commercial', 'cultural resource management', 'development-led', etc.; Brown 2015, 248), *versus* investment in infrastructure required for accession, analysis and care of collections. This is creating a widespread curation crisis (see Voss 2012, 146; Kersel 2015, 44).

The impact of the 'curation crisis' is that some museums are no longer able to function as active repositories for the archives and materials that are generated by archaeological fieldwork. A 2018 survey of museums in England showed that 23 of 148 museums had stopped accepting archaeological archives, with a lack of space being the main reason (74%). Some 67% of the respondents estimated that space would run out in 5 years or less (Boyle, Booth, and Rawden 2018, 2017, 2016; Fernie 2017 for similar datasets). This shortage of storage space is a critical problem that is not limited to England but is a crucial debate across the museum sector in general; confronted by this 'profusion' of materials, museum curators constantly face the question of 'what not to keep' (Macdonald, Morgan, and Fredheim 2020; Morgan and Macdonald 2020). Within this context, some may question why so much material is archived if many boxes are never opened again after reaching stores (Brown 2015, 250). However, projects using archive material to undertake research with large-scale impact for global human populations clearly demonstrate the importance of retaining archival material (Oniszczuk et al. 2021, 7).

Suggestions about how to address the curatorial crisis include deaccessioning existing items and 'rationalising' archives, developing clear principles for future collection policy, and finding additional funding streams that will help to alleviate the cost burden. In Britain, for example, the imposition of fees to deposit archaeological archives generated during commercial excavations may help to alleviate the pressure on storage (Mann and Robertson 2020, 6; Boyle and Rawden 2020, 12). However, even with additional funding, it is clear that all stakeholders, including excavating archaeologists and archaeological specialists, need to engage in developing rationales for the deposition of archaeological archives (Trow 2018, 96). This kind of collaboration is especially important since the number of curatorial staff with expertise in archaeology, or sub-disciplines of archaeological science, is falling (Boyle 2019).

As this curation crisis has been unfolding, archaeological analysis has been going through an 'organics revolution', with an explosion of new techniques for the analysis of organic materials, including biomolecules (e.g. aDNA from tissues, sedaDNA from organic-rich sediments and soils, fatty acids preserved in pottery, faecal biomarkers, etc), anthropogenically-modified organics and ecofacts. (In the absence of any suitable alternative, we use 'ecofact' as a shorthand to describe unworked macroscopic organic materials, despite the fact that this term can be problematic, see Morehart and Morell-Hart 2015). The curation crisis has the potential for an especially significant impact on studies of these items; biomolecules are invisible, while some ecofacts appear 'unglamourous' – charred plant remains, animal bone assemblages and fossil insect remains, for example – when compared to more obviously anthropogenic materials such as metal finds, pottery and so on. Museum curators are understandably biased towards keeping objects with a display value, while decisions about accession are also governed by legislation that has traditionally been influenced by ideas of 'treasure' (e.g. the Treasure Act 1996, which covers England, Wales and Northern Ireland, and the Treasure Trove process in Scotland; Queen's and Lord Treasurer's Remembrancer 2016). This means that there is a danger that organics are discarded, or never taken into storage at all. Given the organics revolution, it is vital that the curation crisis should not diminish our potential to work with ecofacts and biomolecules in the future, which will include work on newly accessioned material as well as archived material with well-established histories of analysis. We contend that the organics revolution should be the starting point of a debate aimed at challenging these latent attitudes to the value of different archaeological resources. In this context, we need to first discuss our current approaches to collecting archaeological material, and then to reassess our understandings of 'value' in these assemblages. This paper highlights some of the issues associated with retention and reuse of organic remains and data; these are global concerns that have a widespread impact upon archaeological practice.

Results

What to keep? Current approaches to ecofact retention

The Europae Archaeologiae Consilium's 'Guidance on Selection in Archaeological Archiving' (Oniszczuk et al. 2021) builds on previous guidance documents (Perrin et al. 2014; Brown 2007, 2015; Brown and Dibby 2019) and highlights the need to:

- develop transparent, explicit and well-founded selection processes,
- strengthen archaeology as a science,
- translate the value of archaeological heritage to non-archaeologists,
- support archaeological research,
- uphold the social responsibilities inherent in caring for archaeological remains.

The Guidance emphasises that parties involved in selection processes have a duty, not only to the communities they represent now but also to future generations, while stressing the context in which archives policy takes place; the challenge is always to distil material into a manageable and cost-efficient archive without compromising its scientific integrity (Oniszczuk et al. 2021). Whilst this unifies the processes of selection, it remains the decision of project and archive stakeholders to assess the significance of materials. We argue that this can be especially detrimental to organic materials for two reasons. Firstly, organic materials sometimes have complex curation needs. The conservation of waterlogged archaeological wood, for example, can take years (Jensen 2005). Secondly, and more perniciously, until the organics revolution the study of organic materials was relatively specialised, with many organic materials regarded by non-specialists as being of less importance than artefacts. This lower status pertains, we suggest, from the longer history of materials studies which, in Europe, can be traced back to antiquarians' collecting practices (Pollard and Heron 2015, 3–6). In contrast, the analysis of organic materials in archaeology is allied to more recent developments in the history of science. Although approaches vary internationally, specialist analysis is often siphoned off from mainstream teaching of archaeology in universities and in professional settings it is often seen as an additional service rather than incorporated into general archaeological practice. The lower status of organic materials also relates to the less obvious 'thinginess' of many ecofacts and non-visible biomolecules, with more obvious anthropogenic materials recognised as having a higher value in studies of human societies.

Case study

Looking in detail at selected jurisdictions in the islands of Ireland and Britain, we can see this tension in the treatment of organic materials. In Scotland, policies and guidelines routinely include ecofacts in the definition of an archaeological archive (e.g. Mann 2020). The 2020 draft consultation document on 'Scotland's Archaeology Strategy' states that Scottish museums will accept ecofacts, and geoarchaeological samples, as they are seen as having good potential for future research. However, the document also explicitly states that archives will not usually accept waterlogged material (Scotland's Archaeology Strategy 2020, 17).

In Wales, the recommendations are that most material from sites dating up to 1539 CE/AD be retained; normally, all 'prehistoric' assemblages are retained, stratified material is retained from Roman, early and late medieval sites, while post-medieval material is not normally retained (National Panel for Archaeological Archives in Wales 2019). Environmental samples are only retained if the sample has been processed, with the exception of charcoal samples, where both processed and unprocessed samples are retained.

In England, the picture is more varied; surveys undertaken between 2016 and 2018 indicated that different deposition guidelines were used across different institutions, with varied approaches to ecofactual material. A small number of surveyed institutions would not take animal bone, waterlogged materials, bulk organics and soil samples (Boyle, Booth, and Rawden 2016, 2017, 2018), which may be due to capacity for curating these types of material (Boyle and Rawden 2020, 12). In a number of cases, institutions would only accept ecofactual material (apart from animal bone), if a definitive programme for future research was established in advance (Boyle, Booth, and Rawden 2017, 35, 2018, 40). Recent 'Guidance on the Rationalisation of Museum Collections' (Baxter, Boyle, and Creighton 2018) and 'Standards and Guidance in the Care of Archaeological Collections' (Boyle and Rawden 2020) promote selection and retention strategies that are developed with all stakeholders relative to the production and curation of an archive. This process can be guided by the Chartered Institute for Archaeologists 'Toolkit for selecting Archaeological Archives'. These guidelines do not make explicit statements about ecofactual materials but do make room for them to be retained if assessed to be significant 'on a case-by-case basis and in consultation with relevant specialists' (Boyle and Rawden 2020, 12).

In Northern Ireland, few of the artefacts, ecofacts and documentary archives from commercial excavations carried out since 1999 have made their way into centralised storage as there is no designated repository for this material (Hull 2011). This has been identified as an issue that requires urgent attention (Way Forward for Archaeology NI Steering Group 2021, 23).

In the Republic of Ireland, the National Museum of Ireland is the main repository for excavated material. Current policy states that animal bone and environmental samples are not automatically accepted but that they may be taken into storage if the excavator and relevant specialists recommend this. Unprocessed samples will not be accepted under any circumstances. Where material is not accepted, the Museum will consider retaining a sample of bones (for example, from different stratigraphic units) for future radiocarbon dating (National Museum of Ireland 2022).

When it comes to residues and products of biomolecular analyses of organic artefacts and ecofacts, archiving policies are even less well-established and governed by individual institutions. Products such as collagen or aDNA extracts, if kept in suitable storage conditions, can reduce the need for further destructive analysis of precious specimens when new analytical techniques are developed. Some museums (e.g. Natural History Museum [London] and Amgueddfa Cymru/National Museum [Wales]) have destructive sampling policies that mandate the return of all residues and products once approved analyses are completed. Products such as aDNA extracts are then stored in purpose-built archiving facilities such as CryoArks biobank (a UK network of zoological biobanks that maintain frozen collections of animal genetic material: https://www.cryoarks.org/). Archival policies in biobanks are governed by the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilisation (Secretariate of the Convention on Biological Diversity 2011), an international legal framework for the treatment of genetic resources in research. However, the vast majority of museums and archives do not have any policy relating to the archiving of leftover products from the scientific analysis of organics, nor do they have the facilities to suitably store products. By default, archiving policies and storage of leftover products are undertaken by individual laboratories, with records of leftover products often not relayed to relevant museum collections or available through accessible databases, preventing the products being easily accessed by future researchers.

As can be seen from the different policies adopted across these jurisdictions, decisions about the retention of organic materials within archaeological archives are uneven; there is no agreed and systematic approach. The rapid rate at which the organics revolution has taken place means that it is timely to review the potential of organic materials, in order to support and assist archiving policy, to retain the value of these resources, and to ensure that the potential of these materials is secured for future research.

Discussion

What is the potential of archived organics?

'Traditional' organics and 'new' organics

Research into plant and animal remains (including vertebrates and invertebrates) has a long history in Europe and America, including the recovery of faunal assemblages from cave explorations (e.g. Buckland 1824) and the Danish 'kitchen midden commissions' (Kristiansen 2002) in the 19th century AD/CE, followed by more systematic study since the 1910s (e.g. Douglass 1919 on dendrochronology; Woodhead 1929, on charcoal for palaeoenvironmental reconstruction).

'Traditional' approaches focus on taxonomic classification, the identification of elements and their quantification, with results illuminating aspects of past human behaviour, ecological changes and human/animal/ecosystem interactions in general. Work on these assemblages is specialised – even within the discipline of archaeology. Practitioners may have studied archaeological science or come from a background in the natural sciences, but all rely on interdisciplinary knowledge. Even until relatively recently, recovery of ecological assemblages from different sites could be quite variable and was often based on the preferences of the individual archaeologists and specialists. The routine development and application of sampling strategies to recover organics is a relatively recent development in professional practice (e.g. in the UK, this dates to the early 1990s; Campbell, Moffett, and Straker 2011).

These 'traditional' organic studies have recently been joined by 'new' organic studies that include an ever-growing range of scientific methods. These include stable isotope evidence to investigate the diets of domestic animals and the growing conditions for crops, aDNA studies, proteomic and lipid residue studies of pottery and amorphous deposits, as well as the development of techniques for radiocarbon dating specific compounds extracted from archaeological pottery (Makarewicz and Sealy 2015; Lodwick and Stroud 2018; Czajkowska et al. 2020; King et al. 2009; Orlando et al. 2021; Mackay et al. 2020; Zavala et al. 2021; Roffet-Salque et al. 2017; Hendy 2021; Casanova et al. 2020).

Both traditional and new approaches to organics demonstrate the important contributions biomolecules and ecofacts make to archaeological research. However, we contend that approaches to the preservation and storage of organics in archaeology have not kept pace with the rate and nature of change in the organics revolution. Failure to recognise the value of biomarkers and ecofacts, and to ensure their conservation, will have a negative impact on the development of future techniques because of the lack of suitable samples (cf. Mooney 2018 on archaeological wood). This may be an under-reported problem given biases against reporting and publishing negative results (Charlton 1987; Knight 2003). The organics revolution also requires a reappraisal of 'ugly' artefacts, as such materials can be the preservation sites of important resources. For example, coarse-ware pottery that is subject to quotidian use (in contrast to fine-wares) are often excellent sources for organic residue analyses and Zooarchaeology by Mass Spectrometry analysis of fragmented faunal remains (unidentifiable using traditional methods) provides the opportunity for complete reappraisals of subsistence strategies (Collins et al. 2010).

How can organics contribute to new archaeological paradigms?

Organic materials have enormous potential to continue to contribute to established lines of archaeological enquiry, which itself is enough to justify ecofact and biomarker retention. However, the evidence that organic materials provide also has a central role to play in emerging lines of archaeological enquiry (cf. Kristiansen 2014).

The first is around Big Data; researchers, including archaeologists, are realising the inherent research potential of composite and heterogeneous datasets that are larger and more complex than datasets traditionally used (Wesson and Cottier 2014; Gattiglia 2015). This is not to suggest that Big Data will abolish models, theories and hypothesis (Anderson 2008, 200). The 'data fetishism' that conceives of data as an answer looks past the need for contextualisation, research design and 'big judgements' that, in the case of archaeology, only archaeologists can provide (Gattiglia 2015). Nevertheless, a number of archaeological studies have collated very large datasets to examine patterns in past human lives and their living environments across geographical or temporal scales that would otherwise not be possible (e.g. Bevan et al. 2017; McLaughlin et al. 2016; Reade et al. 2022). Other studies have sought to address themes that are 'Big Data' in character (such as aDNA studies seeking to represent entire populations, e.g. Slatkin and Racimo 2016). A substantial portion of the chronological, archaeological, isotopic and genetic data within these studies derive from organic samples. Retained ecofactual and biomarker archives represent an invaluable resource to enhance and expand Big Data analytic and interpretive approaches in the future.

Secondly, organics can and should play a significant role in reshaping how archaeologists think and write about time. Archaeological narratives regularly conceive of time as 'blocks' (be those 'cultures', 'groups' or 'periods') defined by specific cultural complexes and artefact typologies. With regard to archaeological periods in particular, these imposed blocks of time essentially reify Culture-Historic approaches (Griffiths 2017, 2022). This becomes especially problematic when looking at change and difference over time and space, as it encourages a picture of periods of stasis, followed by transitions of radical change (Crellin 2017, 111). An alternative is to use time – in years, decades and centuries – as a means to examine what people were doing in the past, and how practices continued, morphed or changed over time, be that within a 'period', or across traditional period boundaries. Central to such a project is the use of radiocarbon data and Bayesian statistical modelling (Bronk Ramsey 2008; Bayliss 2009) to produce high resolution chronological narratives of the past, which allow an examination of life, materials and practices at times, and in places and environmental contexts (cf. Bayliss et al. 2011; Ashmore 1999). In particular, when we are creating molecular chronologies – for instance using the same samples for chronology and aDNA analysis or lipid molecule analysis – we are tracing patterns at a much higher degree of specificity, with consequential implications for granular, nuanced narratives. In the future, genealogical relationships between samples inferred from aDNA analyses may also help to refine chronologies using time, rather than 'periods' (Sedig et al. 2021; Speidel et al. 2019). Therefore, ecofact retention in archives is fundamental to restructuring how we write about time, and therefore to the global practice of archaeology.

Third, ecofactual material is entirely foundational to a range of approaches, such as New Materialism, Assemblage Theory and Multispecies Archaeology, which produce narratives of the past that consider the other-than-human elements of the world, and their relationships to humans (e.g. Pilaar Birch 2018; Harris and Cipolla 2017). These approaches take seriously the potential for nonhumans, including materials, plants, animals, insects, objects or places, to be entwined with the lives of humans, shaping their lives, and in turn being shaped. Moving away from anthropocentric accounts of the past, methods of analysis used to reconstruct aspects of human lives, including stable isotope analysis and palaeogenomics, are now being used to examine nonhumans in the past and the environmental settings that they inhabited (e.g. Jones and Britton 2019; Britton 2018; MacHugh, Larson, and Orlando 2017; Roffet-Salque et al. 2015). These methods are in part employed to understand human actions, but they also have the power to provide a more detailed understanding of the lives of nonhumans (Overton 2018a, 2018b; Noble 2017; van der Veen 2014; Serrano, Ordóñez, and Fregel 2021; Richer and Gearey 2018). Many current studies explore human – nonhuman interactions based on indirect artefactual evidence; in order to take this analysis further, we need the organic remains of the plants and animals that humans interacted with to be retained within archives, as well as the artefacts.

Archived organic material from archaeological contexts also has an important role to play in wider contemporary research themes, notably research into environmental management, restoration, biodiversity, land use and food production strategies within the current climate crisis. Archived material has the potential to counter 'shifting baseline syndrome' (Pauly 1995), the process by which each successive generation considers its own ecology as 'normal', therefore grossly underestimating the severity of biodiversity and climate change. De Groot et al. (2021) have advocated a need for a much stronger understanding of the relationships between past societal responses to climate change as a way to understand our current climate crisis and understand how societies in the past have dealt with change. Research highlights flexibility and adaptation in the past (e.g. Bogaard et al. 2017; de Souza et al. 2019; Dockrill and Bond 2009; Lancelotti and Biagetti 2021) and outlines how the inter-relationships between social, economic and ecological spheres of influence are important for understanding how societies can be resilient (e.g. Lancelotti et al. 2016; Fleitmann et al. 2022; Lawrence, Palmisano, and Gruchy 2021). Organic materials within archives are an irreplaceable source of palaeoclimatic and palaeoenvironmental proxy data (St. Amand et al. 2020; Hedges, Stevens, and Richards 2004; Prendergast et al. 2018; Reade et al. 2020). These provide detailed empirical data – often at the species level – on the long- and shorter-term effects of climate and ecological changes on organisms and their associated ecosystems. In addition, they can provide novel insights into how humans shaped the world around them and responded to environmental challenges.

Ecofacts and biomarkers are particularly interesting when inextricably linked with human activity. These data have the potential to facilitate new examinations of humans' interaction and relationships with the world around them (Bogaard et al. 2021), especially in the context of sustainable practices and environmental changes (e.g. Rockman and Hritz 2020; Roffet-Salque et al. 2018). Furthermore, the threats to sites and the material preserved within them, in part due to climate change itself, only serve to reinforce the importance of archived material (St. Amand et al. 2020), and the need to continue to archive newly excavated material in the future. Organic remains are disproportionately impacted by such changing environmental conditions (see Harmsen et al. 2018; Hollesen et al. 2018; Mooney, Pinta, and Guðmundsdóttir 2022) and high-profile sites are not immune to this (for example, wetland drainage at Star Carr, High et al. 2016). The only way to mitigate these losses is to excavate sites, while material can still be recovered, further increasing the demand for storage space. Crucially, these remains should be archived for future analysis, to ensure that these delicate organics are stored in conditions that facilitate future research and, most importantly, to ensure that there are routes to discovery for the stored organics and materials (like excess bone collagen) that are generated as part of the research process.

In defence of organics

The application of new research techniques to materials from long-stored archives is an affirmation of the importance of retaining material archives; far from being rows of forgotten dusty boxes, they comprise an unparalleled collection of material that is central to the development of current and future research agendas. In this context, organic assemblages are an irreplaceable resource with a huge research potential and should be retained in archives by all possible means (cf. Baker and Worley 2019, 35; Society for Museum Archaeology 2020). Retention allows researchers to return to them to implement new methods of analysis, to review previous interpretations, and for the archive to act as a resource for researchers beyond archaeology. This research potential is not realised if assemblages are only preserved 'by record'.

The 'curation crisis' outlined at the start of this paper means that sometimes museum curators, archaeologists and specialists are under pressure to rationalise storage and retention policies, where such guidance exists. To that end, we present a series of considerations for archiving organic remains, with a restatement that, wherever possible, all material should be retained. Any deselection process should follow all existing national guidance provided for this process in the institution's country (though we note many states do not have such guidance). Policies should minimise loss, be developed for the specific context of the site/assemblage in consultation with relevant specialists and processes should fully document all material to be discarded (Baker and Worley 2019, 35–7; Oniszczuk et al. 2021).

Do current organic retention policies maximise research potential? We suggest that they do not. Here, we propose some key considerations that should inform organic retention policies and help to maximise future research potential. These are not definitive but are included here as a way of opening up discussion, a necessary precursor to maximising future research potential.

- Existing Data. The level of existing reporting on archived assemblages may be inconsistent, due to differences in reporting type (e.g. assessments vs. full publication), regional standards, and the introduction of new/additional elements to standardised reports. There needs to be an alignment between making assemblages and data reports accessible. This is especially the case for recent reporting, where datasets may be born digital. In addition to the organic materials themselves, digital data produced as part of analysis need to be curated as part of the deposition. Digital datasets should be archived and made discoverable in an approved repository. Where such repositories do not exist, they should be developed. These datasets should include scientific metadata and any analytical code applied to datasets (for example R code, or deposit modelling and calibration code).
- Intrinsic research potential. The fundamental lesson from the organics revolution is that specimens that are considered less valuable now may have their value radically altered in the future. The rapid development of organic analyses means that archives of archaeological sites are not 'just' cultural archives but can also be seen as vast ancient 'bioarchives' –

collections of rich biological information from the past. For example, specimens not morphologically identifiable to species (which were considered less useful) can now be identified through biomolecular approaches (Collins et al. 2010) and can inform on differential processing and butchery practices. Materials that in the past may not have been seen as having research potential have been removed from archives (for example, dendrochronological samples of bog oak are now routinely used for stable isotope-based climate work, although there may be a lack of awareness of this work amongst the curatorial community). The size of the assemblage should also not be considered as a defining factor in retention or discard decisions. For example, for archaeobotanical assemblages, the richest and most diverse samples may be considered the most likely to be used for future research. However, this can vary from site to site, and from period to period, with many early prehistoric assemblages represented by quite small quantities of seed (e.g. McClatchie et al. 2014, 209; Bishop, Church, and Rowley-Conwy 2009, 62–72). Waterlogged assemblages of plants and insect remains offer particular challenges in conservation. However, it may be possible to find more stable ways of storing these prior to accession (such as mounting insect specimens on cards), or potentially providing digital representations of these ecofacts to provide new approaches to recording such assemblages. Similarly, it should be possible to deposit prepared pollen slides as part of a physical archive, and digital microscope images of key aspects of an assemblage.

- Allied research potential: radiocarbon measurements. As radiocarbon measurement techniques develop, so the size of potential samples has decreased. New developments (e.g. Casanova et al. 2020; Lanting, Aerts-Bijma, and van der Plicht 2001) also have the potential to radically change the nature of materials that it is possible to produce radiocarbon measurements on. This means that we can use new types of samples to construct chronologies; however, it also means that we need to revise our approaches to curation and conservation of organic materials. Work on osteological specimens can identify elements recovered in articulation, or with refitting unfused epiphyses and diaphysis that indicate specimens were fleshed when deposited. Such samples therefore have high potential for constructing chronologies (Bayliss et al. 2011, 38–40). Similarly, it is now possible to produce measurements on single seeds of domesticated plant species (e.g. Pelling et al. 2015, 86) or individual annual growth rings in trees and timber (e.g. Galimberti, Bronk Ramsey, and Manning 2004; Kuitems et al. 2022; Büntgen, Esper, and Oppenheimer 2022). Measurements on small samples means that we can start to ask qualitative questions about assemblages. We can start to think about the potential for residual and intrusive items within an assemblage (see Pelling et al. 2015, 86) and engage critically with the time-duration represented by large charred assemblages (Valamoti 2005, 262) and the nature of 'good' samples for robust chronologies (see Bayliss et al. 2011, 40, category 7).
- Allied research potential: isotopic, histological and biomolecular potential. For osteological assemblages, isotopic, histological and biomolecular analyses can examine the character and life-history of both animal and human assemblages. Samples from multiple/all individuals present in the assemblage (bone and teeth) provide the greatest opportunity to characterise the similarities or differences between individuals within a species, and between species. For archaeobotanical assemblages, good preservation quality (particularly if the morphology of the grain remains intact despite carbonisation) appears to enhance the likelihood of success with these analytical methods (see Czajkowska et al. 2020; Brinkkemper et al. 2018, 258). Existing assessments of the preservation quality of archaeobotanical assemblages (e.g. Hubbard and Al Azm 1990) can be employed to inform retention policies. Insect remains from archaeological

sites can also be used for stable isotope research; oxygen isotope ratios can inform us about changes in their past physical environment, including past temperatures (Verbruggen et al. 2010), whilst carbon isotope ratios can reflect environmental conditions such as changes in land use and eutrophication, and on changes in food sources (van Hardenbroek et al. 2018). Additionally, the products of biomolecular analyses of organic artefacts and ecofacts should be retained and their location should be made discoverable. This could reduce the need for further destructive analysis of precious specimens when new analytical techniques are developed.

- The changing nature of organic preservation. Climate change will impact on the preservation conditions and change the nature of the archaeological record – such as in the dewatering of sites or erosion or inundating of coastal locations. For example, recent work undertaken as part of the *Climate Change and Coastal Heritage* project ('CHERISH' http://cherishproject.eu/en/) has highlighted the impact of climate change on the archaeological resource around the Irish Sea. In order to mitigate against the impact of climate change on archaeological sites, research priorities will need to be changed, and excavation may be undertaken to record locations at risk from climate change. Such archaeological responses to climate change may therefore result in even greater demands for storage – especially of organics.

It is salutary to recognise that as new methodological and analytical techniques have been developed the value of many organic specimens has *increased* during their deposition in museum archives. Organic materials held by museums arguably now offer greater research potential than some classes of artefacts (which are retained without question due to their anthropogenic nature). We suggest that this banked value in organics has developed at a different rate and trajectory from archaeological materials science because of specific disciplinary concerns, namely, that artefacts have a longer history of systematic study and that the developments in biomolecular, isotopic and ecofactual techniques that underpin the study of organics have been more recent. The organics revolution emphasises that we need to revise our approaches to curation in order to maximise the potential of this value in the future.

Fundamentally, we need an integrated response to maximise the potential for research at the intersection between traditional archaeological materials, organic materials, and data produced through the analysis process (e.g. Griffiths et al. in prep.). This may require new integrated approaches to infrastructure at national levels that effectively signpost areas of expertise and reference collections, and if necessary, directly curates and disseminates digital resources. This need for a connected infrastructure has been recognised for the UK heritage science sector more widely (Horsfield, Edwards, and Stacey 2021) but is clearly an urgent necessity given the impact of the organics revolution we have identified here.

Conclusion

Debating organic archives

The organics revolution has transformed the research potential of biomolecular and ecofactual substances in archaeology, and, as we argue here, the regular retention of organics within archives is vital to keep important research avenues open for current and future study. However, we recognised that the call for increased retention runs counter to the current curation crisis. Our recommendations above are not; then, a list of demands directed towards museums and archival institutions, but instead a call to all stakeholders involved in the archival process to recognise the full potential of these materials, and a wider call to the broader profession to debate this issue. We need international, inter-sectoral, aligned approaches to the generation of organics and to their curation and discoverability, from the excavation project design to the curation of digital data and analyses results. It also calls for those outside of the museum sector but who are dependent on it for archival services to oppose the reduction in funding and support in this sector; for the livelihoods of those working there, for the security of the materials they archive, and for the future research they facilitate.

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