

To curate the molecular past, museums need a carefully considered set of best practices

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Biomolecular research has sparked a methodological revolution in the field of anthropology, and museums are now faced with the curatorial challenge of conserving and evaluating materials for these new methods. Since 2010, hundreds of genome-wide datasets from ancient human samples have been published, and thousands more have been generated; doubling the amount of data in the field of paleogenomics now

requires less time than the publication of a single article (1). Technological advances in laboratory and bioinformatic approaches have also led to a new era in paleomicrobiology, in which entire ancient microbial communities can be recovered from various substrates, such as calcified dental calculus (2). Increasingly, large-scale datasets for other biomolecules, such as proteins and metabolites, are generated and



Fig. 1. Museum collections staff stand among the anthropological collections at the Smithsonian's National Museum of Natural History. Museums are responsible for preserving collections and the information they contain for future generations. But in recent years, they've been given the increasingly challenging task of curating and conserving biomolecular data. Image credit: Chip Clark (Smithsonian Institution, Washington, DC).

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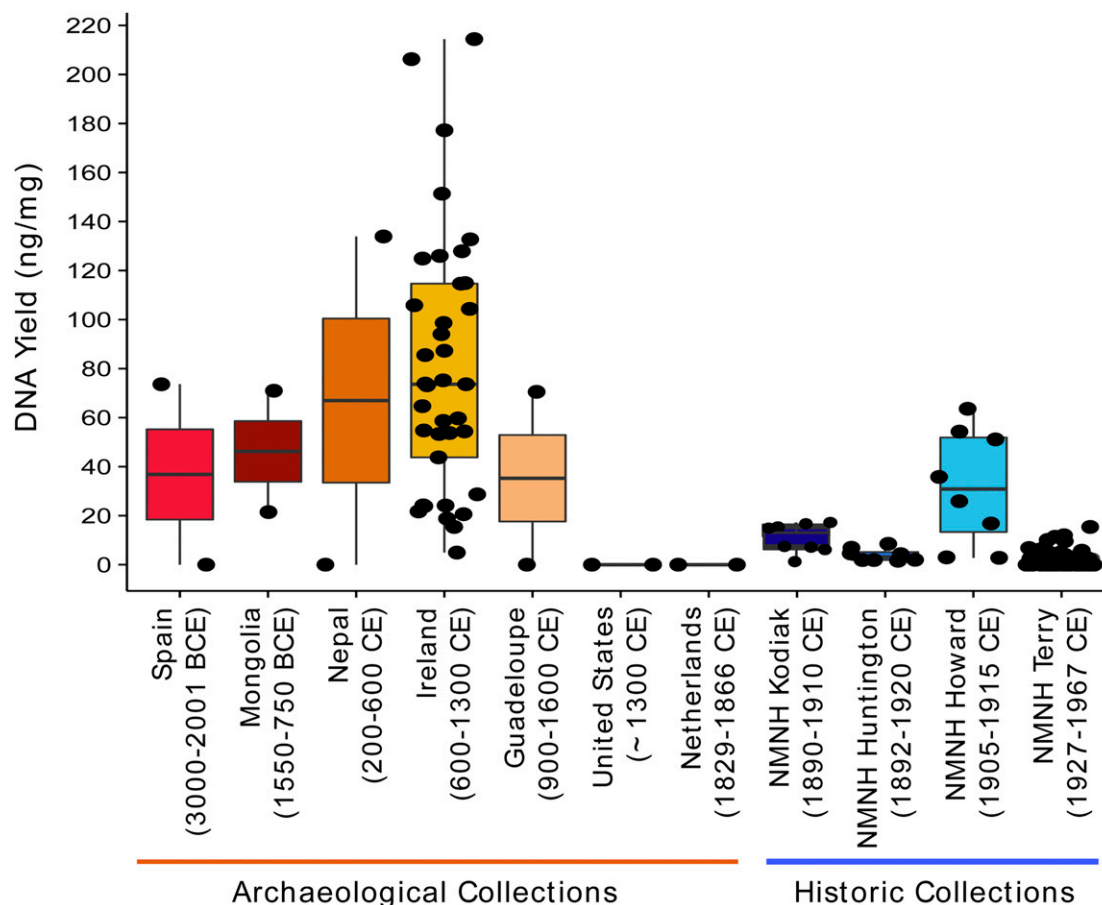


Fig. 2. The graph shows variation in calculus preservation by collection, illustrating DNA yields (nanograms per milligrams) for four 19th- to 20th-century NMNH anatomical collections and archaeological data (14) ranging from 3,000 BCE to the 19th century CE. All DNA samples were extracted with a widely used ancient DNA protocol (16) and quantified using a Qubit fluorometer. The DNA yields for archaeological collections were generally high with a more varied range of values whereas three of the four historic NMNH anatomical collections have consistently low amounts of DNA.

29 collections, highlights the disparate substrate availability within collections. Among 2,793 individuals, only about 11% have at least 5 mg of preserved dental calculus. Postmortem loss of calculus, due to intentional curatorial cleaning or accidental damage, was evident in roughly 50% of assessed individuals ($n = 1,552$). However, about 92% of individuals with calculus also have at least one intact petrous bone. Factors such as substrate availability and postmortem treatment are important to consider during study design, particularly for population-level investigations because collections may not contain sufficient dental calculus, petrous bone, or another substrate for representative analyses.

Moreover, knowledge about the curatorial conditions of collections, as well as historic and modern collection conservation practices (e.g., use of arsenic, glue, shellac, and pesticides) is important for assessing substrate-specific biomolecular yields and for interpreting the resulting data. Although dental calculus has proven to be a reservoir rich in endogenous human, microbial, pathogen, and dietary biomolecules, our analyses have shown considerable variation in DNA preservation between archaeological (14) and NMNH anatomical collections (Fig. 2). The latter collections are

more recent than the former (i.e., 100 versus several thousands of years old), yet yielded very low quantities of DNA, which may be because of postmortem preparation techniques, such as heat and chemical maceration with boiling water and benzene vapors.

As more is learned about factors of ancient DNA decay (15), it's becoming increasingly evident that assumptions should not be made about biomolecule preservation based solely on the age of remains or their provenience. Because the treatment of remains can cause unexpected taphonomic variation in ancient biomolecules, successful molecular recovery from one anatomical and/or archaeological locality does not guarantee comparable success from another. For this reason, researchers may encounter hurdles in obtaining approval for the destructive sampling of collections for which biomolecular preservation is unknown.

In the Department of Anthropology at NMNH, decisions about destructive sampling are based, in part, on the likelihood that the proposed analytical methods will yield the intended results and gain the most possible information from sampled collections. To safeguard these collections for studies in the near or distant future—when improved techniques may be

available—the destructive-sampling committee may approve a pilot test on a small subset of a larger request. The idea is to garner proof that biomolecular preservation is suitable for the proposed research before more extensive sampling can proceed.

Data Dissemination and Retention

A high likelihood of receiving analytical results from the requestor is a common criterion for destructive-sampling approval. Most museums have longstanding policies that require copies of documentation and publications from destructive sampling be kept as permanent records. However, many museums have yet to join with academic institutions, funding bodies, and scientific journals in adopting policies for proactive data archiving, maintenance, and sharing.

There is particular interest in paleogenomic data sharing for empirical investigations because of high experimental reliability and reproducibility standards (9) and museums have the ability to implement policies supporting the open science movement. For sampling requests to analyze nucleic acids (DNA, RNA, and epigenetic markers) from anthropological collections, NMNH has recently introduced requirements about the subsequent accessibility of raw data to ensure complete replicability of research and stable, open access to data deriving from collections. Requestors must now submit a Data Management Plan with their proposal that includes a specific strategy and timeline of data collection, management, backup, and release to field-standard genomic data repositories (https://naturalhistory.si.edu/sites/default/files/media/file/Anthro-SamplingPoliciesProcedures_0.pdf).

Like many institutions and organizations, museums are keen to adapt to changes in science and society. With respect to anthropological collections, museums everywhere face challenges to balance scientific interests, descendant concerns, and the need to preserve collections for future generations. Biomolecular techniques offer new avenues to understand the past, and curating specifically for biomolecules can increase their research applicability and continuing relevance. Although museums may differ in their views and policies toward destructive sampling, active discussion and consultation with stakeholders continue to be critical for preserving collections and developing innovative research partnerships. Museum collections are unique resources, and adjustments to these policies promise the sort of scientific and social benefits that only museums can provide.

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