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Beyond bones: how biomolecular archaeology is challenging the definition of ancient human remains and its ethical implications

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ABSTRACT

Technological advancements in the twenty-first century have profoundly transformed archaeological research. Biomolecular archaeology has emerged as a pivotal field, generating vast quantities of molecular data and products such as DNA extracts and protein profiles. This paper examines how ancient human remains, once studied primarily through osteology and archaeological context, have become data-generating resources, extracted, processed, and circulated as molecular substrates. We explore how this molecular turn challenges traditional definitions of human remains, as biomolecular products increasingly circulate independently of the bodies from which they originate. Drawing on current examples and professional guidelines, we highlight emerging dilemmas by questioning the narrow conceptualization of human remains and addressing the implications of treating them as data. Ultimately, we argue for an ethical framework in biomolecular archaeology that is adaptive, inclusive, and responsive – one that honours scientific innovation while safeguarding the dignity of past individuals and respecting the concerns of present communities.

KEYWORDS

Biomolecular archaeology; human remains; ethics; data stewardship; heritage stakeholders

1. Introduction

Recent advances in technology, data science, and artificial intelligence are reshaping multiple disciplines and provoking debates about ethics, automation, and human agency. Archaeology has experienced a parallel shift: predictions that molecular methods would supplant purely osteological approaches (Renfrew and Bahn 2004) have been realized, bringing biomolecular analyses into routine study of human remains.

This change is part of a broader scientific transformation often called the third scientific revolution (Kristiansen 2014), which has fostered new collaborations across the humanities, social sciences, and natural sciences while exposing tensions over epistemology and data control (e.g. Booth 2019; Ion 2019; Strand, Källén, and Mulcare 2024). At the same time, big data and predictive modelling have expanded analytical possibilities (Green 2023; Marx 2013). These developments are reshaping both methods and the interpretative frameworks used to study human remains. Human remains are long embedded in public imagination and scholarly inquiry and evoke emotional and symbolic connections to the past. As a result, researchers'

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excavation, analysis, and storytelling carry significant ethical and cultural weight (de Baets 2004). Those narratives often culminate in museum displays that engage visitors and support local economies, and they are increasingly informed by a synthesis of traditional osteology and molecular sciences that bridge technical analysis and cultural meaning (Brooks and Rumsey 2007; Walker 2008).

Archaeological theory has transformed our understanding of the body, moving from a passive historical placeholder into an active agent and a locus of ethical and political negotiation (e.g. Hamilakis 2014; Meskell 2011). This shift aligns with theoretical perspectives that conceptualize the human body as a web of relationships linking objects, places and people, introducing nuanced ideas of embodiment and personhood in life and death (Nilsson Stutz and Tarlow 2013). Human remains are no longer viewed as passive artefacts but as dynamic agents bearing lived experience and historical context. The body thus functions as both an object of study and a meaningful subject shaped by biological and cultural forces (Nilsson Stutz 2023; Sofaer 2006). While natural scientists focus on biological traces, scholars in the humanities and social sciences situate individuals within broader historical and cultural narratives. The interplay between technological innovation and theoretical reflection continues to reshape our understanding of the past and underscores the ethical complexities of studying human remains, particularly in archaeology, where scientific inquiry, cultural sensitivity, and interdisciplinary collaboration converge.

Human remains are the material traces of once-living individuals, and their study demands careful ethical consideration. While legal frameworks in many Western societies regulate the treatment of the recently deceased, archaeological or 'old' human remains are frequently treated as cultural heritage or property and are therefore not considered to possess individual legal rights (Nilsson Stutz 2023). Recognizing this legal reality (that the deceased generally do not hold legal rights), many scholars argue that the living bear a moral responsibility to preserve their posthumous dignity (de Baets 2004; Masterton 2010). Establishing a clear and consistent definition of 'human remains' across archaeology and related disciplines is therefore essential. Such a definition can guide best practices, balance regulatory frameworks with cultural sensitivities, and ensure that the voices of the dead, who can no longer speak for themselves, are treated with respect.

Addressing these complexities requires ongoing ethical engagement by researchers, museum curators, descendant communities and the broader public. In this paper, we focus on human remains in biomolecular archaeology and acknowledge that our disciplinary backgrounds shape our perspective. Both authors specialize in archaeology, focusing on the remains of past foragers to reconstruct mortuary practices through archaeoethnatology (Peyroteo Stjerna 2016; Törv 2018). Our laboratory work with stable isotopes and ancient DNA has further revealed challenges at the intersection of social humanities and natural sciences e.g. (Oras et al. 2018; Peyroteo Stjerna et al. 2022; Simões et al. 2024; Törv et al. 2026). Drawing on these perspectives, we begin by reviewing current definitions and conceptualizations of archaeological human remains. We then explore two key questions considering recent biomolecular and scientific advancements:

- To what extent should the definition of human remains be reconsidered in response to extensive molecular analyses of human tissues, especially bones and teeth?
- Which attributes emerging from biomolecular studies of ancient remains should inform a revised definition of human remains?

By moving beyond existing debates, we address a fundamental challenge in biomolecular archaeology: what precisely constitutes human remains. As technological and sociocultural developments

continue to reshape the field, our definitions and methodologies must adapt to ensure both scientific integrity and ethically robust research.

2. Defining human remains

Professional associations, interest groups and individual researchers have produced numerous guidelines, recommendations and best-practice documents for handling human remains. Standard textbooks likewise provide resources and protocols for studying skeletal remains. Yet despite this wealth of material, clear definitions of what constitutes human remains, whether defined as ancient or archaeological, are surprisingly scarce. To illustrate this ambiguity, we reviewed a selection of widely available international documents and textbooks, which we briefly summarize below.

2.1. Implicit and corporeal definitions

In archaeological practice, human remains are typically defined by their physical traces, most commonly bones and teeth, and more rarely preserved skin, hair, or other soft tissue. This commonsense approach has shaped guidelines that devote little attention to defining the term, implicitly equating human remains with skeletal material. Many professional codes simply assume a shared understanding. For example, the Society for American Archaeology's Principles of Archaeological Ethics make no explicit mention of human remains, although their 2021 statement acknowledges that definitions may vary by perspective (SAA 1996, 2021). Similarly, the European Association of Archaeologists emphasizes dignity and respect without providing precise terminology (EAA 2022). The British Association of Biological Anthropology and Osteoarchaeology and the Chartered Institute for Archaeologists refer to 'archaeologically derived human remains', focusing on skeletal material without further classification (Mitchell and Brickley 2017).

This absence of explicit definitions extends to standard textbooks, which necessarily centre on the most common finds in the field. Works such as *The Human Bone Manual*, *Human Osteology*, *Skeleton Keys* and *Juvenile Osteology* (Bass 2005; Schaefer, Black, and Scheuer 2009; Schwartz 2007; White and Folkens 2005) offer comprehensive guidance on individual bones. Organized around identifiable tissues in archaeological contexts, these manuals reinforce the assumption that human remains consist of skeletons plus occasional soft tissue, leaving other dimensions unaddressed.

International instruments reinforce ethical treatment while leaving the definition of the term largely unresolved. The United Nations Declaration on the Rights of Indigenous Peoples (United Nations 2007) recognizes Indigenous communities' right to reclaim ancestral remains but does not clearly define those remains. Other frameworks, such as the Vermillion Accord (WAC 1989) and the Native American Graves Protection and Repatriation Act (NAGPRA) (United States Congress 1990) have sought to establish ethical parameters for handling human remains. These documents emphasize respect for the deceased, acknowledge their continued significance to descendant communities, and advocate for honouring their wishes where possible, yet they offer limited guidance on definitions.

2.2. Expanding and inclusive conceptions

A clearer and more inclusive set of definitions is now beginning to take shape. Norway's *Guidelines for Ethical Research on Human Remains*, for example, define the term to include intact skeletons, fragmented bones, preserved tissues and organs, and any biological materials uncovered during

excavation. Under this framework, whole preserved corpses also qualify as human remains (Norwegian National Research Ethics Committees 2021). National heritage laws further distinguish ancient from recent remains by setting chronological boundaries e.g. (Historic England 2017; Riigikogu 2019; Kulturmiljölagen 1988, 950)., Absolute and relative dating methods provide the chronological data necessary for legal classification and are often used to operationalize definitions of ancient human remains based on temporal thresholds. Chronological boundaries may be set by fixed historical dates (e.g. 1537 in Norway, 1711 in Hungary), fixed age limits (e.g. over 100 years in Iceland, over 50 years in Estonia), or vary between regions within the same country (e.g. Spain), or otherwise be based on the historical-cultural context (e.g. Portugal). Crucially, many states rely on separate cultural heritage laws (which may protect remains up to 50 or 100 years old) and forensic laws (which cover remains only up to 20 or 30 years old), resulting in a ‘legal gap’ where human remains fall outside of protection by either framework (Márquez-Grant and Fibiger 2011), but see (Crescenzi 2025, 235–44) for a recent summary of existing legal systems by country. While absolute and relative dating methods provide the primary framework for legal classification, Biomolecular Archaeology has introduced molecular degradation patterns as criteria for assessing authenticity and contamination. These signatures provide an additional source of evidence to argue for the antiquity of an individual, thereby potentially assisting in the classification of samples as ancient or recent (Pinhasi et al. 2015; Warinner et al. 2017). Nilsson Stutz (2023) offers a more expansive definition of human remains, encompassing all matter derived from human tissue: skeletal elements, cremains, mummified tissue, hair, nails, skin, teeth, organs and body fluids; whether treated as integral to an individual or regarded as an object. She cautions, however, that ethical concerns specific to the deceased, such as posthumous interests, remain largely unexplored, with most ethical debate focusing on impacts to living communities (Nilsson Stutz 2023). These challenges are illustrated in *Duties to Past Persons* (Masterton 2010), where the author explores the ambiguity of posthumous interests and rights. Masterton defines human remains primarily as skeletal material but emphasizes their growing scientific importance, for example, in DNA analysis and facial reconstruction, and argues that any definition of human remains must be supported by an ethical framework balancing research benefits with considerations of privacy, respect and cultural sensitivity.

The *Vienna Protocol* (Polak et al. 2021) exemplifies the difficulty of defining human remains by age or context alone. Developed in response to Holocaust-era remains from Nazi biomedical research, it emphasizes respect for victims of persecution and provides ethical guidelines that extend beyond skeletal material to include the handling and display of related visual and archival records.

Although ethical guidelines abound, definitions of human remains lack consistency, significantly constraining their operationalization in practice. Professional bodies promote respectful treatment but offer few explicit definitions, leaving key decisions such as classification, jurisdiction, and permissible forms of analysis open to interpretation. Meanwhile, some scholars have called for broader, more inclusive definitions that encompass all human-derived materials and stress the importance of continued ethical engagement as analytical techniques expand and the field evolves.

3. Rethinking human remains in the age of biomolecular archaeology

3.1. From osteobiographies to molecular biographies

Archaeologists have long paired osteological analyses of bones and teeth with funerary context, such as grave goods, tomb architecture and burial placement, to construct osteobiographies. These life histories integrate age at death, biological sex, health status, patterns of physical activity and

inferred social roles e.g. (Chapman, Kinnes, and Randsborg 1981; Parker Pearson 1999; Tarlow and Stutz 2013). Over the past two decades, biomolecular techniques have expanded osteoarchaeological narratives into molecular biographies. Ancient DNA sequencing, stable isotope analysis, proteomics, lipid-residue profiling and sedimentary-DNA studies have transformed individual skeletons and even microscopic traces on artefacts into rich archives of genetic ancestry, biochemistry, and microbiomes (Richards and Britton 2020).

This methodological leap compels us to reconsider what constitutes ‘human remains’. The central challenge is whether molecular by-products – such as DNA extracted from a burial shroud or peptides isolated from a tooth – and the data generated through their destructive analysis are entitled to the same legal, ethical, and cultural protections as an intact mandible. As destructive sampling continues to generate new biomolecular collections, the field is increasingly tasked with defining how to balance scientific promise with responsible stewardship, revising existing ethical frameworks, and determining appropriate safeguards for these molecular remnants.

3.2. Ethical and curatorial challenges: key attributes for a revised definition

Biomolecular archaeology has grown rapidly, with increasing demand for destructive sampling of archaeological remains to extract DNA, collagen and other biomolecules, often outpacing existing ethical guidelines and curatorial protocols. Vials of molecular extracts and expansive biomolecular datasets now accompany skeletal collections, yet professional codes remain uneven and rarely address their proper stewardship. It is essential to differentiate between the two distinct forms of molecular material that arise from this work: (1) the physical molecular extracts (e.g. DNA pellets, freeze-dried collagen, vials of lipid extracts) which are finite, tangible remains; and (2) the digital data (e.g. genomic sequences, mass spectra, isotope profiles) which are replicable, vast, and highly transmissible. While both forms carry ethical and legal weight, their respective custodial, access, and repatriation requirements may differ. In practice, decisions regarding destructive sampling, long-term storage, data access, and publication are often centralized within a small number of well-resourced, predominantly Western institutions. These institutions continue to control sample access and knowledge production in ways that shape whose remains are studied, whose data are shared, and who ultimately defines interpretative narratives, thereby perpetuating colonial power dynamics embedded in the discipline (see, for example, Argüelles, Fuentes, and Yáñez 2022; Ávila-Arcos et al. 2022). The long-running dispute over the Kennewick Man, or Ancient One (1996–2021), illustrates how molecular remains, such as DNA, can become contested domains in debates over tribal sovereignty, museum stewardship, and scientific access. Initially treated as biological data separate from the physical skeleton, the extracted DNA ultimately played a decisive role in affirming cultural affiliation and securing repatriation under NAGPRA (Rasmussen et al. 2015). The case sparked extensive legal and ethical debate, revealing tensions between scientific inquiry and Indigenous epistemologies, particularly regarding the role of oral tradition in establishing cultural continuity (Smith 2016). Scholars have argued that the controversy reflected broader efforts to preserve a non-Indigenous narrative of ancient North America, often at the expense of tribal claims and heritage (Kakaliouras 2019; Zimmerman 2005). The reburial of the Ancient One in 2017 marked a turning point in how biomolecular evidence is weighed alongside community perspectives and legal frameworks.

Another example emerges from the expanding practice of digital repatriation, in which cultural heritage is returned in the form of digital surrogates, such as 3D scans, virtual exhibitions, or the vast molecular datasets derived from analysis (e.g. genomic sequence

databases, spectra). This approach has gained traction as a decolonizing strategy that both parallels and diverges from calls for the physical restitution of ancestral remains and artefacts (Poske 2024). The institutional preference for digital repatriation often stems from arguments centred on long-term preservation, universal scholarly access, or a reluctance to relinquish physical custody. However, this asymmetry (where data is returned but the physical remains are retained) is precisely why critics view the practice as an insufficient ethical solution and a potential maintenance of colonial power dynamics. While digital surrogates, including biomolecular data, can reconnect source communities with dispersed heritage, they cannot fully substitute for the return of physical remains, which carry material, spiritual, and legal significance. This case underscores that molecular remains are not supplementary or neutral byproducts of analysis; they carry cultural, ethical, and legal weight. As such, they require the same level of community engagement, regulatory oversight, and ethical consideration as skeletal remains themselves. Critics caution that without substantive shifts in custodial authority, digital repatriation risks becoming a superficial gesture that disguises enduring power imbalances (Carroll et al. 2020; Christen 2015; Stobiecka 2020). This debate intersects directly with archaeological ethics, particularly when molecular datasets are treated as heritage (Claw et al. 2018). As biomolecular data increasingly circulate across institutions and borders, questions of access, consent, and control become central. The ethical challenges surrounding digital data, including who owns it, who governs it, and how it is contextualized, closely parallel those associated with physical remains. At the same time, they call for tailored guidelines on data sovereignty, provenance metadata, and community governance, particularly within global, interdisciplinary collaborations. Addressing these challenges, particularly in ways that confront persistent colonial power dynamics in the secondary use of biomolecular data, requires more than existing data-sharing norms. An important first step in addressing potential colonial power dynamics in the secondary use of biomolecular data is the adoption of the CARE Principles for Indigenous data governance, developed by the International Indigenous Data Sovereignty Interest Group. Complementing the FAIR principles (Wilkinson et al. 2016), CARE emphasizes collective benefit, authority to control, responsibility, and ethics, established through consultation with indigenous peoples, scholars, non-profits, and governments. Unlike FAIR, CARE is explicitly people- and purpose-oriented. Such challenges make clear that any revised definition of human remains must integrate molecular insights with robust ethical considerations.

4. Discussion: new dimensions of human remains and ethical implications

As the third scientific revolution reshapes archaeological research, the molecular turn offers unprecedented insights into past lives, and with them, complex ethical dilemmas that demand sustained attention. This discussion synthesizes the legal, material, and digital challenges explored in this paper to argue that the definition of human remains must be expanded to include molecular substrates and their derived datasets. Rather than advancing a single, definitive definition, it invites the research community to reflect on how expanding or restricting definitional boundaries shapes research governance, ethical oversight, and future archaeological practice. Two guiding questions frame our reflection: to what extent should the definition of human remains be revisited as biomolecular analyses proliferate? And how does the integration of molecular data reshape current and future practices?

4.1. Intersection with medical ethics

Archaeology can draw critical lessons from medical ethics. Historically, physicians studied human remains with minimal oversight, often using bodies from marginalized communities without consent (Tarlow 2023; Walker 2008). Today, medicine is grounded in principles of autonomy, privacy and informed consent. While archaeology continues to define ‘human remains’ primarily as bones and teeth, biomolecular methods now extract proteins, lipids, DNA and other molecules, revealing the inadequacy of this limited definition. Ethically robust frameworks aligned with contemporary standards for research involving human subjects are needed to ensure that molecular research honours the autonomy, privacy, and dignity of both living communities and the deceased. Recent work in ancient DNA research has emphasized the need for ethically grounded practices that respect both the deceased and affected communities. Gibbon, Thompson, and Alves (Gibbon, Thompson, and Alves 2024) propose a model of informed proxy or relational autonomy consent, allowing living individuals to represent the deceased, thereby fostering collaboration, empowering communities, and guiding ethical information flow. Complementing this approach, Wagner et al. (2020) offer practical recommendations, including hypothetical examples and a due diligence checklist, to support responsible and respectful research practices. If molecular materials and their derived data are brought within the definition of human remains, ethical expectations drawn from medical research – such as informed consent, limitations on secondary use, and obligations of ongoing stewardship – would extend beyond skeletal material to the full lifecycle of biomolecular analysis, fundamentally reshaping approval, documentation, and accountability practices in archaeology.

4.2. Human remains as data

A key challenge emerging from the biomolecular revolution is the conceptual shift towards treating human remains as data. When remains are reduced to molecular sequences, protein profiles, or other biomolecular extracts, analysis risks detaching those data from the physicality and lived experiences of the individuals they once were. This transformation enables large-scale comparative studies and novel insights into ancient populations, but it also raises ethical questions distinct from those posed by traditional osteological work.

Molecular datasets risk obscuring the fact that each data point represents a once-living person, potentially weakening the moral imperatives of respect and dignity applied to physical remains. This detachment prompts us to ask: do the ethical dilemmas inherent in handling bones and tissues translate directly when we deal only with extracted data? Whether such data are included within the definition of human remains therefore has significant practical consequences: inclusion would align data governance, access, and reuse with ethical standards applied to tangible specimens, emphasizing contextualization and community oversight, while exclusion risks allowing biomolecular data to circulate independently of the individuals and communities from whom they derive, reinforcing extractive practices and widening the gap between ethical intent and scientific practice.

4.3. Evolving roles of museums, curators, and stakeholders

Museums, curators, descendant communities and regulatory bodies now face the challenge of integrating molecular data into existing collections. As digital and physical heritage converge, power imbalances persist: major Western laboratories often secure larger grants, control data

analysis, and shape publication agendas (Hassett 2018; Nilsson Stutz *et al.* 2024; Richardson 2018). Consent, ownership, and accountability grow more complex when digital molecular datasets (the intangible data) are derived from tangible remains. Addressing these issues requires co-designed policies and sustained funding to empower both curatorial teams and community partners.

4.4. Scope and limitations

This discussion compels the discipline to address the maximal ethical question of scope: where do the boundaries of responsibility lie when molecular traces are recovered from environmental matrices (e.g. eDNA in soils and artefacts)? We maintain that while the logistical burden of extending traditional curatorial mandates to every archaeological matrix is impractical, the ethical duty to the individual must still apply. This necessitates a conceptual shift from governing the physical custody of materials to governing the ethical use, circulation, and data sovereignty of the information derived from human biomarkers – implying that future archaeological practice must focus less on where remains are stored and more on how sampling decisions are justified, how data are governed over time and who retains authority of their interpretation and reuse.

5. Concluding remarks

Integrating biomolecular data into archaeological inquiry enriches our understanding of past societies by revealing individual life stories and reconstructing ancient lifeways. Yet these technical breakthroughs bring ethical responsibilities that cannot be resolved once and for all. They must be adaptively and responsively negotiated among researchers, curators, descendant communities, and other stakeholders. Reflecting on our guiding questions about redefining human remains and integrating molecular data, we conclude that the ambiguity surrounding these materials is no longer tenable. Biomolecular substrates and datasets must be treated as inseparable from the individuals from whom they derive, even in trace environmental context. While critics may raise concerns about the vast logistical and curatorial burdens of an expanded definition, we maintain that the field's ethical duty must remain the primary guiding principle, even where this complicates curatorial or practical research protocols. By clearly linking scientific innovation with an inclusive approach that prioritizes cultural sensitivity, respect for the dead, and accountability to living heirs, biomolecular archaeology can advance responsibly and with integrity.

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