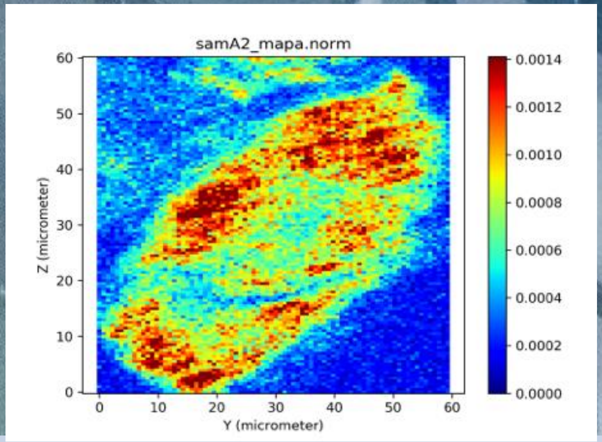
4 Dec 2024 @ Jordan Museum




# Answering key questions in Human Bioarchaeology with Synchrotron radiation enabled approaches at SESAME

Kirsi O. Lorentz,
BioMERA Platform & Science and Technology in Archaeology and Culture Research Center (STARC),
The Cyprus Institute (CyI)
k.lorentz@cyi.ac.cy

“For the first 15 years [of its use in archaeology], most application
essentially using SR to do something that could be done just a
with a conventional source. Many of these applications ... the
early years, simply used archaeological material as ... nusual
samples for analysis, simply to illustrate the p ... chnique. In fact,
the SR scientific community has courted th ... gical and cultural
heritage field very heavily over the ... partly, assuredly, from a
genuine conviction that SR has ... offer, but also, one suspects,
as a deliberate attempt to ... field of application of SR into the
politically sexy area o ... tage. The relative lack of success until
~2000 is a clear ... the lack of communication between the two
fields and s ... spite the best endeavors of both sides, without
the ge ... provided by good science in partnership with
me ... stions, little of value is achieved. Now that this
com ... cation has begun, we can anticipate a fruitful period of the
application of SR techniques in archaeology”.

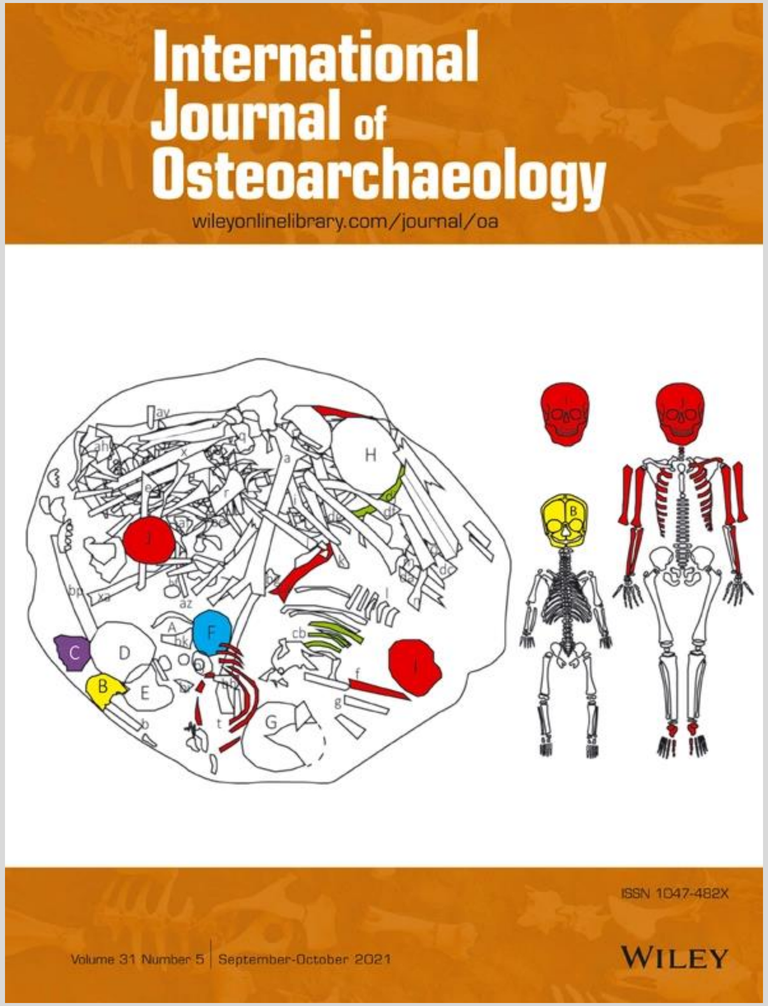
Where are we now, another 15 years later, with Cultural Heritage and SR? What about Human Bioarchaeology and SR?

*Mark Pollard (Oxford University), 2007*

(Human) Bioarchaeology is the study of human remains from archaeological contexts... The field emphasizes integrative, interdisciplinary analysis of the links between biology and culture in past societies. This approach has contributed to an informed understanding of the range of social, behavioral, and economic conditions and circumstances that have shaped the human experience – especially health and well-being, lifestyle, and quality of life – during the last 10,000 years of human evolutionary history.

*Clark Spencer Larsen*

Bioarchaeology: Definition. In: Smith C. (eds) Encyclopedia of Global Archaeology. Springer, New York (2014)




Lorentz et al. (2021) Disposed young: Nonadult element representation and bone positioning in complex mortuary programmes in Chalcolithic Cyprus

## Why should we/you care?

- SR use in Human Bioarchaeology, its history, challenges and potential highlight the need for
  - SR user community building
  - infrastructure development (feeder facilities; synchrotron beamlines)
  - regional and transnational collaboration
- UN sustainable development goals
  - synchrotron radiation enabled human bioarchaeology can afford us insights into many of the UN sustainable development goals, with a long historical/archaeological perspective
  - An example: Human metal use and metal exposure – past & present
    - Relevant UN sustainable development goals: 3 Good health and well being; 5 gender equality; 6 Clean water; 8 Decent work and economic growth; 9 Industry, innovation, and infrastructure; 10 reduced inequalities; 11 sustainable cities and communities; 12 Responsible consumption and production; 14 Life below water; 15 Life on land...
- ability to ask NEW research questions with real impact

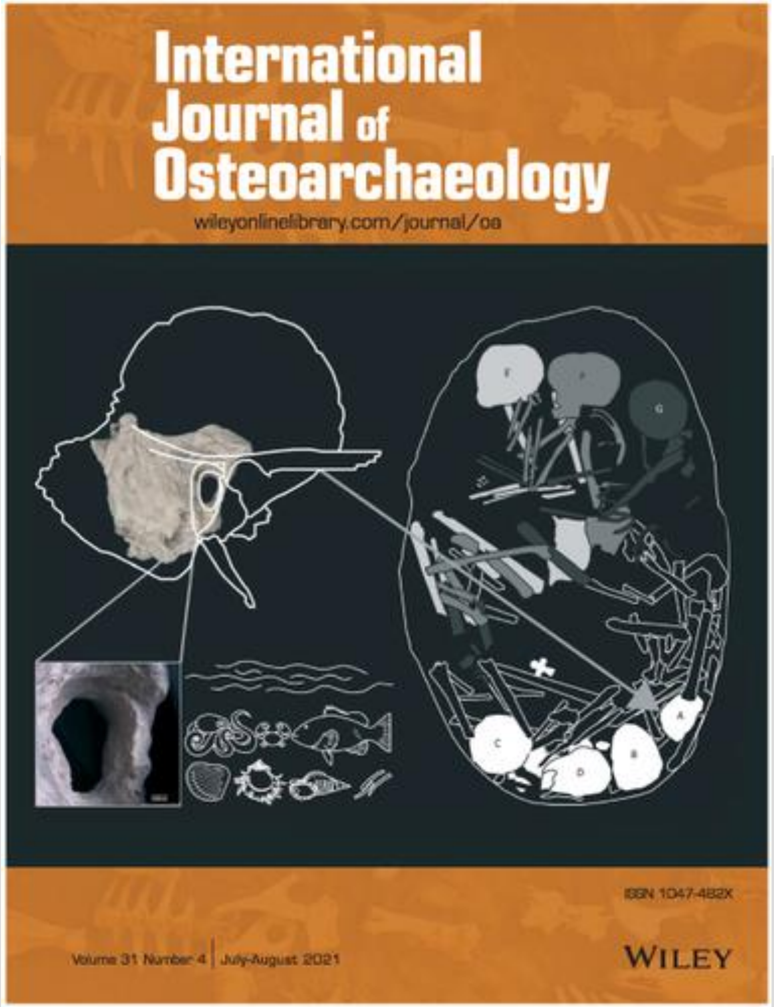

https://worldtop20.org/global-movement/

# OUTLINE

- Human Bioarchaeology: An introduction
- Advances: A brief history of Human Bioarchaeology and synchrotron radiation
  - Research questions
  - SR techniques
- Challenges: From excavation to laboratory to synchrotron
- Key questions in Human Bioarchaeology - Case studies in Human Bioarchaeology and SR: SESAME and ESRF
- Potential: Future prospects

# Human Bioarchaeology: An introduction

- study of human remains from archaeological sites
- lifestyle, health and disease, cultural practices, mortuary practices
- different scales of analysis:
  - population level
  - individual level: life histories (osteobiography)
  - tissue level
- our most direct avenue to access information on past people – our ancestors

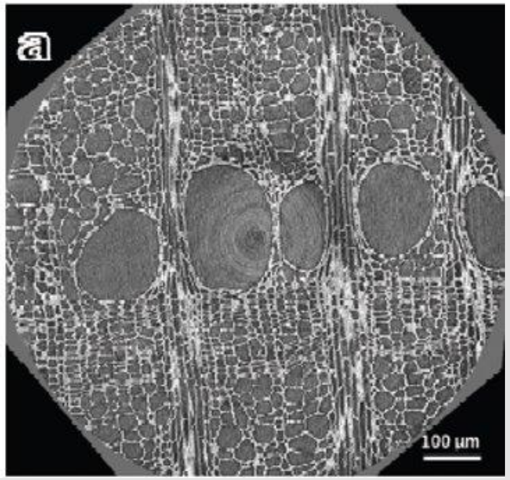



Lorentz & Casa B. (2021). External auditory exostoses, repetitive aquatic activity and increasing social complexity in Chalcolithic Cyprus: Specialists of the sea?

# (Bio)archaeological samples

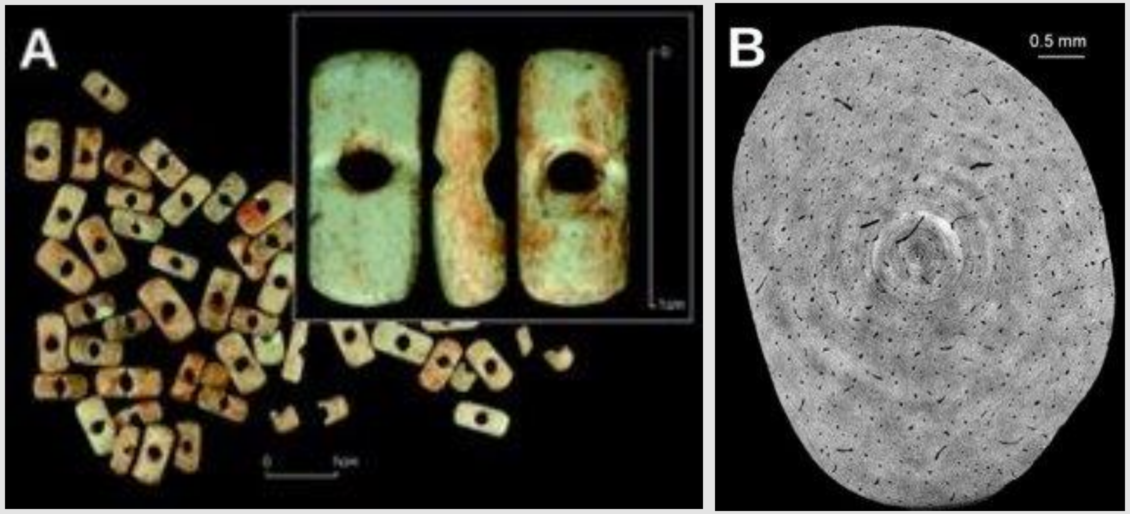
Any biological remains recovered archaeologically, e.g.:

- Animal remains
- Plant remains
- Human remains
- Organic materials/artefacts
- Other organic remains




Ancient wood (Hwang *et al.,* 2020)


Human remains (Lorentz et al., 2020)




Animal bone, antler (Vercoutère et al. 2011)

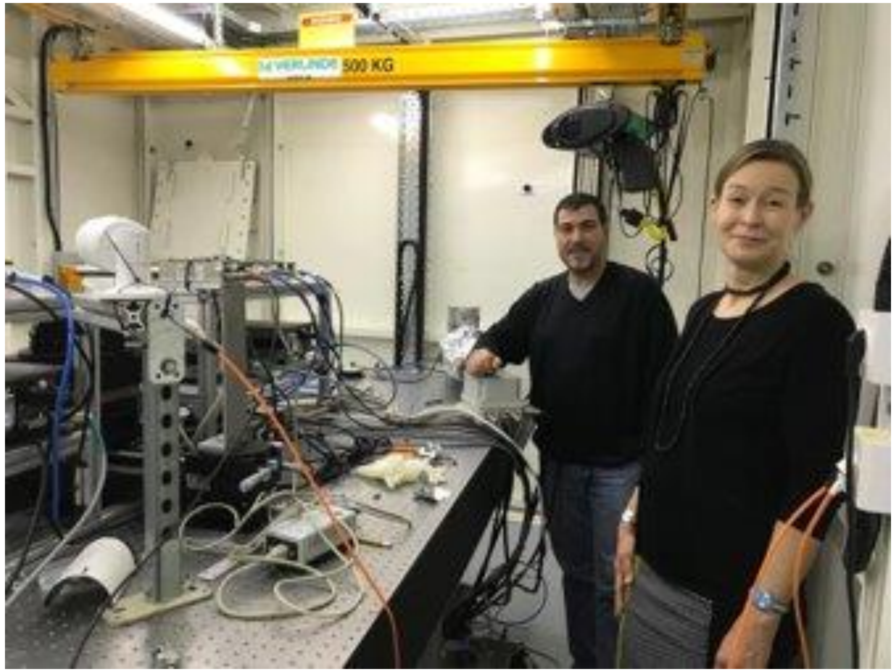
# Human Bioarchaeology and synchrotron radiation: a brief history

# 8 slides with unpublished data (removed)

SESAME

# SESAME has the core techniques for Human Bioarchaeology and CH applications

- IR (operational)
- XRF, XAFS (operational)
- SR-µCT (operational)




# SESAME: Synchrotron-Light for Experimental Science and Applications in the Middle East

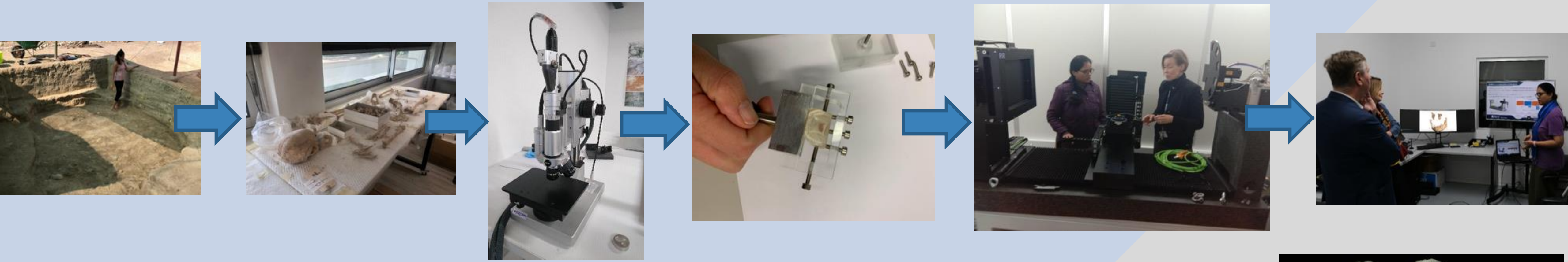
third-generation synchrotron light source that was officially opened in Allan (Jordan) on 16 May 2017

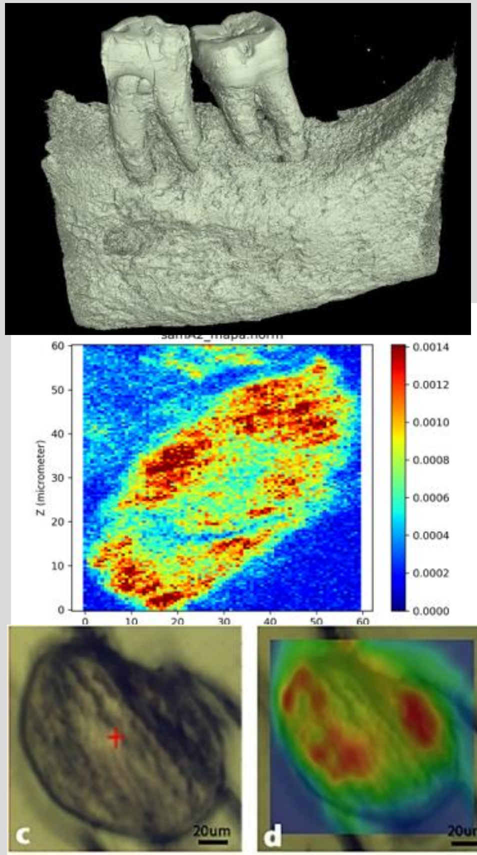
the first synchrotron light source in the Middle East and neighbouring countries; the region's first major international centre of excellence


SESAME

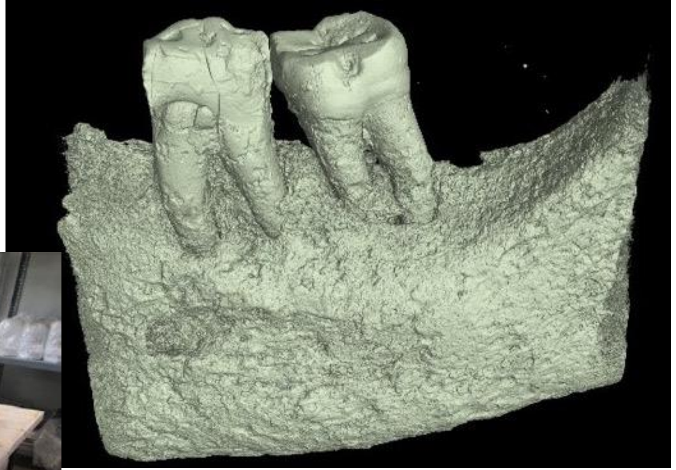
https://www.sesame.org.jo

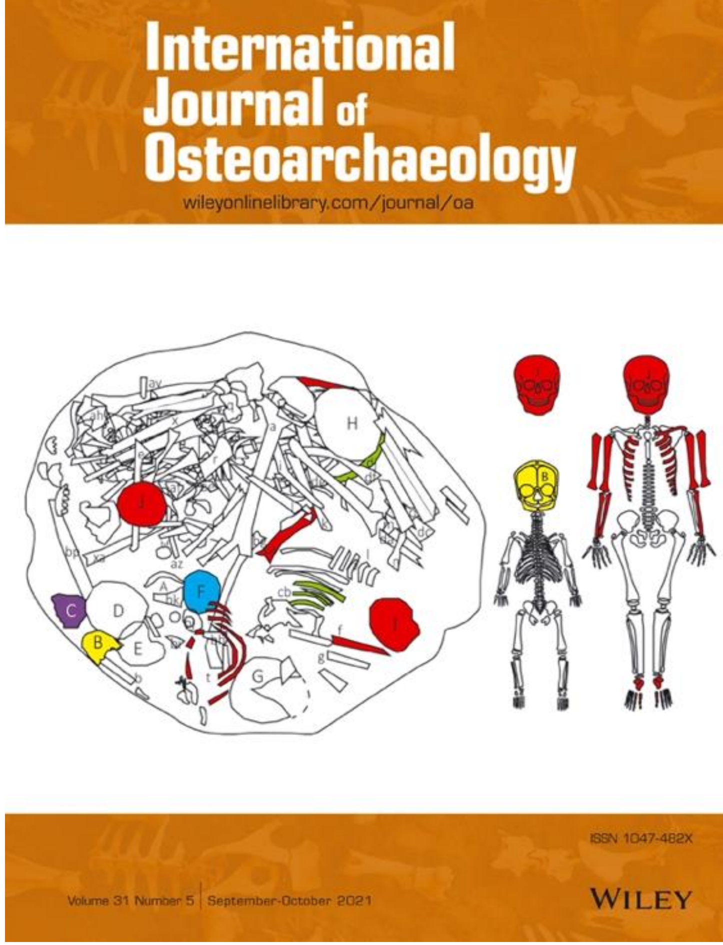
# 2 slides with unpublished data (removed)



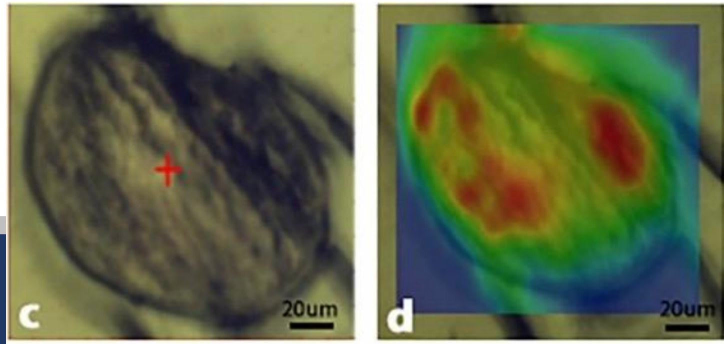



# Challenges: From excavation to laboratory to synchrotron






# The trajectory: from the soil via lab to synchrotron...?




**…but sometimes it is necessary to construct new facilities:**
***BioMERA Platform, Cyprus***

# Platform for Biosciences and Human Health in Cyprus: MicroCT and Synchrotron Radiation Enabled Analyses
## RIF: 1 milion Eur

https://biomera.cyi.ac.cy/

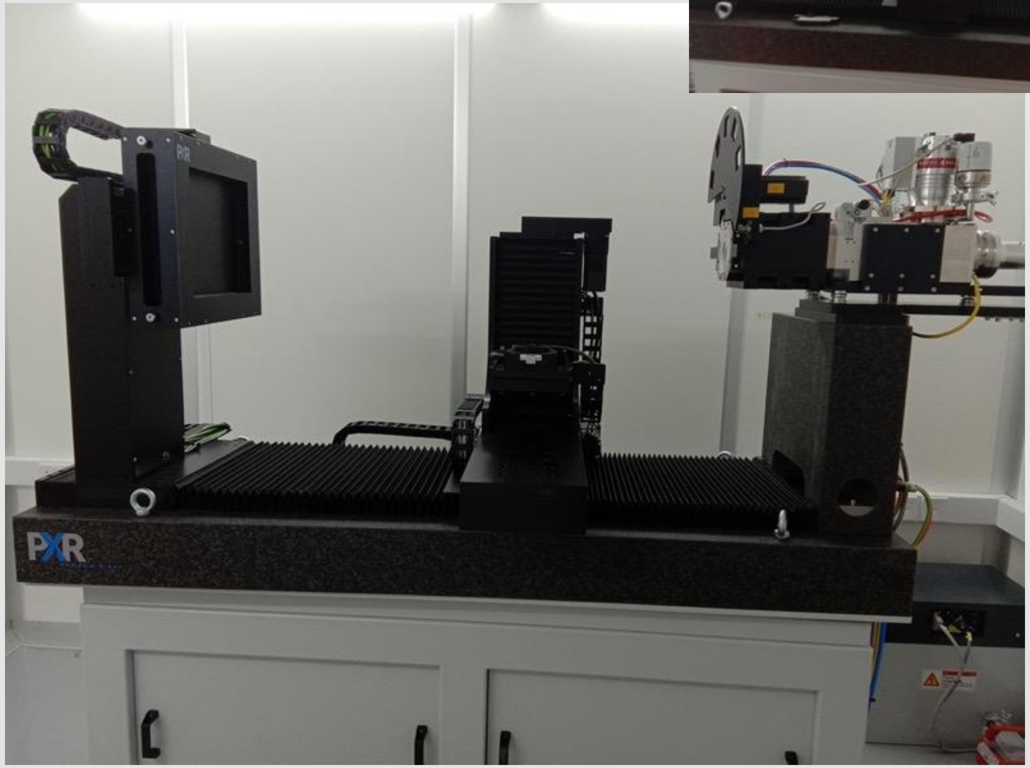
**PI: Kirsi O. Lorentz**, The Cyprus Institute






The Project INFRASTRUCTURES/1216/0009 is co-financed by the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation

- X-ray imaging system: 5 micron focal spot,  flat panel detector, 2 micron voxel size
- microCT data capture on any material samples: life science, material science, cultural heritage/archaeology, food industry...

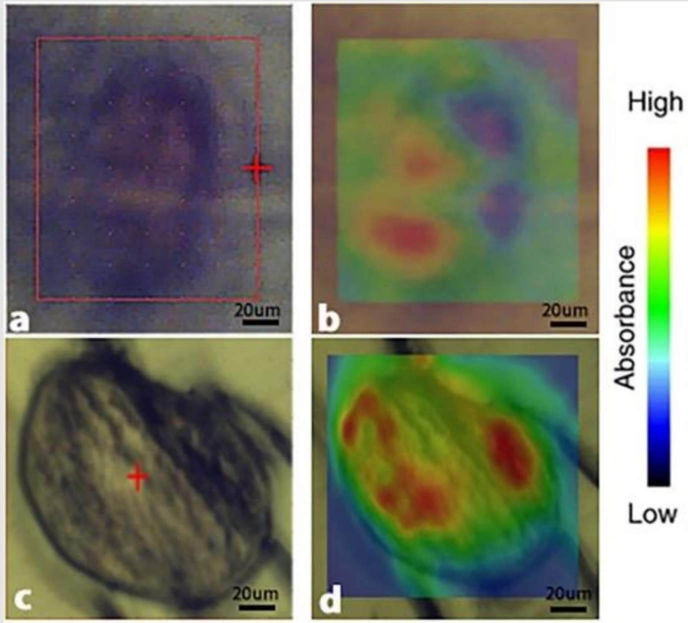



BioMERA microCT system

# Challenges

- Identifying the right approach
- Prior laboratory analyses – access to appropriate facilities
- Sample preparation
- Data analysis, incl. availability of specialised software; expertise
- Aquisition of an archaeologically representative number of data points (limited beamtime; 'quest for firsts and then its over?')
- Exploring frontiers together: pushing the limits of techniques whilst exploring and identifying new research questions enabled by new developments in SR techniques
- Heterogenous samples – correlated multimodal imaging

# Case studies in Human Bioarchaeology and SR: SESAME and ESRF





ELSEVIER

Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy

Volume 274, 5 June 2022, 121026

## Synchrotron Radiation Fourier Transform Infrared (SR-FTIR) spectroscopy in exploring ancient human hair from Roman period Juliopolis: Preservation status and alterations of organic compounds

K.O. Lorentz [a], G. Kamel [b, c], S.A.M. Lemmers [a], Y. Miyauchi [a, d], E. Çubukçu [e], A. Alpagut [f], A.M. Büyükkarakaya [g, h]

**K.O. Lorentz, G. Kamel, S.A.M. Lemmers, Y. Miyauchi, E. Cubukcu, A. Alpagut, A.M. Buyukkarakaya**

SESAME

## Research aim

- evaluate preservation status and alterations of organic compounds prior to putative destructive analyses (e.g. diet – stable isotopes, aDNA)
- alterations of organic compounds in archaeological human hair are caused by biological degradative processes dependent on multifactorial processes acting on the hair since the deposition of a body in a mortuary context

Lorentz et al. 2022; Büyükkarakaya et al. 2018

SESAME

- Human hair from archaeological contexts has high analytical value: diet, geographical origin, ancient DNA, metal exposure...

  ⇨ evaluation of preservation of organic compounds critical

**Material**

- Roman period human hair, M196 from Juliopolis (c. 2000 years BCE)

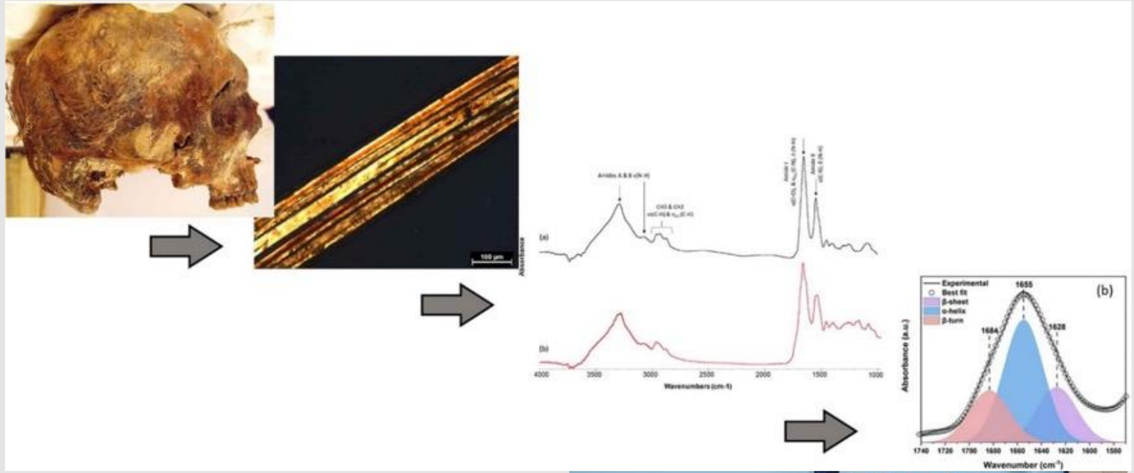
Büyükkarakaya et al. 2018, http://www.nallihan.gov.tr/juliopolis , https://ayder.com.tr/lokasyon/nallihan-juliopolis-antik-kent/650 http://anadoluatlasi.com/index.php/en/ana-sayfa/kayip-kent-juliopolis

## Method

- SR-FTIR microspectroscopy at the IR beamline, SESAME
- IR chemical mapping

## Experimental parameters

- infrared spectra acquired in transmission mode
- spectra recorded with a 32x Schwarzschild objective and a matching 32x condenser using a double path single masking aperture size of 20x20µm
- mid-infrared range 4000-650 $cm^{-1}$
- 4 $cm^{-1}$ spectral resolution
- 128 coadded scans using OMNIC Atlµs™ mapping software (Thermo Fisher Scientific©, USA)
- background spectra collected repeatedly to assess its spectral contribution
- acquired data analysed by Thermo OMNIC© software (Thermo Fisher Scientific©, USA)

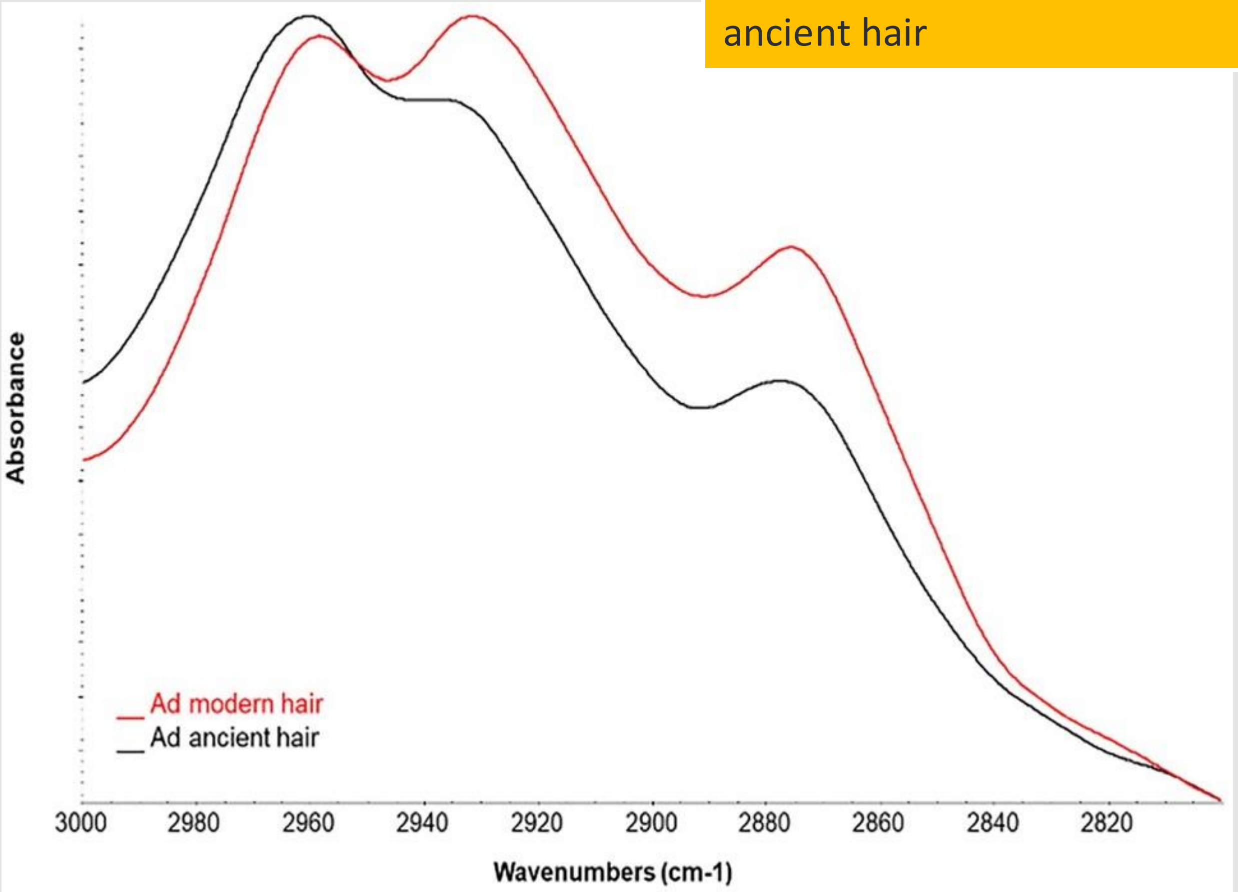


# SR-IR mapping of ancient human hair

Transmission IR spectra showing the typical features of lipids in the region (3000-2800$cm^{-1}$) for both the modern reference and ancient hair

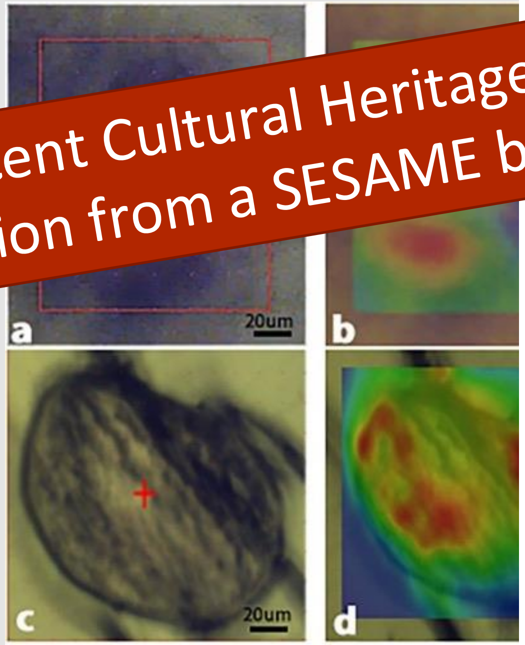
## Results

- keratin: more degraded in comparison to a modern reference sample
- clear potential for further analyses with techniques relying on organic compound preservation
  - e.g. diet, geographical origins, aDNA, metal exposure
- these data make significant contributions to the life history of the individual (osteobiography), as well as contribute towards key archaeological questions



SESAME

Most recent Cultural Heritage publication from a SESAME beamtime

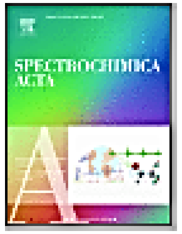



Optical (a, c) and FTIR (chemical) imagi
cross sections (sub-figures a, b) from Ju
a modern reference (sub-figures c, d).
The chemical maps are based on norma
corrected transmission infrared average
map and video images.

ELSEVIER

Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy

Volume 274, 5 June 2022, 121026



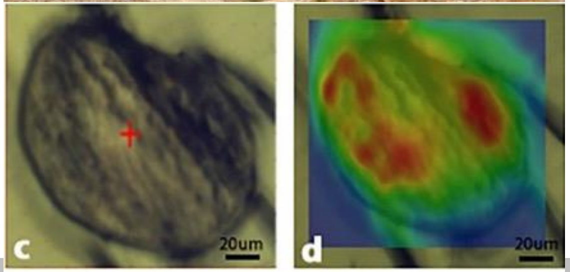

# Synchrotron Radiation Fourier Transform Infrared (SR-FTIR) spectroscopy in exploring ancient human hair from Roman period Juliopolis: Preservation status and alterations of organic compounds

K.O. Lorentz [a], G. Kamel [b, c], S.A.M. Lemmers [a], Y. Miyauchi [a, d], E. Çubukçu [e], A. Alpagut [f], A.M. Büyükkarakaya [g, h]

SESAME

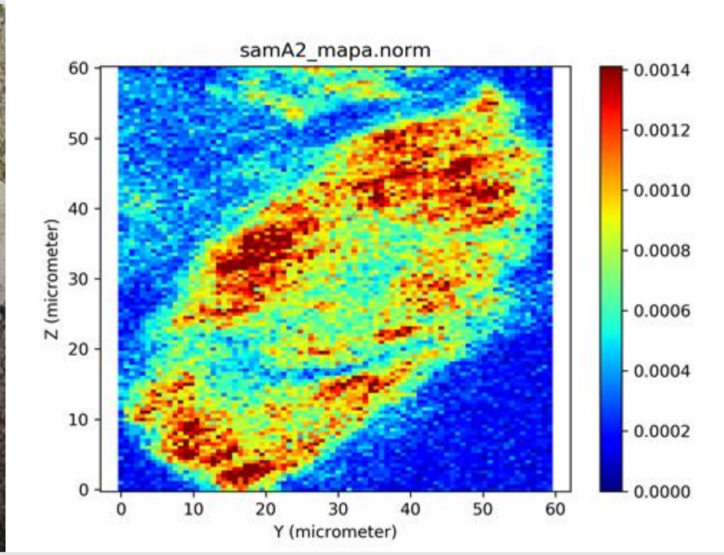
## Acknowledgements for Case Study 1:

KL acknowledges SESAME for the beamtime awarded (IR beamline, 20185110), and the Cyprus Institute, LAAAMP, SESAME, and CALYPSOplus project (under Grant Agreement 730872 from the EU Framework Programme for Research and Innovation HORIZON 2020) for travel funds to the SESAME synchrotron. The authors would like to acknowledge all SESAME staff, SESAME Council, SESAME sponsors and all SESAME supporters for making this research possible; those who conceptualised, nurtured, financed, built and first operated SESAME; and those who continue to do so. AMB acknowledges the Bioarchaeological and High-Tech Research on Skeletal Remains of Juliopolis project. The authors acknowledge the financial support of the project BioMERA: Platform for Biosciences and Human Health in Cyprus - MicroCT and Synchrotron Radiation Enabled Analyses, which is co-financed by the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation (grant no. INFRASTRUCTURES/1216/09).



# (II): Metals and health at 3rd millenium BCE Shahr-i Sokhta (Iran)
# Mapping metal element localisation in ancient hair, SR-XRF






Kirsi O. LORENTZ, Marine COTTE, Wout de NOLF, Grigoria IOANNOU, Mohammad Rajab ZARURI, Farzad FORUZANFAR, Mansur SAJJADI

# Metal element localisation in ancient hair


ESRF
The European Synchrotron


Journal of Archaeological Science 120 (2020) 105193

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas


ELSEVIER

Check for updates

## Synchrotron radiation micro X-Ray Fluorescence (SR-μXRF) elemental mapping of ancient hair: Metals and health at 3rd millennium BCE Shahr-i Sokhta, Iran


K.O. Lorentz [a,*], W. de Nolf [b], M. Cotte [b,c], G. Ioannou [a], F. Foruzanfar [d], M.R. Zaruri [e], S.M. S. Sajjadi [f]

[a] Science and Technology in Archaeology Research Center (STARC), The Cyprus Institute (CyI), Nicosia, Cyprus
[b] European Synchrotron Radiation Facility (ESRF), Grenoble, France
[c] Laboratory of Molecular and Structural Archaeology (LAMS), France
[d] Emeritus of ICAR (Iranian Center of Archaeological Research), Tehran, Iran
[e] RICCHT, Golestan Branch, Iran
[f] ICAR (Iranian Center of Archaeological Research), Tehran, Iran


atures, or compounds containing potentially toxic metal elements. The production and manufacturing of copper has an extensive history in South West Asia, and the Eastern Mediterranean. While we have written records of the detrimental effects to human health of some ancient mining practices, e.g. from the writings of Xenophon (434–359 BCE) and Lucretius (98–55 BCE) who noted that the smoke of lead mines in Attica was harmful to human health, and of Pliny who noted that 'exhalations

in particular, in ancient human hair, deriving from a 3rd millennium BCE site with contextual and artefactual evidence of intensive metal and craft work activities. Only a handful of studies using synchrotron radiation enabled approaches to ancient human hair have been undertaken to date (Bertrand et al., 2003; Kakoulli et al., 2014; Zvereva et al., 2017; a few historical period studies have also been conducted, by Chevallier et al., 2006; Bertrand et al., 2014), few of the studies on ancient hair


* Corresponding author. , Science and Technology in Archaeology and Culture Research Center (STARC), Athalassa Campus, 20 Konstantinou Kavafi St, 2121 Aglantzia, Cyprus; P.O.Box 27456, 1645 Nicosia, Cyprus.
E-mail address: k.o.lorentz@cyi.ac.cy (K.O. Lorentz).



https://doi.org/10.1016/j.jas.2020.105193
Received 17 May 2019; Received in revised form 30 May 2020; Accepted 16 June 2020
Available online 10 July 2020

# Key question in archaeology: Metal exploitation and health

- production and manufacturing of copper has an extensive history in South West Asia, and the Eastern Mediterranean
- written records on the detrimental effects to human health of some ancient mining practices
  - Xenophon (434–359 BCE), Lucretius (98–55 BCE)
    - smoke of lead mines in Attica was harmful to human health
  - Pliny
    - ‘exhalations from silver mines (i.e. galena mines) are dangerous to all animals’
- we have very little evidence as to human health in relation to e.g. copper mining and manufacturing during the prehistoric periods
- -> human remains as source of critical data answering a key archaeological question
- data acquisition on hair requires SR source

Reconstructed image of smelting site of Almas (c. 400BCE), Cyprus
©Cyprus Tourism Organisation

# Key archaeological question: Effects of intensive metal and craft work on human health?

- biogenetic versus diagenetic/environmental uptake of metals

- potential sources of exposure in the past:
  - legacy soil contamination (inhalation, ingestion)
  - contaminated food and water (ingestion)
  - pigments in crafts,
    cosmetics etc (absorption/ingestion/inhalation)

➢first study of biogenic versus diagenetic metal element localisation in ancient human hair at 1 µm resolution

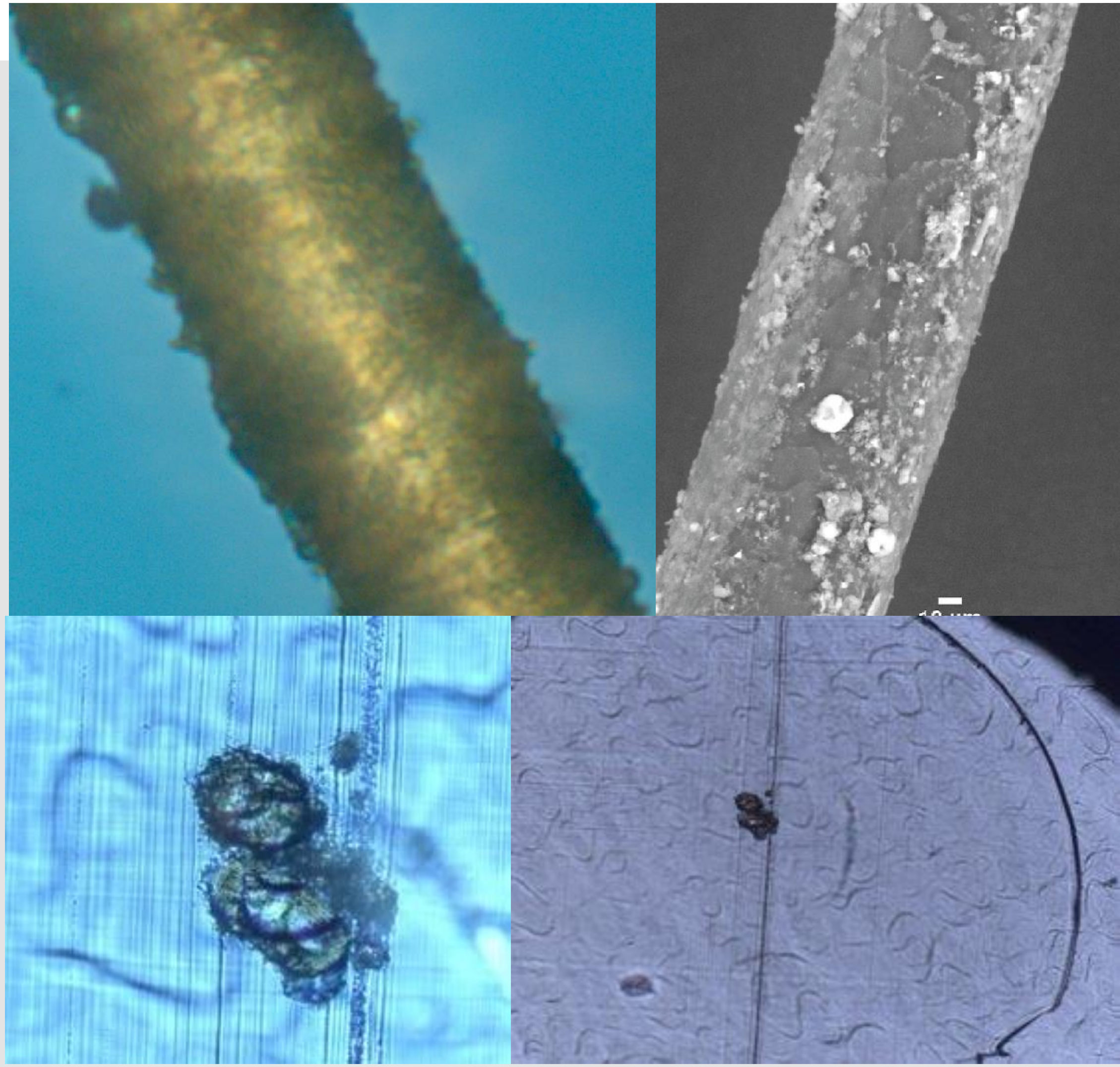
# Metal element localisation in ancient hair

**Materials:**

- ancient hair sections (10 µm) of eight individuals (n=8), as well as modern hair controls (n=2)
- from Shahr-i Sokhta, a 3rd millennium BCE large urban site with intensive metalwork and other craft work activities, along trade routes later known as Silk Route

**Methods:**

- scanning X-ray microscopy, optimized for 2D µXRF elemental maps ID21 at ESRF
- SEM, light microscopy



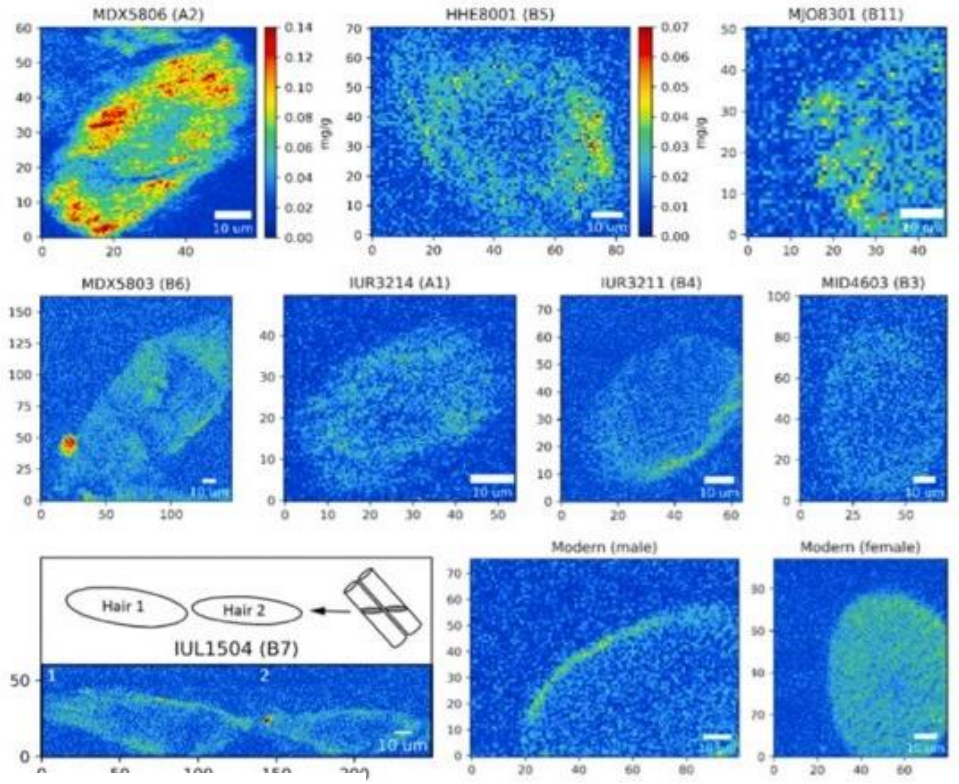
## Experimental parameters

- 31 SR-µXRF elemental maps obtained
- three to four different hair cross sections for each individual were mapped in order to confirm consistency of results
- elemental maps acquired at
  - 9.1keV (above Cu K-edge)
  - pixel size of 1µm
  - over ~100Å~100µm
  - dwell time of ~0.25s (= 45min/map)
  - elemental maps acquired at ID21 were analyzed using PyMCA software

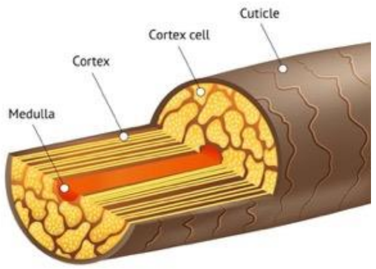
# Metal element localisation in ancient hair

## Results:

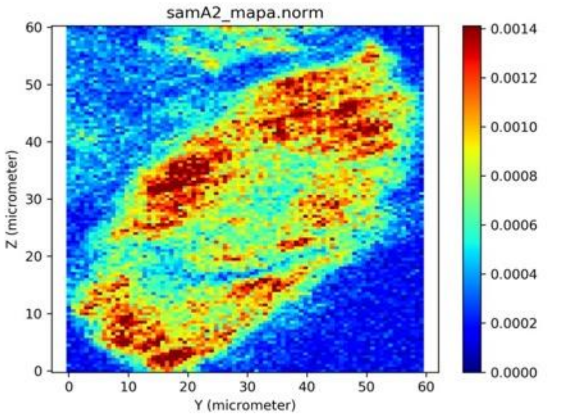
- significant differentiation in the levels and localisation of Cu
- hair of a young female (c. 18-20 years old at death; MDX5806) showed particularly elevated levels of Cu
- the normalised 2D elemental maps of hair cross sections of the eight individuals analysed show that the Cu values of MDX5806 are significantly higher than in the rest of the individuals
- the highest Cu values in MDX5806 are located within the cortex, rather than the cuticle and the medulla area
- other individuals buried nearby MDX5803 do not have values anywhere close to hers
- **the distribution of elevated levels of Cu, together with contextual data, points to biogenic, rather than diagenetic/environmental source for the uptake of Cu**




HAIR STRUCTURE




https://www.hairknowhow.com/know-your-hair-structure



## Broader implications

- elevated Cu levels localised in the cortex indicate exposure in life to Cu containing food, water, cosmetics or airborne substances with Cu
    - (legacy) soil contamination (e.g. due to mining and metal work or other craft work activities) and its effects on food and/or water?
    - engagement in craft or other activities exposing to ingestion or inhalation of Cu?
    - use of Cu containing substances in contact with or on the skin (craft pigments, cosmetics)?
    - any combination of the above?
    - this young female did something different from the others -> higher Cu exposure (specialisation?)

## Human metal exposure is a contemporary challenge

Critical health issues today:

- intensive metal and manufacturing work
- legacy soil contamination due to mining and manufacturing

- These affected individuals and populations since the invention of manufacturing processes involving high temperatures, or compounds containing potentially toxic metal elements

WHO website on lead exposure:
https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health

A child and a woman break rocks extracted from a cobalt mine at a copper quarry and cobalt pit in Lubumbashi, Democratic Republic of the Congo on May 23, 2016. (AFP)

# Acknowledgements for Case Study 2:

KL gratefully acknowledges the invitation to study the Shahr-i Sokhta human remains from the Director of the Shahr-i Sokhta excavations, which take place since 1997 by ICAR (Iranian Center for Archaeological Research), under the direction of Prof. S.M.S. Sajjadi. The Shahr-i Sokhta excavations are funded by ICAR. Further, KL gratefully acknowledges the close collaboration with Dr F. Foruzanfar, and all the members of the Shahr-i Sokhta team, as well as staff at ICAR. KL thanks B. Casa for improving the layout of the images. Funding for research travel enabling sample collection was received from Newcastle University SHS FRF while KL was Director of Wolfson Bioarchaeology Laboratory. Funding for two research residencies at ESRF (European Synchrotron Radiation Facility) enabling sample analyses was provided by two LAAAMP Grants, The Cyprus Institute, Erasmus, and ESRF, which KL and GI gratefully acknowledge. The authors acknowledge further financial support of the *Platform for Biosciences and Human Health in Cyprus: MicroCT and Synchrotron Radiation Enabled Analyses (BioMERA)* project, which is co-financed by the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation (grant no. INFRASTRUCTURES/1216/09).

*...and Hiram Castillo-Michel for showing his tricks for sample preparation and mounting*

ESRF
The European Synchrotron

# BioMERA microCT, EAE, with SXCT @ ESRF ID17

***Unpublished images removed***

EAEs are benign bony growths in the external auditory canal, formed following repetitive aquatic activity over 10 or more years.
Imaging parameters:
Energy=100 keV; Scan range =360, No. of projections= 2158

# Key archaeological question: aquatic resource procurement -> Broad spectrum revolution

International Journal of Paleopathology 30 (2020) 98–104

Contents lists available at ScienceDirect

International Journal of Paleopathology

journal homepage: www.elsevier.com/locate/ijpp

ELSEVIER

External auditory exostoses and early Neolithic aquatic resource procurement in Cyprus: Results from Cypro-PPNB Kissonerga-Mylouthkia in regional context

Kirsi O. Lorentz

*Science and Technology in Archaeology and Culture Research Center, The Cyprus Institute, Konstantinou Kavafi St, 2121, Aglantzia, Nicosia, Cyprus*

***Unpublished images removed***

## slide with unpublished data (removed)

# World's first proportionate dwarf: BioMERA microCT and SXCT at ESRF

ESRF
The European Synchrotron


International Journal of Paleopathology 33 (2021) 158–169

ELSEVIER

Contents lists available at ScienceDirect

International Journal of Paleopathology

journal homepage: www.elsevier.com/locate/ijpp



Check for updates

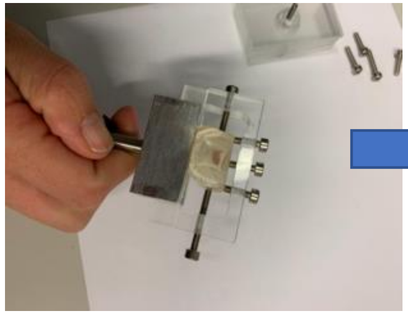
## Majewski/Microcephalic Osteodysplastic Primordial Dwarfism Type II (MOPDII) with generalised microdontia in the 4th millennium BCE Eastern Mediterranean

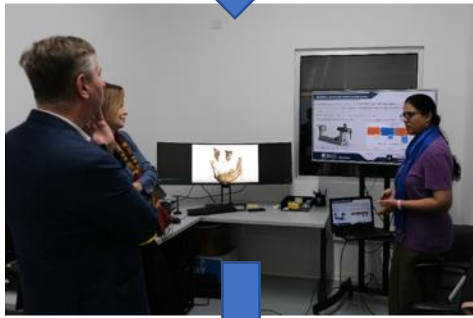

Kirsi O. Lorentz *, Natalie M. Branca, Simone A.M. Lemmers

*Science and Technology in Archaeology and Culture Research Center (STARC), The Cyprus Institute (CyI), Konstantinou Kavafi St, 2121, Aglantzia, Nicosia, Cyprus*

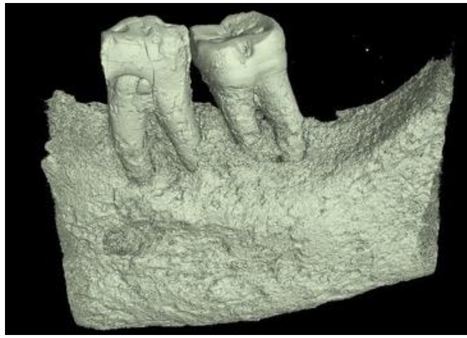

Lorentz et al. 2021

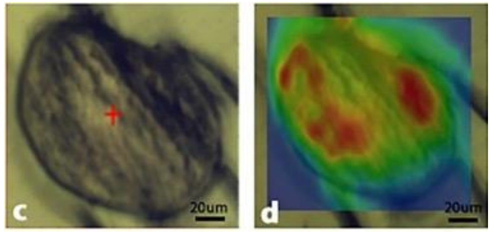
# Future prospects

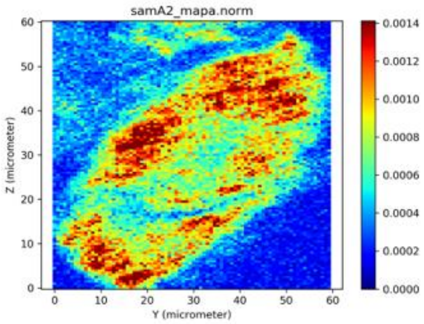




# Connecting the dots - or getting out of the comfort zone?
# From archaeological excavation to the synchrotron

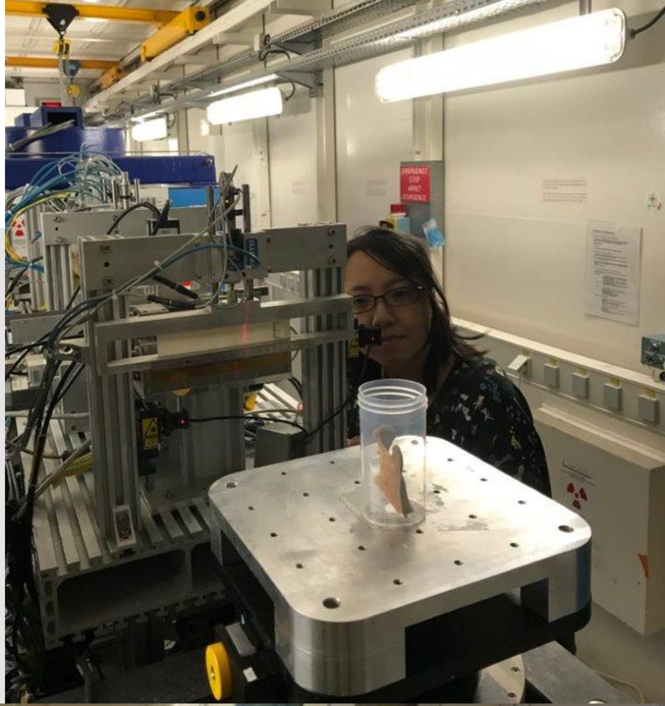


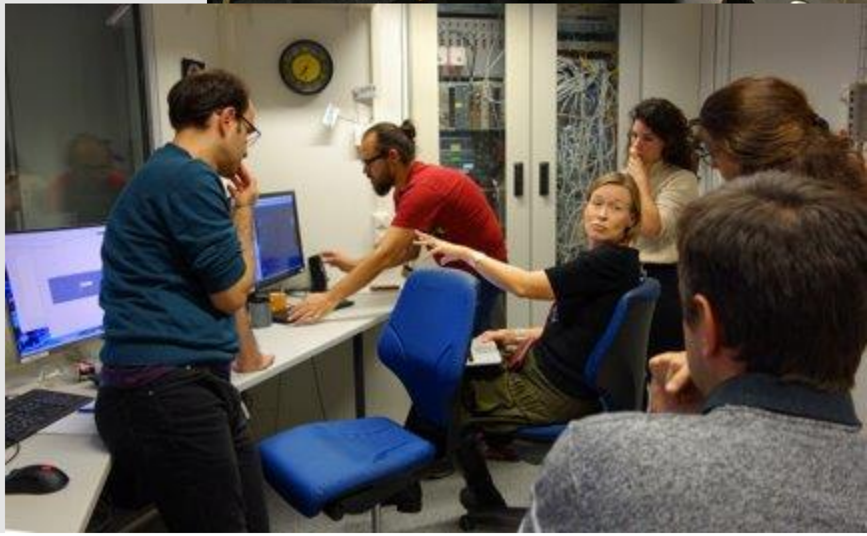


## Future prospects for SR enabled Human Bioarchaeology

- Aquisition of an archaeologically representative number of data points/sets - facilitated by upgrades such as ESRF-EBS
- Exploring frontiers together: pushing the limits of techniques whilst exploring for and identifying new research questions enabled by new developments in SR techniques
- Heterogenous samples – development of truly correlated multimodal imaging approaches and imaging pipelines
- Raising awareness of SR techniques within the putative human bioarchaeological user community: both established faculty and the future generations
- Feeder facilities and training at feeder facilities

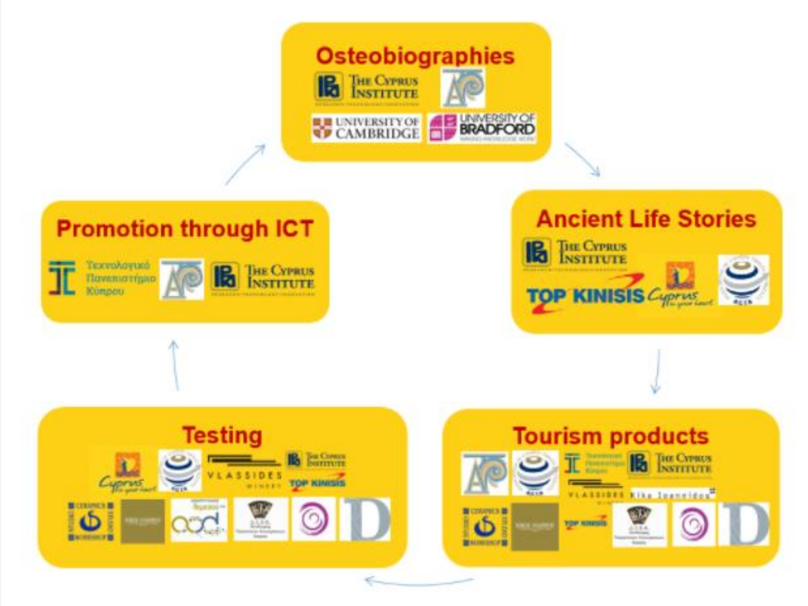




## SR analyses within a funded project on Cypriot human remains; relevance to tourism

# Face to Face: Meet an Ancient Cypriot

### RIF: 1 million Eur

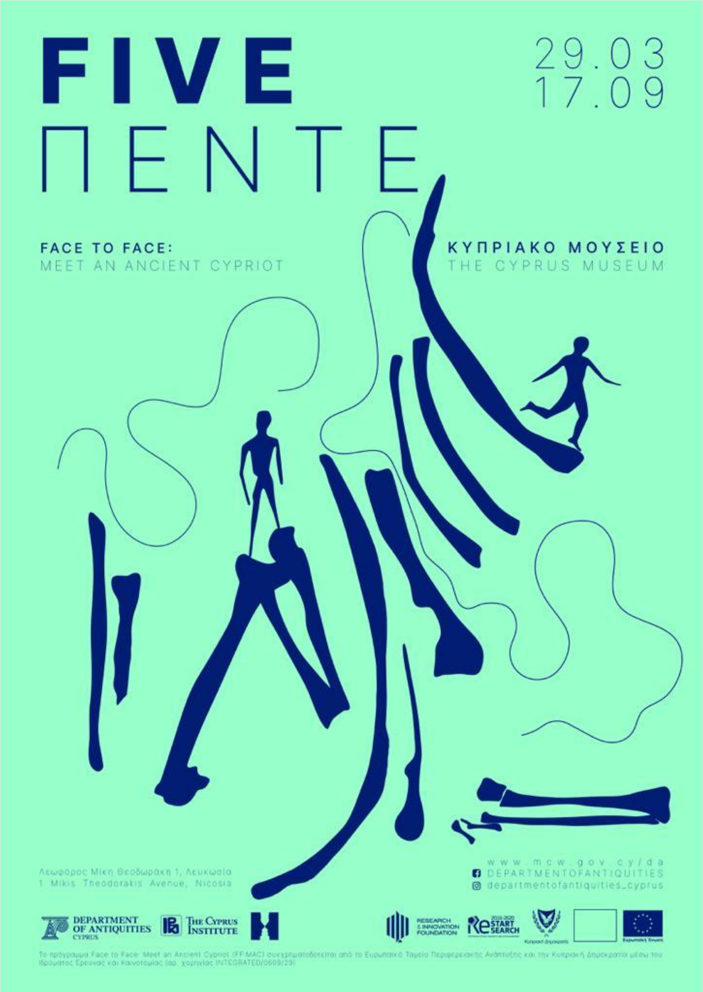



**PI: Kirsi O. Lorentz, The Cyprus Institute**

https://face2face.cyi.ac.cy/

The Project with Grant No. INTEGRATED/0609/29 is co-financed by the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation.

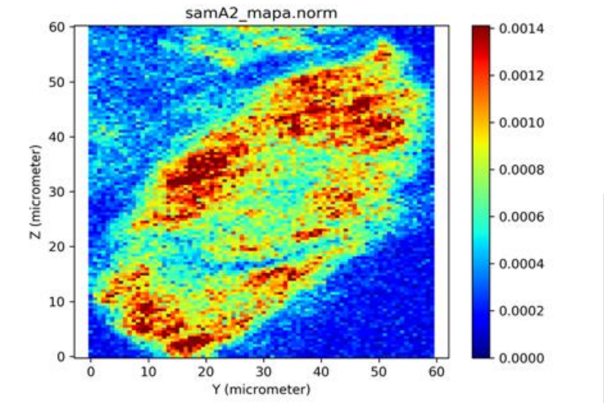
# SR analyses within a funded project on Cypriot human remains; relevance to tourism





The Cyprus Museum

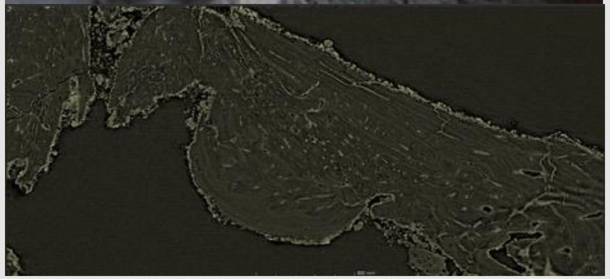
## Take-home message




**Synchrotron radiation enables us to**

- gather data to provide **better answers to longstanding, critical questions** in (bio)archaeology

- **ask entirely new questions**



# Thank you for your attention

contact: k.lorentz@cyi.ac.cy