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Sampling the irreplaceable: towards a more sustainable biomolecular archaeology in Estonia

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ABSTRACT

As the use of biomolecular methods in the study of archaeological and heritage materials continues to expand, increasing attention has been drawn to the sustainability and ethics of current research practices. Ethical discussions have largely focused on method- or material-specific concerns; however, depending on research traditions and scholarly communities, not all materials and approaches receive equal consideration. Furthermore, these debates do not always include heritage stakeholders – such as museums and collection managers – whose responsibility is to preserve cultural heritage for future generations. We propose a cross-methodological and cross-material list of best practices that balance the interests of archaeological materials, society, research, and future generations. Using Estonia as a case study we discuss how to balance innovation and protection in the field of archaeological sciences.

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KEYWORDS
sampling ethics, biomolecular archaeology, destructive sampling.

Introduction

The rapid expansion of biomolecular archaeology has transformed the ways in which archaeological materials are studied, opening unprecedented possibilities for reconstructing the past. At the same time, this growth has introduced new pressures on archaeological materials, particularly human and animal remains, as well as pottery and other artefacts. Most biomolecular analytical techniques are inherently destructive (Aveling & Heron 1998; Galanidou 2006; Pálsdóttir et al. 2019; Chen et al. 2024; Esposito et al. 2024; Stantis et al. 2025), requiring the removal of material from objects that are, by definition, non-renewable (EAA Principles 2022). These pressures are closely tied to the scale and pace at which biomolecular approaches have been adopted in recent years. Over the past decade, the scale of this transformation has increased markedly. Since 2020, the European Commission alone has supported tens of projects focused on the application of advanced biomolecular and chemical methods to archaeological material (CORDIS), including studies on ancient DNA (e.g. Esposito et al. 2024; Gilardet et al. 2025; White et al. 2025), light and heavy isotopes (e.g. Esposito et al. 2024; Tõrv et al. 2026), and organic residues (e.g. Koch et al. 2024; White et al. 2025). As the number of research groups, laboratories, and funded projects continues to grow, competition for access to samples has intensified, along with the total amount of archaeological material subjected to destructive analysis. The widespread adoption of these approaches is understandable, given the remarkably rich insights they provide into past populations (e.g. Allentoft et al. 2015; Charlton et al. 2016; Saag et al. 2019; Rannamäe et al. 2020), economies (e.g. Aguraiuja-Lätti & Malve 2023; Oras et al. 2023), and lifeways (e.g. Heron et al. 2015; Tõrv 2019; Oras et al. 2023). Nevertheless, their increasing use raises fundamental questions about sustainability and responsibility in archaeological research (Gareth Jones & Harris 1998; Galanidou 2006; DeWitte 2015; Charrié-Duhaut et al. 2021; Cortez et al. 2021; Pilaar Birch & Szpak 2022; Nilsson Stutz et al. 2025).

These questions become particularly acute when biomolecular methods are applied to human remains, which have often been among the first and most intensively sampled materials used in the development of new analytical techniques, including ancient DNA analysis (Gareth Jones & Harris 1998; Kaestle & Horsburgh 2002; Mays et al. 2013; DeWitte 2015; Squires et al. 2019; Alpaslan-Roodenberg et al. 2021; Charrié-Duhaut et al. 2021; Cortez et al. 2021; Haponava et al. 2025; Stantis et al. 2025). A substantial body of scholarship has emphasised that research involving human bones or other

tissues may conflict with the beliefs and values of the deceased and associated communities, particularly because informed consent from the dead is impossible (Kaestle & Horsburgh 2002; Squires et al. 2019; Squires & García-Mancuso 2021). Ethical debates have therefore focused on how to preserve the dignity and rights of the deceased while ensuring that descendant and associated living communities are not harmed (Kaestle & Horsburgh 2002; Squires et al. 2019). Consultation with descendant groups has been widely proposed as a key approach to addressing ethical concerns in biomolecular research (Kaestle & Horsburgh 2002; Wagner et al. 2020; Alpaslan-Roodenberg et al. 2021; Vaiglova et al. 2023) and, in many contexts, has become a standard requirement. In research involving the human remains of Indigenous Peoples, such consultation is often non-negotiable, as formalised in legal frameworks such as the Native American Graves Protection and Repatriation Act (NAGPRA). However, consultation is frequently not feasible in cases where direct descendant communities cannot be identified or no longer exist. In addition to ethical discussions, in search of better practices for sampling human remains with destructive methods, efforts have been made to develop new and less destructive techniques, either by reducing the sample size or sampling for multiple analyses at once (Korlević et al. 2018; Fagernäs et al. 2020; Harney et al. 2021).

In contrast, animal remains have traditionally been viewed as less ethically sensitive. As archaeofaunal material is often recovered in large quantities and seen from an anthropocentric viewpoint as a resource or an object (Boyd 2017; Fitzpatrick 2019; Steele et al. 2025), sampling practices have been less restrictive, and destructive analysis has been considered more permissible. Recent research, however, has challenged this assumption, arguing that animal remains must likewise be regarded as a non-renewable archaeological resource (Pálsdóttir et al. 2019). Unregulated or excessive sampling risks diminishing the future research value of assemblages, particularly when destructive analyses are undertaken without sufficient documentation or prior non-destructive study. Scholars have therefore stressed that invasive methods should be carefully justified, preceded by thorough zooarchaeological analysis, and firmly grounded in archaeological context, as certain features – such as bone measurements or taphonomic traces – may be permanently lost (e.g. Pálsdóttir et al. 2019; Ehrlich 2022). In contrast, careful selection of the sampling method and location can minimise information loss while preserving the specimen's potential for future analyses (Fig. 1).



FIG. 1. Sampling of an animal bone. Left: the sampling process, showing the drilling of bone powder from the specimen. Right: the sampled animal bone with associated contextual information, with the damage caused by sampling clearly visible. Photos by Eve Rannamäe.

Comparatively, archaeological artefacts have recently received the least consideration regarding sampling ethics, despite a broad consensus that the integrity of material culture should not be compromised (Razani & Alimirzaei 2025). While artefacts are not associated with the same ethical concerns as human remains or, to a lesser extent, animal remains, archaeological objects nonetheless carry significant cultural, historical, and museological value. At the same time, a wide range of destructive or invasive analytical techniques – such as residue analyses – have long been applied to artefacts (Aveling & Heron 1998; Evershed 2008).

It is crucial to distinguish between *destructive* and *invasive* sampling, as they involve different levels of intervention and are subject to different ethical considerations and permissions. All biomolecular analyses performed today are invasive in the sense that they require some form of physical intervention in the object. Moreover, most are also destructive, meaning that they necessitate the removal of material in a way that results in permanent loss – such as taking a fragment of bone or drilling bone powder from a tooth, neither of which can be replaced once removed. Even when these methods do not always physically destroy an artefact, they may irreversibly alter or remove contextual information, for example by sampling residues adhering to lithics (Galanidou 2006) or pottery (Oras 2025). In the case of ceramics in particular, their relative abundance in archaeological assemblages has likely contributed to a more permissive attitude towards destructive analysis and limited discussion of the long-term ethical and sustainability implications of these practices.

Taken together, the growing reliance on invasive analytical methods raises a fundamental question: how can researchers and collection managers balance the pursuit of new knowledge with the responsibility to preserve archaeological material for future generations? In many countries, including Estonia, clear guidelines or shared frameworks for sustainable destructive sampling are lacking. In their absence, decisions are often shaped by institutional (often unwritten) practices and individual value judgements, a situation that can give rise to conflict when perspectives differ. Against this broader background, we examine the situation in Estonia. The article outlines the legislative and institutional frameworks governing the analysis of archaeological material and explores how destructive sampling has been approached in practice. It further describes the development of a document of best practices for destructive sampling, produced through collaboration between researchers, collection managers, and other stakeholders. The Estonian case demonstrates how locally grounded frameworks can contribute to more ethical, transparent, and sustainable approaches to destructive analysis in archaeology, while also offering insights that may be transferable to other contexts.

Cultural heritage management guidelines and ethics in Estonia

Archaeological material in Estonia is curated primarily by museums and by research collections affiliated with the University of Tartu (UT) and Tallinn University (TLU). The safeguarding and management of this material are regulated through a set of national legal acts, complemented by ethical and professional guidelines. As a member state of the European Union (EU), Estonia follows EU-level charters, conventions, and research ethics frameworks that shape both the protection of cultural heritage and the conduct of scientific research. Many Estonian archaeologists are members of the European Association of Archaeologists (EAA) and follow its Code of Practice (2022) and Principles (2022). Museums and collection managers, in turn, may rely primarily on the Code of Ethics of the International Council of Museums (ICOM, updated 2017),[1] recommended by the Estonian Museum Association and translated into Estonian in 2014, or on the comprehensive and practical Ethical Sampling Guidance, which was prepared under the

1 ICOM adopted a revised Code of Ethics for Museums on 25 June 2026, when this article was already in preparation. The revised code is available here: https://icom.museum/wp-content/uploads/2026/07/ICOM-Code-of-Ethics-for-Museums_2026_EN.pdf.

leadership of the Icon Heritage Science Group and contains questions and guidelines that researchers and collection managers can follow in their work to ensure that destructive sampling is carried out ethically (Quye & Strlič 2019). However, it is not known to what extent this guidance is applied in Estonian museums and collections.

At the national level, the protection of archaeological heritage relies primarily on the Museums Act (2019, amended 2025) and the Heritage Conservation Act (2019, amended 2025). The Museums Act focuses on the regulation of museum work and includes a provision allowing museums to make objects available for research purposes. The Heritage Conservation Act, by contrast, concentrates on the definition and protection of archaeological monuments in situ, both on land and underwater, and on regulating activities associated with them.

Alongside the legislative framework, archaeological research in Estonia is guided by several ethical codes of conduct, most notably the Ethical Principles of an Archaeologist (Eetikakoodeks 2010). This code emerged from a collaborative, 'bottom-up' initiative involving both students and experts in response to public controversies surrounding human remains, illegal metal detecting, and urban development. Organised into four main chapters, the guidelines emphasise adherence to scientific standards, respectful treatment of finds, and transparent communication with the public, thereby reinforcing professional accountability and fostering societal trust. Invasive or destructive sampling is framed within a fundamental ethical tension between advancing scientific knowledge and preserving cultural heritage, with explicit encouragement to prioritise minimally destructive methods wherever possible (Livin 2011). The excavation and sampling of human remains are identified as particularly sensitive, requiring demonstrable scientific justification and careful communication to ensure respect for the dignity of the deceased and to avoid perceptions of archaeologists as 'grave looters' (Eetikakoodeks 2010; Livin 2011). At the same time, interdisciplinary approaches – including laboratory analyses drawing on chemistry, physics, genetics, and geology – are highly valued for making archaeological research more comprehensive and informative, even when sampling is required (Livin 2012). In addition, research institutions in Estonia adhere to the Estonian Code of Conduct for Research Integrity (2017), which requires researchers to consider both the potential benefits and possible harms of their work to all parties involved when planning research.

Research collections affiliated with universities have developed standardised procedures for invasive sampling to protect archaeological heritage and fulfil their institutional and ethical responsibilities. Central to these procedures is the use of a formal sampling protocol, which documents the condition of the object or bone prior to sampling, specifies the method and purpose of the analysis, identifies the responsible researcher, and defines requirements for reporting results and returning any remaining material. In this way, the protocol serves both as a practical tool for documenting the sampling process and as a formal agreement that sets the conditions under which destructive analysis is permitted. Practical guidance for collection management is further supported by the collaboratively developed online Collections Management Handbook (*Kogude töö käsiraamat*), created under the leadership of the Estonian Museum Association.[2] Although this resource provides general guidance on collection management, it currently does not address scientific or invasive analyses of artefacts.

In Estonia, invasive or destructive sampling of archaeological material is only partially addressed within existing legislative frameworks and ethical codes of conduct. National laws such as the Museums Act and the Heritage Conservation Act regulate the protection, management, and research use of cultural heritage, but they do not provide detailed provisions specifically tailored to scientific sampling practices. Ethical guidance is more explicit: the Ethical Principles of an Archaeologist (Eetikakoodeks 2010) and the Estonian Code of Conduct for Research Integrity (2017) emphasise the responsibility to balance scientific inquiry with heritage preservation, to prioritise minimally destructive methods, and to justify the study of sensitive materials such as human remains. In practice, university-affiliated research collections (UT and TLU) have developed formal sampling protocols that operationalise these ethical principles. Thus, while invasive sampling is not comprehensively regulated by law, it is governed through a combination of general heritage legislation, professional ethical standards, and institutional protocols that collectively aim to safeguard archaeological resources. Nevertheless, the growing scale and complexity of biomolecular research have highlighted the need for dedicated best-practice guidelines specifically addressing invasive sampling, which could provide clearer and more consistent guidance.

2 The Estonian Museum Association (EMA), founded in 1988, is a professional organisation of over 400 museum specialists working in state, public, and private museums, dedicated to preserving cultural heritage and promoting the sustainable development of museums by supporting and advancing the museum profession.

The limits of existing regulation: ethical ambiguities in destructive sampling

While the framework described above demonstrates a clear commitment to responsible practice, its practical implementation reveals significant limitations. Despite the existence of legislative acts, ethical codes, and institutional tools, the available documents are often formulated in broad terms and do not define clear or consistent boundaries for destructive sampling. Consequently, researchers and heritage managers may lack sufficiently detailed guidance to support shared ethical agreements and transparent, comparable decision-making in everyday practice.

As shown in Table 1, Estonian legislation addresses the scientific study of cultural heritage only in general terms, placing primary emphasis on preservation rather than on regulating specific research practices. Ethical codes and best-practice guidelines likewise refer to destructive sampling only briefly, typically advising researchers to prefer minimally invasive methods and to balance anticipated scientific benefits against potential damage to the material. The ICOM Code of Ethics for Museums addresses destructive sampling somewhat more directly, but mainly from the perspective of documentation, requiring that such interventions be properly recorded and incorporated into museum records. In practice, it is primarily the institutional guidelines of research collections that provide concrete procedural requirements governing invasive and destructive analyses.

These frameworks are intended to support responsible research while safeguarding archaeological heritage. On the one hand, it is reasonable that responsibility for ethical research rests with the researcher, who is expected to understand the methods employed, including their limitations, risks, and analytical potential (see also Livin 2012). Ethical guidelines are therefore most effective at the planning stage, where they encourage reflection and justification. However, they often provide limited practical guidance once research is underway – particularly when researchers must determine how to conduct destructive sampling in a way that meaningfully advances knowledge while minimising irreversible damage.

At the same time, these documents are even less instructive for collection managers and curators, who are frequently in the position of deciding whether sampling requests should be approved. Unlike researchers, they are not necessarily expected to follow rapid methodological developments in analytical science, yet they bear direct responsibility for the long-term preservation of archaeological collections. In this context, the questions become broader and more structural: while ethical frameworks emphasise facilitating scholarly access to collections, under what conditions should

access be limited? Should every request for sampling be granted, or should clearer criteria guide decisions that balance research goals with preservin heritage for future generations?

TABLE 1. Areas of convergence and gaps in legal and ethical frameworks governing destructive sampling of archaeological material in Estonia

Document	Legal/ ethical status	Material covered	Explicit on destructive sampling	Authority responsible for sampling decisions	Conditions for sampling	Documentation and reporting	Gaps/ ambiguities
European Association of Archaeologists Code of Practice	Ethical	Archaeological practices	No	Not determined	Gains must outweigh the damage	No clear guidance	No criteria for scientific sampling decisions
European Association of Archaeologists Principles	Ethical	Archaeological practices	No	Not determined	Seek to minimise damage to materials	No clear guidance	No criteria for scientific sampling decisions
International Council of Museums Code of Ethics for Museums	Ethical	Museum collections	Yes	Not determined	Upon sampling, documentation should become an integral part of the object	No clear guidance	No criteria for scientific sampling decisions
The Institute of Conservation Ethical Sampling Guidance	Ethical	Heritage objects	Yes	Owner/ custodian of the heritage object	Transparent practices, clear checklist	Explicit guidelines for documentation and reporting	Comprehensive guidance on ethical practice, but does not establish agreed standards of good practice
Estonian Museums Act	Legal	Museum collections	No	Not determined	Not specified	No clear guidance	No criteria for scientific sampling decisions
Estonian Heritage Conservation Act	Legal	Estonian (archaeological) heritage	No	Not determined	Not specified	No clear guidance	No criteria for scientific sampling decisions
Code of Ethics for Estonian Archaeologists	Ethical	Archaeological practices	Indirectly	Not determined	Consider possible methods, choose less destructive ones	No clear guidance	Does not address destructive sampling specifically
Estonian Code Of Conduct for Research Integrity	Ethical	Research practices	No	Not determined	Not specified	No clear guidance	No criteria for scientific sampling decisions
University of Tartu / Tallinn University sampling protocols	Institutional practice	Specific collections	Yes	Not determined	Thorough documentation	Clear guidelines for documentation	Only for institutional use
Collections Management Handbook	Institutional practice	Museum/ collection material	No (at this stage)	Not determined	Not specified	No clear guidance	No criteria for scientific sampling decisions

To sample or not to sample?

Destructive methods in archaeology create tension between advancing scientific knowledge and preserving cultural heritage for future generations. A central question, therefore, is whether the scientific benefits justify the irreversible damage inflicted on the objects. One perspective argues that research itself can enhance the value of the material by generating new knowledge and meaning (Tite 2002; Baars 2010). A well-established approach involves developing more nuanced interpretations of human remains by combining biomolecular methods with strong contextual information and non-invasive osteological analysis. Such approaches allow researchers to reconstruct increasingly detailed life histories of past individuals (e.g. Mitchell et al. 2013; King et al. 2014; Lamb et al. 2014; Varul et al. 2019). Yet the interpretive potential of biomolecular archaeology is even more striking in cases such as that of Lola – a woman identified solely through chemical and genetic analysis of a piece of chewed birch-tar resin dating to 5700 years ago (Jensen et al. 2019). This case shows how previously overlooked or 'unknown' materials can yield new insights, made possible by the maturity of biomolecular archaeology. However, such studies must always be guided by clear research aims, justified sampling strategies, a well-defined methodological framework, and ethical considerations.

A careful research design – grounded in clearly articulated research questions and a thorough understanding of existing scholarship – provides the essential starting point for ethical practice. From this basis, both the nature of the material and the proposed analytical method must be critically evaluated: is the material exceptionally rare? To what extent has it already been studied? How destructive is the method? Have similar analyses previously yielded meaningful results? These are the kinds of questions collection managers may pose when deciding whether to grant access for invasive sampling or defer it in anticipation of advances in methodology, particularly given that they cannot be expected to remain fully informed about the latest methodological developments across all scientific fields. Admittedly, providing clear guidance on when invasive analyses are justified is challenging. However, weighing the potential loss of heritage material against the anticipated scientific gains will usually inform the decision. Consequently, the responsibility to present a comprehensive and well-substantiated justification for destructive sampling must ultimately rest with the researcher.

In cases of exceptional finds, or when working with human remains that require sensitivity, a conservative approach – such as limiting or postponing destructive sampling – may represent the most responsible course of action. One example dates from 1996, when samples of Estonian Stone Age human

remains were sent via Maris Laan to Svante Pääbo's laboratory at Max Planck, where she was conducting postdoctoral research at the time (Maris Laan, email, 26.11.2012). The initially planned DNA analyses required rather large samples (compared with those required by contemporary methodologies), and hence large pieces of bone were cut. However, ancient DNA methodologies had not yet advanced sufficiently to yield reliable results, and the sampled material remained unanalysed for nearly two decades before being returned to the Archaeological Research Collection at TLU by Mari Tõrv. In retrospect, this cautious decision proved advantageous, as the subsequent development of next-generation sequencing (NGS) technologies made it possible to analyse the remains and obtain meaningful genetic data (Mittnik et al. 2018; Saag 2019) that might not have been possible at the same level of quality in the late 1990s. Although sampling altered the human remains, the unprocessed portions of these bone pieces remained available for future analyses. This case demonstrates how postponing analysis until methodological standards are sufficiently robust can prevent the premature loss of irreplaceable material and information.

At the same time, such caution must be weighed against another fundamental reality: archaeological material, although finite, is also perishable. Even under curated conditions, biomolecular components continue to degrade. For instance, studies comparing recently excavated material with specimens stored for decades in museum collections show a measurable loss of DNA over time. Eriksen et al. (2025) found that DNA extracted from samples stored for 43 years was substantially more degraded than DNA from newly excavated material from the same site. Similarly, Pruvost et al. (2007) demonstrated that approximately 3200-year-old aurochs bones excavated from the same site in two seasons 57 years apart yielded no amplifiable DNA from the long-stored specimens, whereas all the recently excavated bones produced authentic sequences. Moreover, the authors estimated that DNA degradation during just 57 years in storage matched the loss that had occurred over the preceding 3200 years of burial. Conservation treatments may further complicate future analyses (Devièse et al. 2021; van der Sluis et al. 2023). In addition, long-term preservation is vulnerable to unforeseen events, such as the fire at the National Museum of Brazil (BBC 2018) or the inferno at Notre-Dame Cathedral in Paris (BBC 2019). Thus, while delaying sampling may sometimes protect material until better methods are available, delay also carries the risk of biomolecular loss, highlighting the need for carefully balanced, context-sensitive decision-making.

Finally, biomolecular research may also be understood as contributing to the creation of a digital, data-driven twin of archaeological material – one that extends beyond visual documentation such as photographs or 3D models to capture its molecular characteristics. Such datasets can be preserved,

replicated, and shared more reliably over the long term than the original material. However, they also raise important questions concerning data management, stewardship, and long-term accessibility (Clarke 2015; Kintigh et al. 2015; Gupta et al. 2023; Nicholson et al. 2023). Moreover, these emerging forms of data introduce additional ethical implications that researchers, heritage institutions, and source communities must actively confront (Peyroteo-Stjerna & Tõrv 2026); the adoption of the CARE principles (Hudson et al. 2023) represents an important first step in this wider discussion. Taken together, these considerations highlight the need to balance precaution with timely analysis, recognising both the risks of premature destruction and those of irreversible molecular loss.

Best Practice for Invasive Sampling of Archaeological Finds and Museum Objects

The absence of detailed and widely shared guidance, together with the fragmented character of existing legal and ethical frameworks, has created an immediate need for more comprehensive best-practice guidance on destructive sampling in Estonia. In response, the Best Practice for Invasive Sampling of Archaeological Finds and Museum Objects (*Hea tava arheoloogiliste leidude ja museaalide invasiivseks proovide võtmiseks*, 2026; see Appendix) was developed. Rather than replacing existing legislation or professional codes, this document seeks to operationalise their underlying principles by translating them into a practical and transparent framework that supports consistent decision-making in everyday research, collection management, and the publication of results. The proposed guidance is designed to ensure that both researchers and collection managers can proceed with a shared understanding of ethical responsibilities and practical expectations (Table 2). In contrast to existing guidelines, which are often tailored to specific methods or materials (Alpaslan-Roodenberg et al. 2021; Sørensen et al. 2025; Stantis et al. 2025), this framework is deliberately broader in scope. It establishes a set of common principles and agreements that align with European legal and cultural contexts and are intended to be applicable across diverse archaeological materials and analytical techniques, while remaining meaningful and workable for both researchers and collection managers.

TABLE 2. Summary of the responsibilities of the parties involved in the Best Practice for Invasive Sampling of Archaeological Finds and Museum Objects

Key consideration	Researchers	Collection holders / managing institutions	Publishers / scientific journals
Research justification	Plan research so that questions can be answered using minimally destructive methods	Ensure the long-term preservation of archaeological finds and museum objects and the responsible stewardship of culturally sensitive materials, including human remains	Verify before publication that data have been obtained in accordance with accepted research ethics and good practice
Minimising destruction	Prefer less destructive analytical methods and avoid duplicate sampling	Assess sampling requests and allow sampling only when the scientific purpose and research questions are sufficiently justified	Use peer reviewers with relevant expertise to evaluate methods and ethical compliance
Permissions and accountability	Obtain permission from the holding institution	Consult experts, when necessary, during the decision-making process	Define data and reporting requirements for authors
Sampling amount and location	Take only the minimum amount of material necessary and, where possible, sample from already damaged or fragmented objects	Refuse sampling requests if necessary	Refuse publication if underlying data from destructive analyses are not provided
Documentation and archiving	Submit a comprehensive sampling protocol	Review sampling protocols	Promote the availability of underlying datasets and transparency, including the publication of negative results
Data transparency	Provide the holding institution with research results, including negative results	Archive documentation and research results and provide researchers with information about previous analyses	Promote open access to datasets or their publication in accessible repositories
Sample management	Return unused sample material if required	Define rules for the storage or return of remaining sample material	
Context and research value	Make full use of the research potential of samples by considering contextual data		
Human remains and sensitive materials	Treat human remains with respect and sample them only when there is strong justification		

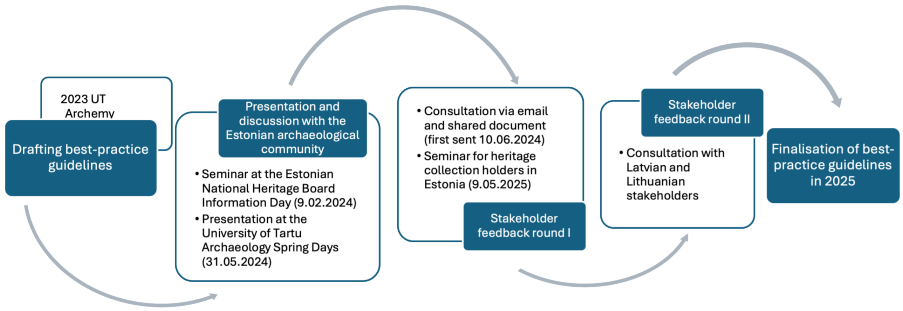

FIG. 2. Development process of the best-practice guidelines. As this is a living document, the process is inherently iterative. Whenever necessary, it can be reinitiated from the stakeholder feedback stage, allowing for multiple rounds of discussion and revision, as required.

The development of these best-practice guidelines followed the example of the Ethical Principles of an Archaeologist (Eetikakoodeks 2010; Livin 2011) and was conceived as a bottom-up, collaborative process lasting approximately two years (2023–2025; Fig. 2). It began with the drafting of an initial set of core principles, which were subsequently refined through multiple rounds of consultation involving a broad range of stakeholders, including collection managers, museum representatives, archaeologists, and other heritage professionals. Feedback was gathered both through written exchanges, such as email correspondence, and through discussions held at seminars and professional meetings, where successive drafts of the document were presented and critically debated. The resulting guidelines therefore represent a negotiated consensus rather than a top-down directive. Importantly, they are intended as a living document that can be revised and adapted to changes in legislation, research methodologies, societal expectations, and institutional needs.

The guidelines are organised into four sections (see Appendix): (1) general principles, (2) the responsibilities of the researcher, (3) the responsibilities of the collection manager, and (4) the responsibilities of the publisher. The first section outlines the fundamental values that should guide both those who conduct research on archaeological material and those entrusted with its long-term preservation. At the foundation of these principles lies a shared acknowledgment that archaeological material is a non-renewable resource and that destructive sampling is justified only when it demonstrably contributes to a meaningful advance in knowledge about the past and/or to the creation of a well-documented, data-driven record of the object.

(1) General principles. On this basis, the guidelines emphasise careful research planning and justification. Researchers are expected to define the anticipated outcomes of the analysis in advance and to design sampling strategies that minimise damage and preserve the potential for future study. Wherever possible, sampling should avoid areas that retain diagnostic features or (taphonomic) modifications characteristic of the object. In cases where analysis requires the destruction of an entire object or sampling from morphologically significant areas, thorough documentation must be undertaken prior to sampling. The general principles further stress the importance of early communication and coordination. Researchers are encouraged to contact the relevant museum or collection at an early stage of the project to establish preliminary agreements concerning sampling, documentation, and the handling of results. When research involves human remains, the guidelines underscore the need for respectful treatment at all stages of the research process and, where known, consideration of the religious beliefs of the deceased. If remains can be reasonably associated with a living community, consultation with that community should also be considered.

(2) The responsibilities of the researcher. Researchers planning and conducting destructive analyses bear the primary ethical responsibility to act with care, transparency, and deliberation, consistent with values long upheld within the archaeological community (Livin 2011; 2012). Accordingly, the obligation to record and report all destructive procedures lies firmly with the researcher, even if such documentation is not explicitly required by the holding institution. Researchers must also anticipate that some collections – especially smaller regional or provincial museums with limited prior experience of destructive analyses – may lack formalised protocols or review mechanisms. It is therefore essential that researchers provide clear communication, methodological transparency, and complete postsampling documentation to ensure accountability and uphold best practice in the stewardship of cultural heritage materials.

If complete objects are removed for analysis, they must be returned to the collection at the earliest opportunity. Agreements should also be made regarding any remaining material from sampled objects that may be suitable for further analyses; for example, collagen extracted from bones may be suitable for multiple isotopic studies, zooarchaeology by mass-spectrometry analyses, or accelerator mass spectrometry (AMS) radiocarbon dating (Charlton et al. 2016; Johanson et al. 2025). Upon obtaining analytical results, researchers should share them with the institution that granted access to the samples, either by notifying the institution of resulting publications and/or by providing raw data if the results are not disseminated through academic outlets. Finally, the researcher must ensure that the full scientific potential

of the sample is realised by thoroughly understanding the contextual background and, where necessary, involving (local) specialists with relevant expertise.

(3) The responsibilities of the collection manager. Museums and collections have a primary responsibility to assess the plans submitted by researchers and to evaluate whether the proposed destructive sampling of the requested material is justified and capable of generating new scientific knowledge that cannot be obtained by other means. As noted above, collection managers may not always possess the specialised expertise required to independently assess complex sampling plans. Therefore, the establishment of clear institutional procedures and decision-making frameworks is essential. Institutional responsibility also encompasses the development of transparent procedural regulations, including defined timelines for the submission of required documentation and research results, policies governing the treatment of leftover samples, and clear guidelines specifying whether sampling may occur off-site or must be conducted on institutional premises. Heritage-holding institutions are also responsible for maintaining an overview of analyses already conducted and for informing researchers if the same material has previously been studied, thereby preventing unnecessary duplication of analyses. Finally, collection managers should ensure that researchers adhere to the established best practices and, in cases of non-compliance – such as failure to provide required documentation – institutions should notify relevant parties and, where justified, refuse permission for sampling.

(4) The responsibilities of the publisher. Good practice in publishing includes ensuring that data presented in a publication have been obtained in accordance with ethical principles and reported with sufficient transparency and detail to enable verification and comparison by other researchers, as well as encouraging the dissemination of negative as well as positive results. These principles constitute fundamental pillars of scientific inquiry, and publishers should also hold researchers accountable for adhering to them, preventing the circumvention of such standards through rigorous editorial and peer-review processes. It is essential that publishers assume greater responsibility and agency by clearly articulating their ethical frameworks and editorial standards. This transparency enables prospective authors and researchers who rely on published work to understand the level of responsibility, quality, and integrity they may expect from a given publication. Finally, it should become standard practice to provide open access to underlying destructive sampling data in accordance with the FAIR principles (Wilkinson et al. 2016). This does not necessarily imply that all articles must be fully open access; rather, it means that primary datasets should not be placed behind paywalls. Such accessibility is important in

the case of destructive sampling, where open data provide an additional safeguard by allowing researchers and collection stewards to maintain oversight of previously conducted analyses and to prevent the repeated damage of heritage objects.

Conclusion

A central challenge in heritage research is finding an appropriate balance between the potential for significant scientific discovery and the responsibility to safeguard irreplaceable cultural material. Invasive sampling can generate transformative knowledge, yet it also entails irreversible intervention. The boundary between justified investigation and unacceptable damage can be extremely narrow – and is sometimes only fully understood in retrospect. For this reason, decision-making must be guided by clearly articulated ethical standards. The Best Practice for Invasive Sampling of Archaeological Finds and Museum Objects provides such a framework. If followed, it helps to ensure that invasive research is undertaken only when it is scientifically justified, carefully prepared, and proportionate to the expected gain in knowledge. Potential harm can be minimised through responsible practice: thorough advance planning, clear research questions, transparent evaluation of necessity, and meticulous documentation of every stage of the process. Equally important is a considered – though not unnecessarily restrictive – approach to data sharing and publication, ensuring that knowledge derived from sampling benefits the wider research community. Maintaining a permanent and traceable record of an object's research history in collections and publications further safeguards its integrity, integrating scientific intervention into the object's continuing biography.

Although heritage objects are non-renewable resources, they are inherently fragile and remain vulnerable to time, environmental factors, and unforeseen accidents that may irreversibly diminish both their physical condition and research potential. In this context, justified and ethically conducted sampling can represent not only a risk but also a means of responsible knowledge preservation, securing information that might otherwise be lost. The significance of heritage objects extends beyond their visible form, as some of the most compelling insights into human history reside within their chemical and biological composition. Advances in scientific methods now allow access to these hidden layers of evidence, enriching interpretation and deepening our understanding of the past. The Best Practice for Invasive Sampling of Archaeological Finds and Museum Objects provides guidance for conducting such research with care, proportionality, and accountability.

While the development of these guidelines adds an important layer to existing laws and professional codes, their adoption does not guarantee that all actors will automatically behave ethically. The purpose of such guidelines is not enforcement but awareness: to cultivate greater awareness among researchers, heritage professionals, and publishers – the three primary groups addressed – of the consequences of their decisions when working with irreplaceable archaeological materials. Yet no guidelines can be effective without individuals committed to upholding them. Ultimately, ethical practice depends on the actions of researchers themselves, the shared expectations within scholarly and professional communities, and collectively maintained standards of accountability.

DATA AVAILABILITY STATEMENT

All data are contained within the article.

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AI tools (M365 Copilot and ChatGPT) were used solely to assist with English-language translation and editing to improve clarity, precision, and readability. All ideas, arguments, and interpretations presented in the article are the authors' own.

References

Aguraiuja-Lätti, Ü. & Malve, M. 2023. Dietary habits in medieval and early modern Estonia: evidence from stable isotope analysis. – Estonian Journal of Archaeology, 27: 3S, 144–164. https://doi.org/10.3176/arch.2023.3S.07

Allentoft, M. E., Sikora, M., Sjögren, K.-G., Rasmussen, S., Rasmussen, M., Stenderup, J. et al. 2015. Population genomics of Bronze Age Eurasia. – Nature, 522, 167–172. https://doi.org/10.1038/nature14507

Alpaslan-Roodenberg, S., Anthony, D., Babiker, H., Bánffy, E., Booth, T., Capone, P. et al. 2021. Ethics of DNA research on human remains: five globally applicable guidelines. – Nature, 599, 41–46. https://doi.org/10.1038/s41586-021-04008-x

Aveling, E. & Heron, C. 1998. Identification of birch bark tar at the Mesolithic site of Star Carr. – Ancient Biomolecules, 2, 69–80.

Baars, C. 2010. Dare to prepare? The value of preparing and sampling historically important museum collections. – The Geological Curator, 9: 4, 237–242.

BBC. 2018. Brazil museum fire: funding sought to rebuild collection. https://www.bbc.com/news/world-latin-america-45404310 (last accessed 16.02.2026).

BBC. 2019. Notre-Dame: massive fire ravages Paris cathedral. https://www.bbc.com/news/world-europe-47941794 (last accessed 16.02.2026).

Boyd, B. 2017. Archaeology and human–animal relations: thinking through anthropocentrism. – Annual Review of Anthropology, 46, 299–316. https://doi.org/10.1146/annurev-anthro-102116-041346

Charlton, S., Alexander, M., Collins, M., Milner, N., Mellars, P., O'Connell, T. C. et al. 2016. Finding Britain's last hunter-gatherers: a new biomolecular approach to 'unidentifiable' bone fragments utilising bone collagen. – Journal of Archaeological Science, 73, 55–61. https://doi.org/10.1016/j.jas.2016.07.014

Charrié-Duhaut, A., Philipps, M. & Richardin, P. 2021. Significant advances of ethical considerations in biomolecular archaeometry studies of human remains and related materials. The specific case of mummies hair characterization. – Ethics, Medicine and Public Health, 17, 100658. https://doi.org/10.1016/j.jemep.2021.100658

Chen, S., Johanson, K., Matthews, J. A., Sammler, S., Blehner, M. A., Salmar, S. et al. 2024. Multi-proxy analysis of starchy plant consumption: a case study of pottery food crusts from a Late Iron Age settlement at Pada, northeast Estonia. – Vegetation History and Archaeobotany, 33, 407–423. https://doi.org/10.1007/s00334-023-00950-0

Clarke, M. 2015. The digital dilemma: preservation and the digital archaeological record. – Advances in Archaeological Practice, 3: 4, 313–330. https://doi.org/10.7183/2326-3768.3.4.313

CORDIS | European Commission. https://cordis.europa.eu (last accessed 16.03.2026).

Cortez, A. D., Bolnick, D. A., Nicholas, G., Bardill, J. & Colwell, C. 2021. An ethical crisis in ancient DNA research: insights from the Chaco Canyon controversy as a case study. – Journal of Social Archaeology, 21: 2, 157–178. https://doi.org/10.1177/1469605321991600

Devièse, T., Abrams, G., Hajdinjak, M., Pirson, S., De Groote, I., Di Modica, K. et al. 2021. Reevaluating the timing of Neanderthal disappearance in Northwest Europe. – Proceedings of the National Academy of Sciences, 118: 12, e2022466118. https://doi.org/10.1073/pnas.2022466118

DeWitte, S. N. 2015. Bioarchaeology and the ethics of research using human skeletal remains. – History Compass, 13: 1, 10–19. https://doi.org/10.1111/hic3.12213

EAA Code of Practice 2022. https://www.e-a-a.org/EAA/About_EAA/Codes/EAA/About/Codes.aspx?hkey=7e8d4e64-4282-4728-bd6f-5eb1484db9c7 (last accessed 16.02.2026).

EAA Principles 2022. https://www.e-a-a.org/EAA/About_EAA/Codes/EAA/About/Codes.aspx?hkey=7e8d4e64-4282-4728-bd6f-5eb1484db9c7 (last accessed 15.02.2026).

Eetikakoodeks 2010. https://arheoloogideliit.ee/kasulik-teada/eetikakoodeks/ (last accessed 16.02.2026).

Ehrlich, F. 2022. Birds in Estonian Zooarchaeological Material: Diversity, Importance and the Earliest Appearance of Domesticated Species. Doctoral thesis. University of Tartu. https://dspace.ut.ee/items/af0a97d2-b639-4f14-950c-72de8354a1e4

Eriksen, A. M. H., Rodríguez, J. A., Seersholm, F., Hollund, H. I., Gotfredsen, A. B., Collins, M. J. et al. 2025. Exploring DNA degradation in situ and in museum storage through genomics and metagenomics. – Communications Biology, 8, 210. https://doi.org/10.1038/s42003-025-07616-9

Esposito, C., Higgins, O. A., Galbusera, A., Gigante, M., Lugli, F., Müller, W. et al. 2024. *NOthing goes to WAste (NOWA)*: a protocol to optimise sampling of ancient teeth. – Journal of Archaeological Science, 171, 106087. https://doi.org/10.1016/j.jas.2024.106087

Estonian Code of Conduct for Research Integrity. 2017. Centre for Ethics, University of Tartu. https://ut.ee/sites/default/files/inline-files/code_of_conduct_for_research_integrity_eng_1.pdf (last accessed 16.02.2026).

Evershed, R. P. 2008. Organic residue analysis in archaeology: the archaeological biomarker revolution. – Archaeometry, 50: 6, 895–924. https://doi.org/10.1111/j.1475-4754.2008.00446.x

Fagernäs, Z., García-Collado, M. I., Hendy, J., Hofman, C. A., Speller, C., Velsko, I. et al. 2020. A unified protocol for simultaneous extraction of DNA and proteins from archaeological dental calculus. – Journal of Archaeological Science, 118, 105135. https://doi.org/10.1016/j.jas.2020.105135

Fitzpatrick, A. 2019. Should we respect rover's remains? A discussion on ethics, or the lack thereof, in zooarchaeology. – Animal Remains Conference, ShARC, 29–30 April 2019, Sheffield, UK. https://doi.org/10.17605/OSF.IO/YSQ2D

Galanidou, N. 2006. Analytical and ethical issues concerning organic residues on Paleolithic chipped stone tools from NW Greece. – Journal of Field Archaeology, 31: 4, 351–362. https://doi.org/10.1179/009346906791071855

Gareth Jones, D. & Harris, R. J. 1998. Archeological human remains: scientific, cultural, and ethical considerations. – Current Anthropology, 39: 2, 253–264. https://doi.org/10.1086/204723

Gilardet, A., Lord, E., García, G. O., Xenikoudakis, G., Douka, K., Wooller, M. J. et al. 2025. A high-throughput ancient DNA extraction method for large-scale sample screening. – Molecular Ecology Resources, 25: 4, e14077. https://doi.org/10.1111/1755-0998.14077

Gupta, N., Martindale, A., Supernant, K. & Elvidge, M. 2023. The CARE principles and the reuse, sharing, and curation of indigenous data in Canadian archaeology. – Advances in Archaeological Practice, 11: 1, 76–89. https://doi.org/10.1017/aap.2022.33

Haponava, V., Fibiger, L., Butler, I. B. & Pickard, C. 2025. Towards responsible destructive analysis: a guide to the recording of archaeological tooth samples with laboratory process visualisation. – Internet Archaeology, 69. https://doi.org/10.11141/ia.69.4

Harney, É., Cheronet, O., Fernandes, D. M., Sirak, K., Mah, M., Bernardos, R. et al. 2021. A minimally destructive protocol for DNA extraction from ancient teeth. – Genome Research, 31: 3, 472–483. https://doi.org/10.1101/gr.267534.120

Heritage Conservation Act [Muinsuskaitseseadus] 2019. Riigi Teataja. https://www.riigiteataja.ee/en/eli/ee/Riigikogu/act/520102025004/consolide (last accessed 16.02.2026).

Heron, C., Craig, O. E., Luquin, A., Steele, V. J., Thompson, A. & Piličiauskas, G. 2015. Cooking fish and drinking milk? Patterns in pottery use in the southeastern Baltic, 3300–2400 cal BC. – Journal of Archaeological Science, 63, 33–43. https://doi.org/10.1016/j.jas.2015.08.002

Hudson, M., Carroll, S. R., Anderson, J., Blackwater, D., Cordova-Marks, F. M., Cummins, J. et al. 2023. Indigenous Peoples' rights in data: a contribution toward indigenous research sovereignty. – Frontiers in Research Metrics and Analytics, 8, 1173805. https://doi.org/10.3389/frma.2023.1173805

ICOM = International Council of Museums. 2017. ICOM Code of Ethics for Museums. https://icom.museum/wp-content/uploads/2018/07/ICOM-code-En-web.pdf (last accessed 17.12.2025).

ICOMi muuseumide eetikakoodeks. 2014. Trans. Jüri Estam, eds A. Aljas & K. Koll. ICOM Eesti Rahvuskomitee.

Jensen, T. Z. T., Niemann, J., Iversen, K. H., Fotakis, A. K., Gopalakrishnan, S., Vågene, Å. J. et al. 2019. A 5700 year-old human genome and oral microbiome from chewed birch pitch. – Nature Communications, 10, 5520. https://doi.org/10.1038/s41467-019-13549-9

Johanson, K., Rammo, R., Haak, A., Jonuks, T., Kiudsoo, M., Luik, H. et al. 2025. Materjalid arheoloogias. Kõrgkooliõpik. Ed. R. Rammo. Tartu Ülikooli kirjastus, Tartu.

Kaestle, F. A. & Horsburgh, K. A. 2002. Ancient DNA in anthropology: methods, applications, and ethics. – American Journal of Physical Anthropology, 119: S35, 92–130. https://doi.org/10.1002/ajpa.10179

King, T. E., Fortes, G. G., Balaresque, P., Thomas, M. G., Balding, D., Delser, P. M. et al. 2014. Identification of the remains of King Richard III. – Nature Communications, 5, 5631. https://doi.org/10.1038/ncomms6631

Kintigh, K. W., Altschul, J. H., Kinzig, A. P., Limp, W. F., Michener, W. K., Sabloff, J. A. et al. 2015. Cultural dynamics, deep time, and data: planning cyberinfrastructure investments for archaeology. – Advances in Archaeological Practice, 3: 1, 1–15. https://doi.org/10.7183/2326-3768.3.1.1

Koch, T. J., Saurel, M., Bocquillon, H., Pisani, D. F., Bonnabel, L., Little, A. et al. 2024. Differences in birch tar composition are explained by adhesive function in the central European Iron Age. – PLoS ONE, 19: 4, e0301103. https://doi.org/10.1371/journal.pone.0301103

Kogude töö käsiraamat. https://muuwik.muuseum.ee (last accessed 16.02.2026).

Korlević, P., Talamo, S. & Meyer, M. 2018. A combined method for DNA analysis and radiocarbon dating from a single sample. – Scientific Reports, 8, 4127. https://doi.org/10.1038/s41598-018-22472-w

Lamb, A. L., Evans, J. E., Buckley, R. & Appleby, J. 2014. Multi-isotope analysis demonstrates significant lifestyle changes in King Richard III. – Journal of Archaeological Science, 50, 559–565. https://doi.org/10.1016/j.jas.2014.06.021

Livin, L. 2011. 'Ethical principles of an archaeologist' – a code of ethics for Estonian archaeologists. – Archaeological Fieldwork in Estonia 2010, 243–247. https://doi.org/10.15157/ave.vi.24996

Livin, L. 2012. The realm of values of Estonian archaeologists. – Estonian Journal of Archaeology, 16: 1, 70–84. https://doi.org/10.3176/arch.2012.1.03

Mays, S., Elders, J., Humphrey, L., White, W. & Marshall, P. 2013. Science and the Dead: A Guideline for the Destructive Sampling of Archaeological Human Remains for Scientific Analysis. English Heritage, Swindon.

Mitchell, P. D., Yeh, H.-Y., Appleby, J. & Buckley, R. 2013. The intestinal parasites of King Richard III. – The Lancet, 382: 9895, 888. https://doi.org/10.1016/S0140-6736(13)61757-2

Mittnik, A., Wang, C.-C., Pfrengle, S., Daubaras, M., Zariņa, G., Hallgren, F. et al. 2018. The genetic prehistory of the Baltic Sea region. – Nature Communications, 9, 442. https://doi.org/10.1038/s41467-018-02825-9

Museums Act [Muuseumiseadus] 2019. Riigi Teataja. https://www.riigiteataja.ee/en/eli/ee/Riigikogu/act/530092025009/consolide (last accessed 16.02.2026).

NAGPRA = Native American Graves Protection and Repatriation Act. 1990. Public Law 101-601, 104 Stat. 3048–3058; 25 U.S.C. 3001 et seq. 101st United States Congress, Washington, D.C. https://www.govinfo.gov/content/pkg/STATUTE-104/pdf/STATUTE-104-Pg3048.pdf (last accessed 20.03.2026).

Nicholson, C., Kansa, S., Gupta, N. & Fernandez, R. 2023. Will it ever be FAIR? Making archaeological data findable, accessible, interoperable, and reusable. – Advances in Archaeological Practice, 11: 1, 63–75. https://doi.org/10.1017/aap.2022.40

Nilsson Stutz, L., Peyroteo Strjerna, R. 2025. Ethical entanglements: human remains, museums and ethics in a European perspective. – Antiquity, 99: 403, e8. https://doi.org/10.15184/aqy.2024.177

Oras, E. 2025. Ceramics and organic residue analysis (ORA). https://sisu.ut.ee/wp-content/uploads/sites/965/Ceramics.pdf (last accessed 20.03.2026).

Oras, E., Tõrv, M., Johanson, K., Rannamäe, E., Poska, A., Lõugas, L. et al. 2023. Parallel worlds and mixed economies: multi-proxy analysis reveals complex subsistence systems at the dawn of early farming in the northeast Baltic. – Royal Society Open Science, 10: 10, 230880. https://doi.org/10.1098/rsos.230880

Pálsdóttir, A. H., Bläuer, A., Rannamäe, E., Boessenkool, S. & Hallsson, J. H. 2019. Not a limitless resource: ethics and guidelines for destructive sampling of archaeofaunal remains. – Royal Society Open Science, 6: 10, 191059. https://doi.org/10.1098/rsos.191059

Peyroteo-Stjerna, R. & Tõrv, M. 2026. Beyond bones: how biomolecular archaeology is challenging the definition of ancient human remains and its ethical implications. – World Archaeology, 57: 2, 161–172. https://doi.org/10.1080/00438243.2026.2632228

Pilaar Birch, S. E. & Szpak, P. 2022. Current developments and future directions in archaeological science. – Proceedings of the National Academy of Sciences, 119: 43, e2212490119. https://doi.org/10.1073/pnas.2212490119

Pruvost, M., Schwarz, R., Correia, V. B., Champlot, S., Braguier, S., Morel, N. et al. 2007. Freshly excavated fossil bones are best for amplification of ancient DNA. – Proceedings of the National Academy of Sciences, 104: 3, 739–744. https://doi.org/10.1073/pnas.0610257104

Quye, A. & Strlič, M. 2019. Ethical Sampling Guidance. Icon Heritage Science Group. https://www.icon.org.uk/static/3e959f66-580b-406c-a5fce17367aa4c13/iconhsgethicalsamplingguidance-jan2019.pdf

Rannamäe, E., Saarma, U., Ärmpalu-Idvand, A., Teasdale, M. D. & Speller, C. 2020. Retroviral analysis reveals the ancient origin of Kihnu native sheep in Estonia: implications for breed conservation. – Scientific Reports, 10, 17340. https://doi.org/10.1038/s41598-020-74415-z

Razani, M. & Alimirzaei, F. 2025. Scientific and ethical considerations in sampling artefacts in archaeological sciences. – Iranian Journal of Archaeological Studies, 15: 2, 99–118. https://doi.org/10.22111/ijas.2025.51593.1344

Saag, L. 2019. The Prehistory of Estonia from a Genetic Perspective: New Insights from Ancient DNA. (Dissertationes biologicae Universitatis Tartuensis, 356.) University of Tartu Press, Tartu.

Saag, L., Laneman, M., Varul, L., Malve, M., Valk, H., Razzak, M. A. et al. 2019. The arrival of Siberian ancestry connecting the Eastern Baltic to Uralic speakers further East. – Current Biology, 29: 10, 1701–1711.e16. https://doi.org/10.1016/j.cub.2019.04.026

van der Sluis, L. G., McGrath, K., Thil, F., Cersoy, S., Pétillon, J.-M. & Zazzo, A. 2023. Identification and tentative removal of collagen glue in Palaeolithic worked bone objects: implications for ZooMS and radiocarbon dating. – Scientific Reports, 13, 22119. https://doi.org/10.1038/s41598-023-49242-7

Sørensen, M. L. S., Hofmann, D., Kristiansen, K., Demeter, F., Nielsen, R. & Willerslev, E. 2025. A framework for archaeological involvement with human genetic data for European prehistory. – Open Archaeology, 11: 1, 20250053. https://doi.org/10.1515/opar-2025-0053

Squires, K., Booth, T. & Roberts, C. A. 2019. The ethics of sampling human skeletal remains for destructive analyses. – Ethical Approaches to Human Remains: A Global Challenge in Bioarchaeology and Forensic Anthropology. Eds K. Squires, D. Errickson & N. Márquez-Grant. Springer International Publishing, Cham, 265–297.

Squires, K. & García-Mancuso, R. 2021. Desafíos éticos asociados al estudio y tratamiento de restos humanos en las ciencias antropológicas en el siglo XXI. – Revista Argentina de Antropología Biológica, 23: 2, 1–22. https://doi.org/10.24215/18536387e034

Stantis, C., Schaefer, B. J., Correia, M. A., Alaica, A. K., Huffer, D., Plomp, E. et al. 2025. Ethics and applications of isotope analysis in archaeology. – American Journal of Biological Anthropology, 186: 1, e24992. https://doi.org/10.1002/ajpa.24992

Steele, T. E., Gallo, G. & Martisius, N. L. 2025. Animal resources in experimental archaeology: a reflection on standards and ethics. – Journal of Archaeological Science: Reports, 61, 104901. https://doi.org/10.1016/j.jasrep.2024.104901

Tite, M. S. 2002. Archaeological collections: invasive sampling versus object integrity. – Papers from the Institute of Archaeology, 13: 1, 1–5. https://doi.org/10.5334/pia.189

Tõrv, M. 2019. Persistent Practices. A Multi-Disciplinary Study of Hunter-Gatherer: Mortuary Remains from c. 6500–2600 cal. BC, Estonia. (Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein und im Ostseeraum, 9.) Wachholtz Verlag – Murmann Publishers, Kiel, Hamburg.

Tõrv, M., Chen, S., Unt, A., Johanson, K., Rannamäe, E., Varul, L. et al. 2026. Segregated food culture? Bronze Age (1250–500cal BCE) dietary practices in northern Estonia. – Journal of Archaeological Science: Reports, 69, 105514. https://doi.org/10.1016/j.jasrep.2025.105514

Vaiglova, P., Lazar, N. A., Stroud, E. A., Loftus, E. & Makarewicz, C. A. 2023. Best practices for selecting samples, analyzing data, and publishing results in isotope archaeology. – Quaternary International, 650, 86–100. https://doi.org/10.1016/j.quaint.2022.02.027

Varul, L., Galeev, R. M., Malytina, A. A., Tõrv, M., Vasilyev, S. V., Lõugas, L. et al. 2019. Complex mortuary treatment of a Corded Ware Culture individual from the Eastern Baltic: a case study of a secondary deposit in Sope, Estonia. – Journal of Archaeological Science: Reports, 24, 463–472. https://doi.org/10.1016/j.jasrep.2019.02.003

Wagner, J. K., Colwell, C., Claw, K. G., Stone, A. C., Bolnick, D. A., Hawks, J. et al. 2020. Fostering responsible research on ancient DNA. – American Journal of Human Genetics, 107: 2, 183–195. https://doi.org/10.1016/j.ajhg.2020.06.017

White, A. E., Koch, T. J., Jensen, T. Z. T., Niemann, J., Pedersen, M. W., Søtofte, M. B. et al. 2025. Ancient DNA and biomarkers from artefacts: insights into technology and cultural practices in Neolithic Europe. – Proceedings of the Royal Society B: Biological Sciences, 292: 2057, 20250092. https://doi.org/10.1098/rspb.2025.0092

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A. et al. 2016. The FAIR Guiding Principles for scientific data management and stewardship. – Scientific Data, 3, 160018. https://doi.org/10.1038/sdata.2016.18

Analüüsides asendamatut: suund jätkusuutlikuma biomolekulaarse arheoloogia poole Eestis

Silvia-Kristiin Kask, Eve Rannamäe ja Mari Tõrv

RESÜMEE

Üks keskseid väljakutseid kultuuripärandi uurimisel on tasakaalu leidmine uue teadmise loomise ja asendamatu arheoloogilise materjali kaitsmise vahel. Lõhkuv proovivõtt võib avada täiesti uusi uurimisvõimalusi, kuid sellega kaasneb pöördumatu sekkumine, mille lubatavuse piir on sageli väga õhuke ning mõnikord nähtav alles tagantjärele. Seetõttu peab proovivõtt lähtuma selgelt sõnastatud eetilistest põhimõtetest. Hea tava pakub terviklikumat ja laiapõhjalisemat praktilist raamistikku: see aitab tagada, et uuritakse üksnes teaduslikult põhjendatud juhtudel, põhjaliku ettevalmistuse ja proportsionaalse riskihindamise alusel. Vastutustundlik tegutsemine – läbimõeldud uurimiskava, selged uurimisküsimused, läbipaistev vajaduse hindamine ja iga sammu dokumenteerimine – minimeerib kahju ning toetab teadmiste laiemat jagamist. Samavõrd oluline on tagada, et proovivõtu ja analüüside käik oleks kogudes ja publikatsioonides selgelt jälgitav, sidudes teadusliku sekkumise objekti jätkuva elulooga. Samas ei taga hea tava olemasolu automaatselt seda, et kõik käituvad edaspidi eetiliselt. Juhendi eesmärk ei ole kontroll, vaid teadlikkuse kasvatamine: suunata uurijaid, pärandivaldkonna spetsialiste ja kirjastajaid mõtlema oma otsuste tagajärgedele, kui nad töötavad asendamatu arheoloogilise materjaliga.

Appendix. Best Practice for Invasive Sampling of Archaeological Finds and Museum Objects

Hea tava arheoloogiliste leidude ja museaalide lõhkuvate proovide võtmiseks

Sissejuhatus

Viimasel kümnendil on suurenenud arheoloogiliste leidude ja museaalide analüüsimine viisil, mis nõuab nende kahjustamist või lõhkumist. Eelkõige on seesugune trend seotud biomolekulaarsete meetodite laiema rakendamise ja uute biomolekulaarsete meetodite kasutuselevõtuga arheoloogias, eelkõige luustike analüüsimisel (vana DNA, stabiilsete isotoopide analüüsid, lipiidide uuringud jne), aga ka savinõukildude, metallesemete ja teiste leidude uurimisel.

Arheoloogilise leiu all peame silmas muinsuskaitseseaduse § 24 lõikes 1 sätestatut:

arheoloogiline leid on maasse, maapinnale, ehitisse, veekogusse või selle põhjasetetesse ladestunud või peidetud arheoloogiline, sealhulgas ajaloolise, kunstilise, teadusliku või muu kultuuriväärtusega inimtekkeline ese või esemete kogum, millel ei ole omanikku või mille omanikku ei ole võimalik kindlaks teha.

Peale esemete (artefaktide) kuuluvad arheoloogiliste leidude hulka ka inim- ja loomaluud ning muud inimtegevuse tulemusel pinnasesse ladestunud orgaanilised jäänused (ökofaktid).

Museaali all peame silmas muuseumiseaduses § 2 lõikes 2 sätestatut:

Museaal on muuseumis arvele võetud kultuuriväärtusega asi, mille üle peetakse arvestust muuseumide rahvusvahelistest dokumenteerimispõhimõtetest lähtudes.

Käesolev hea tava on koostatud selleks, et koondada põhimõtted, mida tuleb järgida arheoloogilistest leidudest ja museaalidest proovide võtmisel. Hea tava on elav dokument, milles sisalduvaid põhimõtteid tuleb vajaduse korral aeg-ajalt üle vaadata ja ajakohastada.

Hea tava koostamisel on lähtutud järgmistest rahvusvahelistest konventsioonidest, Eesti seadustest ja arheoloogilisi leide säilitavate asutuste dokumentidest:

1. Soovitus muuseumide ja kogude, nende mitmekesisuse ja ühiskondliku ülesande kaitsmise ja edendamise kohta (UNESCO Eesti Rahvuslik Komisjon, 2015)
2. Muinsuskaitseseadus
3. Muuseumiseadus
4. Kultuuriväärtuste väljaveo, ekspordi ja sisseveo seadus
5. Tallinna Ülikooli arheoloogia teaduskogus hoitavate kollektsioonide ja arhiivi vastuvõtmise, säilitamise ja kasutamise kord
6. Arheoloogi eetilised põhimõtted

Best Practice for Invasive Sampling of Archaeological Finds and Museum Objects

Introduction

Over the past decade, the use of analytical methods that involve damaging or destructive sampling of archaeological finds and museum objects has increased significantly. In particular, this trend is linked to the expansion and introduction of new biomolecular methods in archaeology, especially in the analysis of skeletal remains (ancient DNA, stable isotope analyses, lipid studies, etc.), as well as pottery, metal objects, and other archaeological finds.

By ‘archaeological find’ we refer to the definition provided in §24(1) of the Heritage Conservation Act:

An **archaeological find** is an object or set of objects created by human activity and sedimented or hidden in the ground or on the surface of the ground, inside a structure, water body or the sediments thereof, which has an archaeological, including historical, artistic, scientific or other cultural value and which has no owner or the owner of which cannot be ascertained.

In addition to artefacts, archaeological finds also include human and animal remains and other organic remains deposited in the soil as a result of human activity (ecofacts).

By ‘museum object’ we refer to the definition provided in §2(2) of the Museums Act:

A **museum object** is a thing of cultural value registered in a museum, for which records are maintained pursuant to the international principles of museum documentation.

These best-practice guidelines have been prepared to compile and clarify the principles that should be followed when taking samples from archaeological finds and museum objects. They are intended to constitute a living document, meaning that the principles they contain should be periodically reviewed and updated as necessary.

The preparation of these guidelines was based on the following international conventions, Estonian laws, and documentation from institutions that preserve archaeological finds:

1. Recommendation concerning the Protection and Promotion of Museums and Collections, their Diversity and their Role in Society (UNESCO Estonian National Commission, 2015)
2. Heritage Conservation Act
3. Museums Act
4. Intra-Community Transport, Export and Import of Cultural Objects Act
5. Regulations for the Acceptance, Preservation and Use of Collections and Archives Held in the Archaeological Research Collection of Tallinn University
6. Ethical Principles of an Archaeologist

Üldpõhimõtted

1. Arheoloogilised leiud ja museaalid on osa kultuuripärandist. Need on taastumatu vara, millega tuleb ümber käia säästvalt.

2. Arheoloogilist leidu/museaali lõhkuvate proovide võtmine on õigustatud, kui see aitab avada ajalugu ja sealseid sündmusi detailsemalt ja/või uue nurga alt ning analüüsi tulemused aitavad luua sellest andmepõhist koopiat.

3. Proovivõtu strateegiat välja töötades tuleb põhjendada, kuidas proovist saadava teadusliku info väärtus ja vajalikkus vastab objektile tehtava kahju suurusele.

4. Uurijal tuleb taotleda nõusolek proovide võtmiseks arheoloogilisi leide/museaale hoiustavalt asutuselt juba teadustöö planeerimise ja uuritava teema kinnitamise ajal, et tagada juurdepääs leidudele/museaalidele uurimistöö perioodiks.

5. Proovi võttes tuleb võimalikult vähe rikkuda leiu/museaali või luuleiu tervikvälimust ning analüüsitaval objektil leiduvaid iseloomulikke ja informatiivseid tunnuseid, et tulevikus saaks sama objekti veel uurida ja/või analüüsida.

6. Inimsäilmed, mida siinses heas tavas käsitletakse arheoloogilise leiu ühe alaliigina, on kunagi elanud inimeste säilmed ja nendest proovide võtmisel tuleb neisse suhtuda erilise lugupidamise ja tundlikkusega.

a. Inimsäilmetest võib proove võtta vaid juhul, kui see on ammendavalt põhjendatud, uurimistöö võib luua uut teadmist ja/või uurimisküsimuse lahendamine on muul moel võimatu või ressursikulukas.

b. Proovide võtmisel vaagib uurija, kas konkreetsed inimsäilmed võivad olla seotud mõne kogukonnaga, kelle seisukohti, huve ja soove tuleb arvesse võtta.

c. Uurija annab oma parima, et inimsäilmeid koheldaks proovivõtu ajal lugupidavalt.

Uurija vastutus:

1. Uurija planeerib uurimistöö nii, et uurimisküsimusele vastuse saamiseks on võimalik rakendada arheoloogilist leidu/museaali minimaalselt lõhkuvaid analüüse.

2. Alternatiivsete meetodite olemasolul valib uurija meetodi, mis lõhub arheoloogilist leidu/museaali võimalikult vähe.

3. Arheoloogilisest leiust/museaalist proovi võttes piirdub uurija alati minimaalse vajaliku kogusega. Kui proovimaterjali jääb üle, tagastab ta selle leidu/museaali hoiustavale asutusele.

4. Arheoloogilist leidu/museaali lõhkuvate analüüside puhul valib uurija võimalusel proovi võtmiseks objekti, mis on juba katki või fragment.

General Principles

1. Archaeological finds and museum objects are part of cultural heritage. They are non-renewable resources and must be handled responsibly and sustainably.

2. Destructive sampling of an archaeological find or museum object is justified only when it contributes to a more detailed understanding of the past and/or offers new perspectives on historical processes, and when the results of the analysis help produce a data-based record of the object.

3. When developing a sampling strategy, researchers must clearly justify how the expected scientific value and necessity of the information obtained from the sample correspond to the degree of damage caused to the object.

4. Researchers must request permission to take samples from the institution responsible for storing the archaeological finds or museum objects already during the planning phase of the research and at the stage when the research topic is approved, in order to ensure access to the materials during the research period.

5. When taking samples, the overall appearance and integrity of the find, museum object, or skeletal specimen should be affected as little as possible. Particular care should be taken to ensure that diagnostic, characteristic, and otherwise informative features of the object are not damaged, so that the same object can be examined and analysed again in the future if necessary.

6. Human remains, which in these guidelines are treated as a subtype of archaeological finds, represent the remains of once-living individuals and must therefore be treated with particular respect and sensitivity during sampling.

a. Samples from human remains may only be taken when the need is thoroughly justified, when the research has the potential to generate new scientific knowledge, and/or when the research question cannot reasonably be addressed through other, less destructive or less resource-intensive methods.

b. When taking samples, researchers should consider whether the specific human remains may be associated with a particular community whose perspectives, interests, or wishes should be taken into account.

c. Researchers must make every effort to ensure that sampling is conducted in a respectful manner.

Responsibility of the Researcher:

1. Researchers must plan their work in such a way that the research question can be addressed using methods that are least destructive to the archaeological find or museum object.

2. Where alternative analytical methods exist, researchers must prefer methods that cause the least possible damage to the archaeological find or museum object.

3. When taking a sample from an archaeological find or museum object, the researcher must always limit the sample size to the minimum quantity necessary for the analysis. If any sample material remains after analysis, it must be returned to the institution storing the find or museum object.

5. Uurija esitab arheoloogilist leidu/museaali hoiustavale asutusele proovivõtuprotokolli, mis sisaldab vähemalt järgmist teavet: i) analüüsi võtmise eesmärk, ii) proovi võtmise protsessi kirjeldus, iii) uurimisküsimus(ed), mille proovi(de) analüüs lahendab, iv) objekti lõhkuva analüüsi puhul objekti seisukorra dokumentatsioon enne ja pärast proovivõttu, millest nähtub selgelt proovivõtu koht ja ulatus.

6. Uurija järgib arheoloogilist leidu/museaali hoiustava asutuse kehtestatud lisainformatsiooni esitamise nõudeid ja aruandlustähtaegu.

7. Pärast analüüsitulemuste kättesaamist peab uurija esitama need, sealhulgas negatiivsed või mitteüheselt tõlgendatavad tulemused, arheoloogilist leidu/museaali hoiustavale asutusele esimesel võimalusel või asutuse määratud tähtaja jooksul:

a. teaduspublikatsioonina;

b. juhul, kui tehtud analüüsi tulemusi ei avaldata teaduskirjanduses, arhiivis säilitamiseks sobiva aruandena;

c. muus muuseumi või kogu soovitud formaadis.

8. Uurija väldib samast arheoloogilisest leiust/museaalist korduvat proovi võtmist sama analüüsimeetodiga. Korduvate proovide võtmine võib olla õigustatud, kui analüüsimeetod on muutunud täpsemaks, varasemad tulemused on ebausaldusväärsed või neile puudub ka mõistliku aja möödudes ligipääs.

9. Uurija peab tagama, et proovi valimisel, võtmisel ja tulemuste tõlgendamisel kasutatakse võimalikult täielikult ära proovi/leiu/museaali teaduslik potentsiaal. See eeldab taustandmestiku põhjalikku tundmist ja võimaluse korral asjakohaste eriteadmistega (kohalike) teadlaste kaasamist uurimistöösse.

Objekte haldava ja/või hoidva asutuse vastutus:

1. Tagab arheoloogiliste leidude/museaalide säilimise tulevastele põlvedele ja jälgib, et objektidest ei võetaks tarbetult lõhkuvaid proove.

2. Võimaldab uurijatel proove võtta, kui nende teaduslik eesmärk ja uurimisküsimus on piisavalt põhjendatud.

3. Haldab leiukogusid heaperemehelikult ja võib keelduda lõhkuvate proovide lubamisest, kui see on vajalik pärandi kaitsmiseks, muu hulgas järgmistel juhtudel:

a. kui uurija ei ole varem järginud head tava ega täitnud (kogu) kehtestatud kohustusi ja tingimusi;

b. kui proovide võtmise teaduslik eesmärk ei ole selge, ammendav või dubleerib varem tehtud uuringuid samast allikmaterjalist;

4. When destructive analyses are required, researchers should, whenever possible, select an object that is already broken or select a fragment rather than a complete object.

5. Researchers must submit a sampling protocol to the institution storing the archaeological find or museum object. The protocol must include at least the following information: i) the purpose of the analysis, ii) a description of the sampling procedure, iii) the research question(s) that the analysis of the sample(s) is intended to address, iv) in the case of destructive analysis, documentation of the object's condition before and after sampling, clearly indicating the location and extent of the sample taken.

6. Researchers must follow any additional information requirements and reporting deadlines established by the institution that stores the find or museum object.

7. After receiving the analytical results, including negative or inconclusive results, researchers must submit them to the institution storing the archaeological find or museum object at the earliest possible opportunity or within the timeframe specified by the institution, in one of the following formats:

a. a scientific publication;

b. if the results are not published in the scientific literature, a report suitable for archival storage;

c. another format requested by the museum or collection.

8. Researchers should avoid repeatedly taking samples from the same archaeological find or museum object using the same analytical method. Repeated sampling may be justified if analytical techniques have significantly improved, if earlier results are unreliable, or if those results remain inaccessible after a reasonable period of time.

9. Researchers must ensure that the full research potential of the sample, find, or museum object is utilised during sample selection, sampling, and interpretation of results. This requires a thorough understanding of the available contextual and background data and, where possible, collaboration with (local) researchers who possess relevant expertise.

Responsibility of the Institution Managing and/or Holding the Objects:

1. The institution is responsible for ensuring the preservation of archaeological finds and museum objects for future generations and must ensure that unnecessary destructive sampling does not occur.

2. The institution allows researchers to take samples when the scientific purpose and research question are sufficiently justified.

3. The institution manages collections responsibly and may refuse permission for destructive sampling when this is necessary to protect cultural heritage, for example (but not limited to):

a. when the researcher has previously failed to comply with good practice or with obligations and conditions established by the collection;

b. when the scientific purpose of the sampling is unclear, insufficiently justified, or duplicates previous research conducted on the same material;

c. kui uurijal puudub seos mõne teadusasutusega;

d. kui allikmaterjal on ainulaadne ja habras ning lõhkuvate proovide tegemine kahjustab tulevaste põlvede õigusi sellele.

4. Et vältida ühest arheoloogilisest leiust/museaalist liigset proovivõttu, annab uurijale ülevaate varem tehtud analüüsidest:

a. teavitab uurijat varasematest samaväärsetest proovidest, mille tulemusi ei ole veel avaldatud;

b. teavitab uurijat, kui mitmel uurijal on soov analüüsida sama leidu/museaali/leiukogumit sarnaste meetoditega.

5. Kontrollib uurija täidetud proovivõtuprotokolli korrektsust.

6. Teavitab uurijat leiukogu tingimustest, mis puudutavad proovivõtmisest üle jäävat proovimaterjali, ning lepib kokku selle edasise käitlemise, kui materjali ei ole võimalik või otstarbekas kogus säilitada.

7. Tervikleidude proovivõtuks väljaandmise korral leide hoidvast asutusest koostab ja kinnitab laenutusakti.

Teadusajakirjade/kirjastajate vastutus:

1. Kontrollivad enne tulemuste avaldamist, et andmed oleksid saadud kehtivaid teaduseetika põhimõtteid silmas pidades.

2. Tagavad, et iga avaldatud andmekogumiga kaasneb piisavalt konteksti- ja metoodikateavet, et teised uurijad saaksid tulemusi hinnata ja kontrollida.

Selleks:

a. sõnastavad nõuded andmekogumite avaldamisele;

b. kaasavad asjakohaste valdkondlike eriteadmistega retsensente.

3. Suunavad autoreid avaldama ka negatiivseid või mitteüheselt tõlgendatavaid tulemusi, et vältida pärandi korduvat lõhkumist (nt samast materjalist korduvat proovide võtmist).

4. Tagavad, et artiklis esitatud andmed tehakse avalikult kättesaadavaks.

c. when the researcher does not have an affiliation with a recognised research institution;

d. when the source material is unique or particularly fragile and destructive sampling would compromise the ability of future generations to study it.

4. To ensure that excessive sampling is not carried out on a single find or museum object, the institution provides researchers with information about analyses previously conducted on the material:

a. the institution informs researchers of earlier equivalent samples whose results have not yet been published;

b. the institution notifies researchers if multiple researchers have expressed interest in analysing the same find, museum object, or collection using similar methods.

5. The institution reviews and verifies the correctness of the sampling protocol submitted by the researcher.

6. The institution informs the researcher about the collection's policies regarding any remaining sample material and requests information about its future handling if it cannot reasonably be stored in the collection.

7. When entire finds are removed from the holding institution for sampling, a formal loan agreement must be prepared and approved.

Responsibility of Scientific Journals and Publishers:

1. Scientific journals and publishers must verify before publication that the data were obtained in accordance with accepted principles of research ethics.

2. They must ensure that each published dataset is accompanied by sufficient contextual and methodological information to allow other researchers to evaluate and verify the results. To achieve this, they:

a. define clear requirements for the publication of datasets;

b. involve peer reviewers with relevant subject-specific expertise.

3. Journals and publishers should encourage authors to publish negative or inconclusive results in order to prevent repeated destruction of cultural heritage (for example, through duplicate sampling of the same material).

4. They must ensure that the data presented in the article are made available on an open-access basis.