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Open-access bioarchaeology resources for the Eastern Mediterranean and Middle East (EMME)

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Abstract: *Bioarchaeological data can provide long-term perspectives on humans' complex biosocial nature and interactions with their environments; this includes, among others, issues of animal exploitation, landscape transformation, agricultural practices, and human responses to socio-political and environmental changes. Such perspectives require multi-scalar studies that span different temporal and spatial contexts; however, the majority of relevant research in the Eastern Mediterranean and Middle East (EMME) focuses on case studies, with fewer large-scale comparative analyses and meta-analyses. In recent years, multiple open-access databases and tools have been developed to promote bioarchaeological research at broader spatial and analytical scales in the Eastern Mediterranean and Middle East (EMME) region. These resources include Bi(bli)oArch, an open-access bibliographic database for human bioarchaeological studies from the EMME, and SrIsoMed, an open-access database of published strontium isotopic values across the Mediterranean. In addition, following the Bi(bli)oArch model, ZooBi(bli)oArch and PlantBi(bli)oArch have been established as bibliographic databases for zooarchaeological and archaeobotanical studies in the EMME. More recently, MetaBioarch has been introduced as a database compiling published osteoarchaeological, zooarchaeological, and archaeobotanical data from Hellenistic and Roman contexts in the Central and Eastern Mediterranean, supporting large-scale comparative studies and meta-analyses. To promote standardized data recording and facilitate data sharing, STARC OSTEOARCH was created as a tool for human skeletal data collection. Given the centrality of skeletal sex and age-at-death estimation in human skeletal analyses, AgeEst and Sex-Est were developed as open-access web applications employing machine learning approaches. A separate set of resources was also produced to encourage optimal methodologies and best practices in archaeological science across various sub-fields, particularly in relation to the excavation and analysis of human skeletal remains. In addition, freely available educational guides, such as Archaeological Science Classroom Activities and Bare Bones: Our ancestors' bones have a lot to say, were produced to promote archaeological sciences to the general public.*

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Introduction

This paper provides an overview of open-access resources in bioarchaeology, with a focus on their potential benefits, functionalities, and future directions. All of the resources discussed are fully developed, published, and openly accessible online, including *Bi(bli)oArch*, *SrIsoMed*, *AgeEst*, *SexEst*, *STARC OSTEOARCH*, *ZooBi(bli)oArch*, *PlantBi(bli)oArch*, and *MetaBioarch*. In addition, a series of free-to-download guidebooks are available to access; these include basic guidelines for the excavation and study of human skeletal remains, the analysis of commingled human skeletal remains, the study of burned human skeletal remains, the use of statistics using the R programming language, and the use of best practices when sampling archaeological finds for laboratory analysis. Finally, open-access public outreach resources are also available and include two books: *Archaeological Science Classroom Activities* and *Bare Bones: Our ancestors' bones have a lot to say*.

Bioarchaeology is the study of organic materials retrieved from archaeological sites. It is a multidisciplinary field that integrates archaeological, biological, and social data to reconstruct past lifeways, human-environment interactions, and social practices (Baker & Agarwal 2017). Bioarchaeology encompasses human osteoarchaeology, zooarchaeology, and archaeobotany. Human osteoarchaeology is the contextual analysis of past human remains and may shed light on the impact of diverse biological, environmental, socio-political, historical, and physical forces on recent human evolution (Baker & Agarwal 2017). Zooarchaeology explores the relationships between humans, animals and the (natural and socio-political) environment (Davis 1987). Archaeobotany is the study of plant remains from archaeological sites, and it plays an essential role in reconstructing past human-environmental interactions, including past vegetation and land-use practices, the domestication of plants and the spread of agriculture (Fuller & Lucas, 2020). As such, bioarchaeology provides a unique perspective on long-term issues such as environmental adaptability/plasticity, food security, migration, health and disease, and cultural identity (Buikstra et al. 2022). The Eastern Mediterranean and Middle East (EMME) region, located at the intersection of three continents, presents a rich and complex socio-biological context for bioarchaeological research. Hereby, the EMME region is defined based on modern-day national borders, acknowledging that these borders had little meaning in ancient times. Greece and Libya are the westernmost countries, followed by Turkey, Cyprus, and Egypt, while Iraq and Iran are the easternmost countries. The term Levant has been adopted to jointly denote countries along the Levantine coast and Jordan, while

Arabian Peninsula has been used to capture Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates, and Yemen.

Bioarchaeology in many regions of the EMME has largely kept pace with methodological and conceptual developments in Western Europe and North America, and it has made substantial contributions to the understanding of life in past human communities, elucidating aspects of activity (Karligkioti et al. 2023), demography (Karligkioti et al. 2022), diet (Mardini et al. 2023a; Vergidou et al. 2021), disease (Kharobi et al. 2021; Lorentz et al. 2021), mobility (Maaranen et al. 2021; Mardini et al. 2023b), ecological conditions (Cecilia Western 1971), agricultural practices (Maltas et al. 2022; Margaritis et al. 2021), animal management (Filioglou & Çakırlar 2023), husbandry practices (Hadjikoumis 2021), domestication (Zeder 2012), and ritual practices (Henkel & Margaritis 2022). However, in certain regions, such as the Levant, research only very recently started adopting a more holistic bioarchaeological model that integrates diverse biological parameters (e.g. demography, diet, disease, mobility, etc.) with archaeological and historical evidence, as well as social theory. Reviews by Sheridan (2017) and Perry (2012) on the state of research in the Levant underscore the serious limitations in this region and highlight key future directions. Nonetheless, few studies in the EMME have addressed pressing issues of the past with contemporary implications, such as climate change, or adopted explicitly theoretical approaches that acknowledge the complexity of past identities (e.g. intersectionality) (see review in Mardini & Nikita 2023).

The interpretation of bioarchaeological data in the EMME but also globally faces several challenges including issues related to data quality, sample sizes, preservation biases, and ethical considerations (Castillo 2019; Peres 2010). The growth of bioarchaeological research has led to a proliferation of datasets that are often dispersed, incomplete, or inaccessible, limiting their potential to contribute to broader synthetic analyses, understand large-scale archaeological transformations, or inform policy. To address these challenges, the use of open-access databases and other resources has emerged as a promising strategy to enhance the visibility, quality, and impact of bioarchaeological research, promote the reproducibility and transparency of research, encourage interdisciplinary collaborations, and foster community engagement and public outreach (Bailey 2006).

Facilitation of meta-analyses and syntheses of research findings

Integrating and synthesizing research findings through meta-analyses is integral to contemporary academic discourse, particularly in the field of bioarchaeology, where it enables a holistic and nuanced approach to understanding past human behavior.

Such approaches enable researchers to identify patterns that may not be apparent in individual case studies but also highlight areas that require further investigation. Some examples of such larger-scale studies in human bioarchaeology, zooarchaeology and archaeobotany are given below to illustrate better these points.

In terms of human bioarchaeology, there is a scarcity of data syntheses and meta-analyses, which is an important limitation in the field. Leppard et al. (2021), Müller and Hussein (2017), and Setzer (2014) have, however, demonstrated the potential of this approach, while addressing different research questions. Leppard et al. (2021) conducted the first meta-analysis of radiogenic isotope data from archaeological populations in the Mediterranean, concluding that the long-term cultural and behavioral changes in the Mediterranean were not primarily driven by high levels of human mobility and migration, as previously assumed (but see Perry et al. 2022 for a criticism of the methods adopted). Müller and Hussein (2017) collected and analyzed data on dental diseases in European populations over several hundred years, and found that the mean frequencies of caries and tooth loss increased since the 18th century, likely due to changes in nutrition and dental health. Finally, Setzer (2014) conducted an integrative literature review to identify the current state of malaria research in human remains and identified novel methods to test for malaria infections in archaeological samples.

In what concerns zooarchaeological research, recently, three studies have highlighted the potential of large-scale synthetic work. Conolly et al. (2011) conducted a meta-analysis of animal bone records from 114 sites in Southwest Asia and Southeast Europe, demonstrating significant spatiotemporal variation in the transition from hunting to stock-keeping. Gaastra et al. (2020a) performed a meta-analysis of zooarchaeological data from the Chalcolithic to the Iron Age of the southern Levant and upper Mesopotamia to explore human responses to increased aridity. The expectation was that as aridity increased, animal production would decrease due to the lack of resources available for the animals. However, the results of the meta-analysis revealed a different pattern - animal production did not decrease as aridity increased, and in some cases, it actually increased. This finding is significant because it challenges the conventional understanding of how animal production was affected by changes in environmental conditions. It suggests that other factors, such as human management strategies, may have played a more important role in animal production than previously thought. Gaastra et al. (2020b) performed a meta-analysis of zooarchaeological data from the southern Levant to compare patterns of animal production, provisioning, and consumption between Early Bronze and Middle Bronze Age settlements. The study discovered distinct and regionally specific patterns in animal production and consumption between urban and rural sites, as well as a clear distinction between rural and urban zooarchaeological assemblages from the Early and Middle Bronze

Ages. The findings indicate that rural sites supplied larger fortified settlements, implying that these societies were organized at the state level. Finally, a paper by Slim and Çakırlar (2022) examined the impact of mobility and connectivity on pig husbandry practices during the Anatolian Iron Age, using zooarchaeological data from key sites and a meta-analysis of published data. The study shed light on how pig husbandry practices may have changed dynamically in response to evolving economic and socio-cultural circumstances during this period. The above studies show the potential of meta-analytic approaches for understanding the interactions between humans and animals in the past, especially in regions where diverse ecological, socio-cultural, and political factors have shaped these interactions over time.

Finally, synthetic archaeobotanical studies have shed light on environmental transformations, agricultural transitions, and plant use in different time periods. One such study by Colledge et al. (2004) explored agricultural transitions and the spread of farming during the Neolithic in southwestern Asia and southeastern Europe by analyzing archaeobotanical data from 40 aceramic Neolithic sites. They found that the compositional similarities of the crop package between the Levantine core, Cyprus, and Greece are indicative of both the routes of migration of early farming groups and the early agricultural practices of Europe's first farmers. Moreover, Fyfe et al. (2018) used pollen data from 105 fossil sequences to identify the common transitions from one vegetation grouping to another in the Mediterranean basin. They concluded that anthropogenic factors, such as land exploitation and transformation, played a significant role in shaping the vegetation communities in the region.

The open-access resources currently available for bioarchaeology hold significant promise because they can facilitate and stimulate similar large-scale studies in the EMME, a region that has experienced substantial ecological, socio-cultural, and political changes and has served as a melting pot for many civilizations throughout human history.

Open-access bioarchaeology resources

Bi(bli)oArch

The open-access *Bi(bli)oArch* database covers published works on human skeletal remains in the Eastern Mediterranean and Middle East (EMME) region, ranging from prehistory to early modern times (**Figure 1**). The EMME region is geographically unique and has undergone significant cultural and societal changes throughout history. Human bioarchaeology has been instrumental in studying human adaptation and evolution in this region, but accessing the vast amount of published literature has been challenging for scholars. Many papers have been published in national archaeology journals, excavation monographs, 'grey' literature, technical reports, internal re-

ports, research bulletins, project reports, or graduate theses, often in languages other than English. To address this limitation, *Bi(bli)oArch* was created as an open-access bibliographic database for human bioarchaeological studies from the EMME region (Nikita et al. 2021a). The database currently contains over 3,500 titles and abstracts, including translated titles and abstracts for studies published in languages other than English. All entries are organized per theme: Activity, Ancient DNA, Biodistance, Demography, Diet, Isotopes, Metrics, Mobility, Nonmetrics, Pathology, Stature, and Taphonomy. *Bi(bli)oArch* allows scholars to filter papers by region, theme, and year of publication, making human bioarchaeology papers and reports more easily accessible, with the aspiration to promote bioarchaeological research in the EMME.

The *Bi(bli)oArch* website originally included published works on human skeletal data up to the end of 2021 (Nikita et al. 2021a). Since then, bioarchaeological studies associated with the EMME region from the leading international journals in bioarchaeology, physical anthropology, archaeological science, anthropological archaeology, and palaeopathology have been systematically compiled. These journals include *Archaeometry*, *American Journal of Physical Anthropology* (now *American Journal of Biological Anthropology*), *Bioarchaeology International*, *Bioarchaeology of the Near East*, *Journal of Anthropological Archaeology*, *International Journal of Osteoarchaeology*, *International Journal of Paleopathology*, *Journal of Archaeological Science*, *Journal of Archaeological Science: Reports*, and *Mediterranean Archaeology and Archaeometry*. All information on the recent update is given in **Supplement 1**, while any data prior to 2021 can be accessed through the online database.

With regard to the geographic distribution of the publications from 2021 – March 2023, the Levant and Greece are the most systematically examined regions from a bioarchaeological perspective with 22 and 18 publications respectively, followed by Turkey (10 publications), Egypt (9 articles) and Cyprus (7 publications), then Iran (5 publications). The Arabian Peninsula and Iraq are the least studied regions with 1

Figure 1. Screenshot of the *Bi(bli)oArch* data page.

publication each. 51 articles have not been assigned to a region as they serve a more methodological approach.

The source code for the backend and frontend of the *Bi(bli)oArch* website is available as supplementary material (**Supplement 2**). This allows for transparency and reproducibility of the database, and enables interested parties to develop their own bioarchaeological databases with similar functionalities.

Although not part of the EMME, a similar bibliographic database for bioarchaeological studies from Italy, *Bi(bli)oArch-Italia*, has also been developed and is openly accessible (Caruso et al. 2022) (**Figure 2**). This database presently comprises 1,216 titles categorized by region, theme, and chronology. The database's search functionality makes it easy for scholars to find works on specific topics, such as mobility or disease in specific Italian regions and also for different archaeological time periods. Abstracts and titles published in Italian have been additionally translated into English. The database is particularly useful for scholars who are not aware of national Italian journals and sources as many relevant papers are published in them. The source code for the backend and frontend of the *Bi(bli)oArch-Italia* website is available in **Supplement 3**.

SrIsoMed

SrIsoMed is a repository of published $^{87}Sr/^{86}Sr$ values of organic and inorganic materials that originate from countries along the coastline of the Mediterranean Sea (Nikita et al. 2022). The database's aim is to advance palaeomobility and provenance studies in the Mediterranean region, which has been characterised historically by significant interconnectivity. Users can use the database through a variety of search options and an interactive map (**Figure 3**). *SrIsoMed* contains 11,436 $^{87}Sr/^{86}Sr$ values from 268 studies. Additionally to these values, it includes measurement errors, sample types, sample dates, and publication details. The sampling locations have been georeferenced using longitude-latitude coordinates. The database also includes lithological information for each sampling location, extracted from the Global Lithological Map.

Figure 2. Screenshot of the *Bi(bli)oArch-Italia* data page.

With the help of an interactive map feature, users can visualize the strontium isotopic data across different regions of the Mediterranean, while using different filtering options, making it easier to identify potential places of origin for 'nonlocal' individuals. All data presented in *SrIsoMed* can be downloaded in TSV format.

SrIsoMed is similar to other databases of isotopic values for different chemical elements or regions, such as *ARCHIPELAGO* (Fernandes et al. 2021), *dIANA* (Etu-Sihvola et al. 2019), *IBERLID* (de Madinabeitia et al. 2021), *IRHUM* (Willmes et al. 2014), and *GlobaLID* (Klein et al. 2022), and especially *IsoArcH* (Salesse et al. 2018). These databases highlight the increasing importance of isotopic data in archaeology and the need for larger repositories. The source code for the backend and frontend of the *SrIsoMed* website is available as supplementary material (**Supplement 4**).

AgeEst

AgeEst is a Python-based web application that employs machine-learning algorithms to estimate the age-at-death of human skeletal remains for bioarchaeological and forensic research purposes (Constantinou et al. 2023). To train the machine learning models for age-at-death prediction, an assemblage of 140 skeletons was used from the University of Athens Human Skeletal Reference Collection. *AgeEst* allows for the classification of unknown individuals into age groups (18–34 years, 35–50 years, and 51+ years), as well as the estimation of biological age based on pelvic and cranial changes. The app is user-friendly, with dropdown menus that correspond to different methods or combinations of methods for age prediction. *AgeEst*'s regression and classification

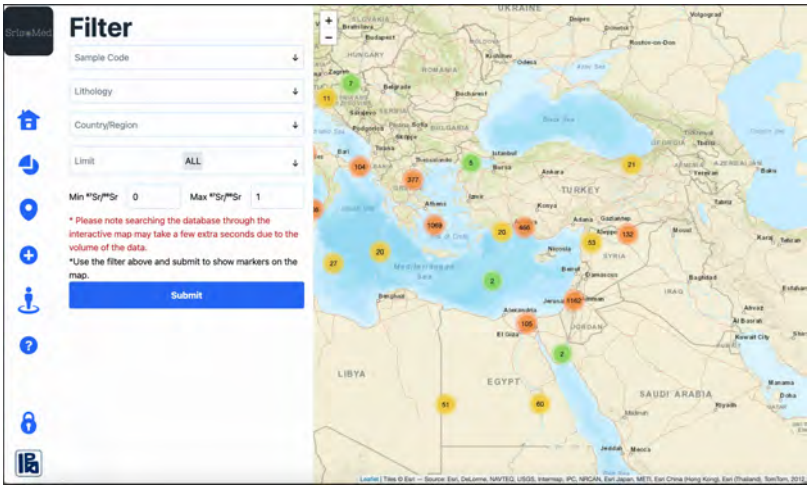

Figure 3. Screenshot of the *SrIsoMed* interactive map that enables users to filter and explore data.

models provide population-specific age-at-death estimates for Eastern Mediterranean populations, though their accuracy is not optimal. Importantly, the code for this application is open access so other scholars can expand it using different skeletal traits or skeletal assemblages, while the creators of *AgeEst* have invited scholars to contribute data from other population groups in order to refine further the training models (see Constantinou et al. 2023 for open-access source code). *AgeEst*'s development demonstrates the potential of machine learning methods in other areas of anthropology and archaeology, potentially encouraging new research avenues. This is due to the crucial role of age-at-death estimation in bioarchaeological research, as it provides valuable insights into mortality patterns, health, and demographic trends in past populations (Paine & Boldsen 2002).

SexEst

SexEst is a free web-based tool that utilizes machine learning classification algorithms to determine the biological sex of skeletal remains based on cranial and postcranial measurements (Constantinou & Nikita 2022) (**Figure 4**). Three machine learning classification algorithms, Linear Discriminant Analysis (LDA), Extreme Gradient Boosting (XGB), and Light Gradient Boosting (LGB), are employed. The machine learning classifiers were trained on the William W. Howells craniometric dataset and the Goldman postcranial dataset, which include thousands of individuals from various geographic locations and time periods (Auerbach & Ruff 2004, 2006; Howells 1973, 1989, 1995). *SexEst* is capable of generating a sex prediction even when a single variable is given, making it applicable to highly fragmented human skeletal remains or remains with incomplete measurements due to pathological or other alterations. Importantly, since the training dataset used in *SexEst* is largely based on

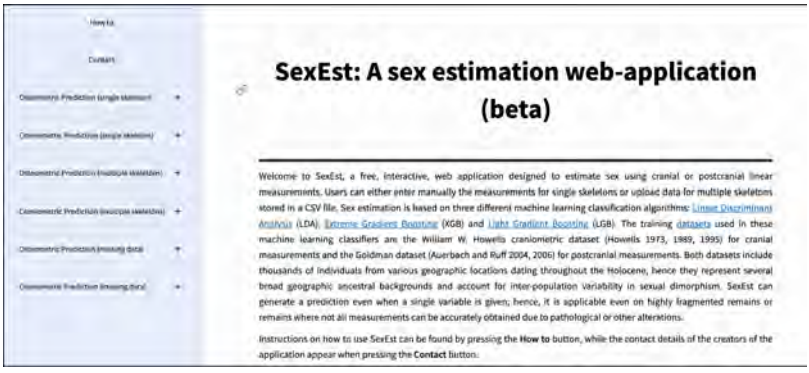

Figure 4. Screenshot of the *SexEst* homepage.

pre-industrialised populations, this tool is more appropriate for archaeological assemblages than modern forensic methods, as it partly accounts for secular change.

By addressing the limitations of traditional methods for sex estimation from skeletal remains, such as the skull and pelvis, which often lack a quantitative framework and population and time-period specificity (Spradley & Stull 2018), machine learning tools like *SexEst* offer a method for aiding archaeological investigations of ancient human groups.

STARC OSTEOARCH

STARC OSTEOARCH is an open-access resource designed to record macroscopic data on human skeletal remains from archaeological contexts (**Figure 5**). The tool is accessible online and is intended to improve standardized practices in human osteoarchaeology (Caruso et al. 2023). The project is built on the cloud-based platform Airtable, which enables easy data collection and organization. It consists of a master table, which provides general information on each skeleton or skeletal element/fragment. Additional tables contain information specific to individual bones or anatomical regions. This structure allows *STARC OSTEOARCH* to accommodate data on both individual skeletons and disassociated commingled elements. The database can be easily customized depending on each scholar's research questions and the preservation of each skeletal assemblage. One of the primary advantages of *STARC OSTEOARCH* is its standardized approach to data collection, where the macroscopic methods selected for data recording are widely used in the literature and are already familiar to most users, hence making any new data comparable to existing datasets. This ensures consistency across different projects and facilitates compatibility between

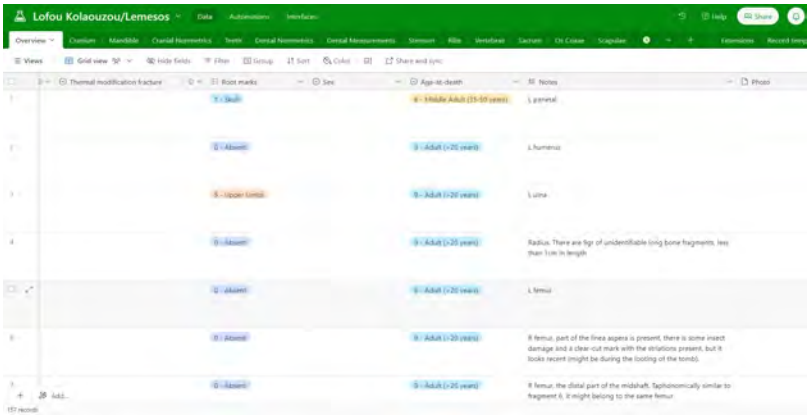

Figure 5. Sample screenshot of the *STARC OSTEOARCH* master table.

datasets. *STARC OSTEOARCH* allows different access options, with some users having full access to add, delete and edit data, and others having more limited roles. In this way, it facilitates collaboration during data collection. Finally, the raw data input can be easily downloaded and shared in different formats (e.g. TSV).

ZooBi(bli)oArch

ZooBi(bli)oArch is a bibliographic database focusing on faunal bioarchaeological studies in the Eastern Mediterranean and Middle East; it covers assemblages from prehistory to early modern times and is an extension of the *Bi(bli)oArch* initiative (**Figure 6**). *ZooBi(bli)oArch* offers a wide range of search criteria and filters, allowing users to refine their search based on specific topics, locations, chronologies, and more. This tool can be useful for the application of large-scale synthesis on topics exploring past human-animal interactions, subsistence strategies, and ecological shifts.

The project's interface is fully functional and accessible online. Data have been compiled to demonstrate publishing trends in the EMME region from the nine leading bioarchaeology journals publishing zooarchaeological research between 2010 and 2023. These journals include *Anthropozoologica*, *Archaeofauna*, *Bioarchaeology of the Near East*, *International Journal of Osteoarchaeology*, *Journal of Archaeological Science*, *Journal of Archaeological Science: Reports*, *Journal of Taphonomy*, *Mediterranean Archaeology and Archaeometry*, and *International Journal of Paleopathology*. The collected titles, DOIs, and abstracts of papers are available as supplementary material (**Supplement 5**).

The analysis of these titles reveals some key trends in the geographic distribution of zooarchaeological publications since 2010-2023. The Levant is the most extensively researched, with 35 publications, followed by Turkey with 26, Egypt with 25, and Greece with 24 publications. The Arabian Peninsula has 15 publications, meanwhile, Iraq, Iran, and Cyprus have the fewest publications, with 6, 5, and 2 publications, respectively. Additionally, 54 publications have not been assigned to a specific region

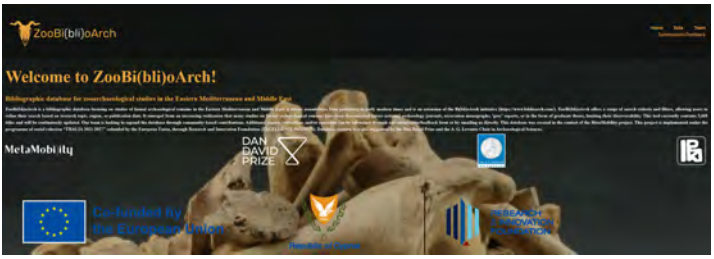

Figure 6. Screenshot of the *ZooBi(bli)oArch* home page.

as they either concentrate on methodological, ethnographic, and/or experimental approaches or they require further scrutiny to be assigned to a region.

MetaBioarch

MetaBioarch is an open-access database compiling published human osteoarchaeological, zooarchaeological, and archaeobotanical data from Hellenistic and Roman contexts in the Central and Eastern Mediterranean, with additional entries from the Balkans and the Middle East. For zooarchaeological and archaeobotanical studies, the database records the frequency of identified animal and plant taxa, while human osteoarchaeological entries include summary data on mechanical stress markers, physiological stress indicators, paleomobility proxies (including cranial and dental non-metric traits, metrics, and strontium and oxygen isotope data), and dental pathologies. *MetaBioarch* is designed to facilitate large-scale comparative research and meta-analyses aimed at improving understanding of mobility, economy, human-environment interactions, and broader socio-economic patterns in Hellenistic and Roman societies. The database is fully functional and allows users to explore the data through an interactive map and multiple filtering options (**Figure** 7).

PlantBi(bli)oArch

PlantBi(bli)oArch is an open-access bibliographic database of archaeobotanical studies conducted in the Central and Eastern Mediterranean and the Middle East, covering periods from prehistory to early modern times (Koullouros et al. 2025) (**Figure 8**). The database encompasses published works on all types of archaeobotanical remains, macroscopic and microscopic. *PlantBi(bli)oArch* aims to facilitate and promote research in archaeobotany in the Eastern Mediterranean and Middle East by making

Figure 7. Screenshot of *MetaBioarch* home page.

the field's bibliography more readily accessible to researchers; it currently contains 2,238 bibliographic records and is fully functional.

Free-to-download resources for bioarchaeological best practices

Present below is a series of guidebooks created to promote best practices in bioarchaeology, including excavation, laboratory analysis, and statistical analysis. These resources aim to aid researchers in the Eastern Mediterranean and Middle East (EMME) region by presenting practical advice and case studies, and facilitating the standardization of recording protocols.

Basic Guidelines for the Excavation and Study of Human Skeletal Remains serves as the inaugural volume in a series of guidelines (Nikita & Karligkioti 2019). The work provides an overview of essential aspects related to the excavation and macroscopic analysis of human skeletal remains recovered from archaeological sites. The guidebook is divided into two sections. The first section offers detailed procedures for the excavation of skeletal remains, providing guidelines for different contexts. The second section outlines the laboratory procedures following excavation, which includes preliminary steps, such as cleaning, and the osteological data collection process, which in turn provides information on the skeletal remains' sex, age-at-death, and stature, among other parameters.

Excavation and Study of Commingled Human Skeletal Remains represents the second volume in the series of guidebooks and focuses on human remains found in commingled contexts (Nikita et al. 2019). Commingled remains, defined as those discovered in contexts containing multiple individuals, can prove challenging to study. Commingling is a common occurrence in archaeological contexts, where bones from multiple individuals may be mixed together due to various factors such as natural processes or human activities (Adams & Byrd 2014). Despite these challenges, the

Figure 8. Screenshot of *PlantBi(bli)oArch* home page.

study of commingled remains offers valuable information regarding burial practices, treatment of the deceased, and the conditions of body deposition, while also providing evidence of social stratification and living conditions. *Excavation and Study of Commingled Human Skeletal Remains* provides a basic guide to various techniques for locating, recording, sorting, identifying, and reconstructing commingled skeletal elements.

The open-access book titled *An Introduction to the Study of Burned Human Skeletal Remains* constitutes the third installment in the above series of guides (Nikita 2021). Its principal objective is to provide insights into the information that can be extracted from human skeletal remains that have been subjected to thermal exposure. The book encompasses a range of considerations, including the recording of damage and alterations to bones resulting from fire, such as changes in color, shrinkage, fragmentation, warping, and microscopic structural and chemical changes. Additionally, it advises on the optimal methods for identifying the minimum number of individuals present within a given context.

Introduction to Statistics using R (for archaeologists) is a guidebook on applied statistics using the R programming language (Nikita 2020). The guidebook highlights the importance of statistical analysis for presenting data in a meaningful and broadly acceptable manner, making results re-evaluable by other scholars, and encouraging associations among researchers. The book focuses on applied statistics, providing the reader with an understanding of the kind of data being analyzed, the most appropriate test to use, the correct implementation of the test using R, and the proper interpretation of results. All examples are drawn from the archaeological sciences.

The latest installment *Field Sampling for Laboratory Analysis in Archaeology* aims at promoting better archaeological practices when sampling finds for laboratory analysis (Margaritis et al. 2023). The guidebook is part of STARC's strategy to develop the archaeological sciences in the Eastern Mediterranean and Middle East. This guide offers an overview of sampling practices and protocols, covering a range of materials including archaeobotany, starches, phytoliths, zooarchaeology, human osteoarchaeology, geoarchaeology, ceramics, ancient glass, lithics, archaeometallurgy, stable isotope analysis, ancient DNA, proteomics, micromorphology, and conservation science. The chapters are written by experts in their respective fields, providing guidelines on the sampling techniques and protocols used for laboratory analysis. The challenges and opportunities associated with each type of analysis are also addressed by the authors, who provide practical advice on how to overcome relevant difficulties. To researchers or practitioners interested in the application of natural and environmental science methods, this reference guide will help implement better research protocols in the archaeological sciences.

Multi-lingual guidebooks for the general public

The interdisciplinary nature of archaeological science allows it to provide a unique lens through which we can explore diverse aspects of our past and present. From investigating the geological origins of raw materials to analyzing the health and mobility of past individuals, archaeological science offers a broad range of topics that can engage students and educators alike. By integrating scientific techniques from fields such as biology, chemistry, geology, and physics, archaeological science offers a dynamic and immersive learning experience that can be customized to individual learners' interests and educational levels (Pollard et al. 2023). The insights gained from archaeological science can provide a basis for exploring and discussing human commonalities across multiple cultural, geographic, and temporal scales. With its ability to shed light on such a wide range of topics, archaeological science represents a particularly valuable pedagogical tool that can inspire students to think critically about the past while also engaging with pressing societal concerns of the present (Tehrani & Riede 2008). In this context, two pedagogical guidebooks that reflect the expertise of members of STARC have been produced in English, Greek, and Arabic to reach a wider audience.

The first is called *Archaeological Science Classroom Activities* and it has been designed primarily for elementary and junior high school students who are interested in learning about archaeological science methods (Nikita et al. 2021b) (**Figure 9**). The guide is divided into two broad fields: bioarchaeology and archaeological materials. Bioarchaeology focuses on the study of organic remains such as human and animal bones, and plant remains, while archaeological materials include ceramics, glass and metals. The activities are designed to be used with minimal preparation and extra required materials, making them easy to implement in a classroom setting. Each ac-

Figure 9. Cover page of *Archaeological science classroom activities*, available in the English, Greek, and Arabic.

tivity includes step-by-step instructions for implementation, as well as forms to be copied and distributed to the class. The guide engages students in hands-on activities, helping them develop an understanding of the various methods available for reconstructing the human past and how different disciplines can be used to elucidate ancient lifeways. The book also includes various activities, such as identifying animal tracks, learning how to estimate stature using multiple or single bones, and creating a replica of an ancient ceramic vessel using traditional techniques such as coil building or wheel throwing.

Bare Bones: Our ancestors' bones have a lot to say is an illustrated book that offers a glimpse into the fascinating world of osteoarchaeology (Nikita & Mardini 2022) (**Figure 10**). It explores the many ways in which human skeletal remains provide invaluable insights into the lives of our ancestors. The book is suited for school children whilst also providing educational value to a wider audience. It was designed to be visually appealing, with every concept and principle illustrated through graphics and images. No real images of skeletons have been used; instead, all bones have been illustrated, making it an ideal resource for public outreach. *Bare Bones* delves into topics such as the functions of the skeleton, age-at-death estimation, ancestry, diet, activity patterns, pathologies, and the work of osteoarchaeologists in the field and laboratory.

Conclusions and future directions

This paper provided an overview of the open-access resources developed for bioarchaeological research. While some of these resources have already been outlined in

Figure 10. Cover page of *Bare Bones: Our ancestors' bones have a lot to say* in English and Greek.

dedicated publications, the aim here was to present them all together to highlight their complementarity and reach a different audience from the Eastern Mediterranean and Middle East. The key objective behind the creation of *Bi(bli)oArch*, *ZooBi(bli)oArch* and *PlantBi(bli)oArch* was to make the rich bioarchaeological research in the EMME known to regional and international scholars so that they can assess what kind of data is available and could be synthesized in larger narratives and what gaps still exist. Given the major role that human mobility has played across the Mediterranean, *SrIsoMed* was developed to promote palaeomobility studies and to support the identification of potential places of origin of 'non-local' individuals, addressing issues of equifinality inherent in strontium isotopic analysis. *AgeEst* and *SexEst* focused on the estimation of key demographic parameters, age-at-death and sex, respectively, employing machine learning as a more computationally advanced approach compared to most currently available methods for the region. *AgeEst* is based on a modern Greek reference collection, which makes it potentially more appropriate for Eastern Mediterranean and Middle Eastern groups, while *SexEst* is based on a worldwide pre-industrial sample, which although not geographically-focused on the EMME, is potentially more appropriate than forensic samples. *STARC OSTEOARCH* is a tool that emerged in response to the difficulty of reusing published osteoarchaeological data in large-scale meta-analyses, due to methodological variety, insufficient reporting of analytical protocols, and limited sharing of raw data. The platform facilitates standardized data collection using established protocols, as well as straightforward export and sharing of primary datasets. *MetaBioarch* complements these initiatives by compiling published osteoarchaeological, zooarchaeological, and archaeobotanical data to promote large-scale comparative analyses of mobility, economy, and human-environment interactions in Hellenistic and Roman contexts across the Mediterranean. In addition, a series of guides addressing the excavation and study of human remains (including commingled and burned assemblages) as well as statistical analysis have been produced to promote standardization and best practices. Finally, recognizing the importance of public outreach and communication, two educational resources aimed at teachers, parents, and the general public have also been made available. The first, *Archaeological Science Classroom Activities*, proposes activities for human osteoarchaeology, zooarchaeology, archaeobotany, and archaeological materials, while the second, *Bare Bones*, is a science book on osteoarchaeology for children that highlights the different types of information regarding past life that can be extracted from human skeletal remains.

All source-codes are provided in **Supplements 2**, **3** and **4** and can be freely accessed on GitLab through the link: https://gitlab.com/ohmyshell. Any new developer can access the source code, modify it, and build the same database application. *AgeEst* and *SexEst* are also open-source web applications, thus again all code is open-access and

can be readily accessed and updated. These applications are hosted on The Cyprus Institute's server.

Looking towards the future, several potential directions and recommendations can be identified for advancing bioarchaeological research. One important area of focus is the continued updating and long-term maintenance of the resources discussed above. Second, to improve the functionality of bibliographic infrastructures, it may be beneficial to integrate multiple databases in order to provide a more comprehensive overview of the state of bioarchaeological research in the Eastern Mediterranean and Middle East (EMME). Finally, future developments may move beyond the provision of bibliographic information for past plant, human, and animal studies toward broader sharing of the primary data generated by these studies. Part of this effort for the Hellenistic and Roman period took place under the *MetaMobility* project. The databases were implemented under the programme of social cohesion "THALIA 2021–2027" co-funded by the European Union, through Research and Innovation Foundation (EXCELLENCE/0421/0376). As our understanding of the past and its relevance to the present and future continues to evolve, bioarchaeology will play an increasingly important role in shaping our knowledge of human history and development; hence, it is imperative to continuously develop resources that will facilitate and promote relevant research.

Resources

Bi(bli)oArch	https://www.biblioarch.com
Bi(bli)oArch-Italia	https://italia.biblioarch.com
SrIsoMed	https://srisomed.emmebioarch.com
AgeEst	http://ageest.hpcf.cyi.ac.cy
SexEst	http://sexest.cyi.ac.cy
STARC OSTEOARCH	https://airtable.com/appxKXYlY9QJrOFM6/shr4mDZga3uMFN35n/tblYaqDNF8RxmYJGc/viw00xmA11yxDf0e
ZooBi(bli)oArch	https://zoobiblioarch.emmebioarch.com
MetaBioarch	https://metabioarch.emmebioarch.com
PlantBi(bli)oArch	https://plantbiblioarch.emmebioarch.com

Basic Guidelines for the Excavation and Study of Human Skeletal Remains	https://zenodo.org/record/4641953
Excavation and Study of Commingled Human Skeletal Remains	https://zenodo.org/record/4641958
An Introduction to the Study of Burned Human Skeletal Remains	https://zenodo.org/record/4782968
Introduction to Statistics using R (for archaeologists)	https://zenodo.org/record/6990414
Field Sampling for Laboratory Analysis in Archaeology	https://zenodo.org/record/7730627
Archaeological Science Classroom Activities (English)	https://zenodo.org/record/4641959
Archaeological Science Classroom Activities (Greek)	https://zenodo.org/record/4641964
Archaeological Science Classroom Activities (Arabic)	https://zenodo.org/record/5515375
Bare Bones: Our ancestors' bones have a lot to say (English)	https://zenodo.org/record/6988455
Bare Bones: Our ancestors' bones have a lot to say (Greek)	https://zenodo.org/record/7393250

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