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ABSTRACTS

Testing paleoepidemiological methods using agent-based models.

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Paleoepidemiologists estimate the presence and magnitude of mortality risk associated with a given skeletal lesion based on that lesion's frequency among individuals of various ages in a cemetery. However, a lesion's age distribution is shaped not just by mortality risks, but also by the age-specific probability of forming this lesion during life. To illustrate the impact of lesion formation timing on estimates of lesion-associated mortality, we simulated a series of computer-generated populations and conducted hazard analyses of apparent lesion-associated mortality risks in the resulting cemeteries. By design, skeletal lesions had no actual effect on individual mortality risk in the simulations, and all individuals experienced the same age-specific risk of death, defined by a siler function. Simulated environments differed only in the age-specific probability of developing a skeletal lesion during different periods of childhood. When analyses of the simulated cemeteries were limited to individuals too old to form these childhood skeletal lesions, hazard analyses produced estimates of relative mortality risk close to the true value specified in the simulation. However, lesions falsely appeared to be associated with a survival advantage when analyses included ages within the lesion's developmental window, and this false signal was greater for lesions capable of forming during a broader range of ages. Hazard analyses including non-adults are thus likely to underestimate mortality associated with childhood stress indicators unless they account for age-specific lesion formation processes. Future work will develop statistical methods to incorporate knowledge about lesion formation dynamics into paleoepidemiological analysis.

Assessing the severity of dorsal pit scarring on female and male *os coxae* based on known variables.

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It has been suggested that dorsal pit formation on the pubis is due to the loosening of ligamentous attachment sites during pregnancy and has thus been used to determine parity status. However, researchers remain undecided about whether the presence or severity of dorsal pits can reliably indicate an individual's parity status. If parity status is not the primary cause of dorsal pit scarring, researchers should consider other potential causes, including pathological explanations. A total of 58 males, 38 nulliparous, 30 uniparous, and 54 multiparous females were examined in three donated skeletal collections. The dorsal side of the pubis was observed for any pathology, taphonomy, or other irregularities. A ratio representing the area occupied by dorsal pitting was calculated using the dimensions of the pubic bone and the combined size of the dorsal scars. The quartile ranges of the ratios were then used to create a scoring system, which intends to standardize future research in this area. Of the pelves examined, 3% of males, 37% or nulliparous, 43% of uniparous, and 50% of multiparous females displayed some form of dorsal pitting. The data indicate that dorsal pitting is correlated heavily with the female sex but not necessarily with the parity status. Considering the appearance of the pits, an alternative explanation, such as pathologies that primarily affect women, needs to be considered and its role in pregnancy determinations rethought. Several pubic bones demonstrated bony pathologies including proliferative and degenerative lesions that ranged from the auricular surface through the ischiopubic ramus.

Comparative analysis of periodontal disease between individuals with early and late stage acquired syphilis.

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Research on the pathogenesis and pathophysiology of acquired syphilis requires a more robust understanding of the human host characteristics associated with persistent, late-stage infection, for both past and living populations. Here, we address co-infection with syphilis and periodontal disease (PD): Is PD (presence/absence, severity) associated with early stage (primary, secondary) vs. late (latent, tertiary) syphilis, independent of age-at-death? Though representative of local inflammation, PD is associated with systemic inflammatory processes and may indicate a hyper-inflammatory response or phenotype (HIP); individuals with a HIP may be vulnerable to persistent syphilis, potentially enabling continued transmission and late-stage morbidity and mortality. We assess this association amongst early 20th-century, pre-antibiotic-era individuals ($N = 136$) with clinical, antemortem syphilis diagnoses in the Hamann-Todd Osteological (late: $n = 91$; early: $n = 9$), Robert J. Terry Anatomical (late: $n = 24$; early: $n = 9$), and George S. Huntington Anatomical Collections (late: $n = 3$; early: $n = 0$). PD is assessed following Kerr (1988), which aligns clinical PD staging with alveolar resorption evident in dry bone. Results from Fisher's exact test ($p = 0.765$) suggest that PD presence does not differ relative to syphilis

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stage (late: 79.6%; early: 77.8%), possibly because of the small number of people in the early-stage group; future work will focus on increasing the early-stage group size and incorporating PD severity. The crude prevalence of PD across the total group (79.4%) may indicate a widespread HIP across all stages of syphilis, so future work including a control group will further assess these relationships.

Infectious, metastatic, and bone-turnover conditions identified in individuals from a northern Utah Fremont archaeological population (CE 900–1200).

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Human remains were discovered eroding out and disturbed near Willard Bay in Box Elder County, Utah. Consultation with the Utah Division of State History and the Utah Division of Indian Affairs deemed excavation to be the best option to avoid further disturbance. Analysis was initially conducted by Utah State University, but the human remains were re-examined for reporting under the State of Utah NAGPRA process. Standard osteological macroscopic and morphometric methods of analysis and recording were utilized; pathological conditions were identified using standard paleopathology resources. Ultimately, eleven individuals are represented in this assemblage (five adult males, three adult females, one indeterminate adult, and two subadults); one individual is only represented by a femur and was excluded from statistical analyses. In the original analysis, two individuals with prolific, remodeled periosteal bone formation (including 'sabre tibia') were attributed to treponemal disease. The recent analysis reexamined these individuals finding additional lesions (lytic cavitations and further periosteal lesions). After differential diagnosis, treponemal disease is considered the most probable diagnosis. In this new analysis, treponemal consistent lesions were also identified in a third individual. Further notable pathological conditions observed in this assemblage include probable senile osteoporosis and possible metastatic disease (lytic and hypervascular lesions, as well as "fibrous" and "coral-like" bone formation). Differential diagnoses of these conditions are considered and the implications discussed (evidence of probable treponemal disease in prehistoric Utah, evidence of possible infectious community spread, and a possible example of prehistoric metastatic disease in Utah, which has been infrequently recorded).

Metabolic and infectious illnesses in 19th century Quebec City: an integrative approach to differential diagnosis.

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The Saint-Louis cemetery, in Québec City, Canada, opened in 1832 during the city's first cholera epidemic and became the resting place for thousands of deceased, many of which of Irish origin, during the successive waves of cholera and typhus until its closure in 1879. The 2023 excavations identified a portion of the cemetery reserved for children; the remains of 32 non-adults were recovered. In the context of 19th-century Québec City, factors such as epidemics, poor sanitation and overpopulation highly contributed to child morbidity. The current study focuses on the paleopathological examination of the non-adult population to evaluate the co-occurrence of nutritional deficiencies. The results revealed a series of lesions including abnormal new bone formation, porous lesions, bending deformities, lytic destruction, and poor mineralization of long bone metaphyses. The differential diagnosis includes non-specific infections, metabolic disorders, and trauma lesions. The high frequency of porotic and abnormal new bone lesions (78%) on cranial elements, ilia and scapulae suggests scurvy as the most prevalent condition at the time of death. Co-occurrence with rickets was observed in five individuals presenting bone bending deformities, metaphyseal cupping and costochondral flaring, while co-occurrence with anemia was suggested in nine individuals showing cribriotic lesions. Additionally, four individuals presented lesions consistent with tuberculosis, including *serpens endocrania symmetrica* (SES). The high prevalence of co-occurring nutritional deficiencies identified evidences the underlying synergies between health and environment. Further research incorporating radiographic, histological and isotopic analysis could help investigate disease load and frequency to better understand morbidity and mortality risk among the population.

The price of longevity: adult health during the Industrial Revolution in England and Wales.

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This paper explores patterns of mortality and palaeopathology in adults who died during the Industrial Revolution to elucidate the impact of increased longevity on patterns of disease and investigate the limitations of macroscopic skeletal analysis. We will explore the documentary and skeletal evidence of health, highlighting the lived experience of those who lived into older age. We collated age-at-death data from the annual report of the Registrar General for 1837-8 ($n = 335055$ deaths) and osteological data (age, sex, pathology) collated from 18 cemetery excavations ($n = 4157$ skeletons). Infants, young children and older adults are underrepresented in the skeletal assemblages. Older adults (>45, $n = 829$) had higher prevalence rates of fractures (33.5%), osteoarthritis (47.3%), osteoporosis (6.0%), skeletal malignancy (1.1%), DISH (7.6%) and gout (2.2%) than younger adults ($p < 0.01$). The decline in crude prevalence of caries, periapical lesions and enamel hypoplasia probably relates to antemortem tooth loss, whereas lower rates of treponemal disease, TB and visceral rib lesions probably suggest these conditions are associated with, or could lead to, a younger age-at-death. Interestingly, residual rickets was identified more commonly in older adults (3.5%) than young/middle adults (2.0%/2.8%), suggesting childhood vitamin D deficiency was not associated with increased frailty. The fall in prevalence of *cribra orbitalia* may be due to lesions remodeling, increased frailty or a combination of the two. Overall, the health challenges faced by older people in the 18th and 19th centuries are similar to those faced by the elderly today. Further comparison of documentary and skeletal data will build on these findings.

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Climate change and its impact on health conditions: the Late Antique Little Ice Age in Central and Northern Italy.

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The Late Antique Little Ice Age (LALIA) was a period of climatic cooling that contributed to social and biological changes, including disease spread and susceptibility. This study evaluates whether the LALIA caused periods of episodic stress and disease in individuals from the 6th-8th century CE northern-central Italy from three archaeological sites. Well-established criteria of adult stature, physiological dental and skeletal stress markers, and upper respiratory disease were observed. Ninety-four individuals were assessed, comprising 68 adults (38 males, 20 females) and 26 nonadults. Average female stature equated with other published Medieval Italian assemblages, whereas males were of greater stature. Porous cranial lesions involved *cribra orbitalia* (38.09%) and *cranii* (14.7%), while post-cranial lesions included *cribra femora* (3.84%) and periosteal reaction on long bones (21.42%). Linear enamel hypoplasia occurred in 43.24% of individuals. Finally, chronic maxillary sinusitis occurred in 46.66% of individuals and otitis media in 59.09%. The results indicate that roughly half of the assessed individuals exhibited evidence of physiological stress and/or respiratory disease, and this was higher than in the few comparable studies from Italy. This

could be explained by nutritional deficiencies due to crop failure and famine during the LALIA. Stature discrepancies may reflect the arrival of Goths and Longobards, as evidenced at sites in this study. This research demonstrates the biological impact of climatic stress and has implications for understanding resilience in the past. Poor preservation, commingling, and the absence of comparative data limited this study. Future research should investigate these assemblages diachronically and through isotopic and molecular analysis.
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Serum vitamin D levels at birth are not associated with the formation of interglobular dentine in deciduous incisors of modern New Zealand children.
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Interglobular dentine (IGD) has been used as a biomarker for vitamin D deficiency (VDD) by some paleopathologists. However, an evidence-based threshold for the levels of serum vitamin D associated with IGD has not been established. Here, we explore the association between perinatal serum vitamin D levels and IGD in the deciduous teeth of modern children from Otago, New Zealand. Ground sections were created from the deciduous central or lateral mandibular incisors of 54 six-year-old children (27M, 28F) with known umbilical cord blood vitamin D levels. Vitamin D levels at birth were classified as deficient ($\leq$30 nmol/L), insufficient ($<$50 nmol/L), or sufficient ($\geq$50 nmol/L) and scanned slides were scored blind by two observers for IGD presence or absence. Thirty-eight individuals (70.4%) exhibited IGD. The distribution of IGD was similar across vitamin D deficient (34.2%), insufficient (34.2%) and sufficient (31.6%) groups and no significant association was found between IGD presence and vitamin D status by Chi-squared test ($p = 0.968$). Our findings do not support a clear association between IGD formation in deciduous teeth and vitamin D levels at birth. The high prevalence of IGD across the sample, particularly at the periphery of the pulp chamber, suggests IGD may be a common variation in dentine mineralization patterns. However, it is important to note that cord blood vitamin D levels do not accurately reflect the individual's vitamin D status during the entire formation of their deciduous incisors. Additional longitudinal clinical research is needed to further explore the relationship between VDD and IGD formation.

Possible scurvy at Early Bronze Age Bab adh-Dhra', Jordan.
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As part of the ongoing analysis of deceased persons from ancient Bab adh-Dhra (modern Jordan), this case study focuses on the analysis of porotic and vascular lesions in a non-adult (estimated age: 2.5–6.5 years) from the A22 charnel house, a significantly commingled and fragmentary burial structure. The charnel house (3100-2400 BCE) dates to a nascent urban occupation of the site with an intensification of agriculture including fruit orchards. Excavation records and refitting were employed to reassociate fragmented cranial elements, including both parietals, a partial occipital, a partial frontal (including one orbit), and a maxilla. Macroscopic and low magnification analysis revealed significant abnormalities associated with hypervascularization, particularly on the parietal bones, which display bilateral, but asymmetric, cortical porosity and hypertrophic bone formation on enlarged parietal bosses, aligning with examples of "parrot swelling." Differential diagnosis based on the distribution and morphology of lesions associated with this individual suggests scurvy (vitamin C deficiency), representing the first possible case identified in a non-adult during urban occupation at Bab adh-Dhra'. However, limited preservation and an inability to reassociate fragmented elements limit this research and a definitive diagnosis. This finding provides insight into juvenile health and diet in the context of the Early Bronze Age, offering a window into broader patterns of nutritional stress and health during a regional experimentation with urbanization. Future research will extend this analysis, with the goal of refining our understanding of nutritional deficiencies at the site and its implications for health and dietary practices in ancient Jordan.

From fields to fever: malaria mortality and socio-environmental factors in 19th-century Ontario, Canada.
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This study investigates probable malaria-related mortality in 19th-century southern Ontario (1840-1895), focusing on the demographic, occupational, and environmental factors shaping disease vulnerability. Data from $n = 1781$ individuals were collected from Ontario death certificates and cemetery burial records; these data are preliminary, with collection still ongoing. Children under five represented the largest group of malaria-related deaths (24%), underscoring their heightened susceptibility. However, tests showed that sex was not a significant factor in malaria mortality ($p = 0.092$), and differences in mortality across age-at-death categories were also non-significant ($p = 0.158$). Geographically, mortality was concentrated in southwestern Ontario, with 66% of malaria-related deaths occurring in this region. Temporal analysis revealed significant seasonal variation, with malaria mortality rates peaking during warmer months ($p = 0.001$). Higher mean temperatures correlated with increased mortality ($p = 0.025$), underscoring temperature's role in malaria prevalence, while precipitation levels did not have a statistically significant impact on mortality rates ($p = 0.538$). Analysis revealed an occupational influence on malaria susceptibility; individuals involved in agricultural work, and their families, faced significantly higher mortality rates than other occupational groups ($p < 0.001$). These findings underscore a significant interplay between environmental factors, occupational risks, and mortality outcomes in southern Ontario following colonial settlement, situating malaria within a socio-environmental framework. Furthermore, these findings contribute to paleopathology by providing a broader understanding of how specific ecological and social contexts may influence disease patterns in historic communities, offering a basis for comparative insights across different times and places.

Paleoproteomics as a potential complement to reconstruct skeletal inflammatory phenotypes in Colonial Perú.
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Localized skeletal conditions such as periodontitis (PD) and periostosis (PL) offer insights into local and systemic inflammatory responses, allowing us to use them as markers for an ancient individual's skeletal inflammatory phenotype. This project combines different macroscopic criteria and proteomic analysis to assess the severity and co-occurrence of PD and PL in individuals from Colonial northwest Peru. These observations are, for the first time, combined with proteomic analysis to identify inflammatory proteins within each bone lesion – enhancing our understanding of PD and PL severity. Proteomic analysis is used as a complement and validation for the macroscopic analysis. Our study included 165 individuals from late pre-Hispanic ($n = 88$) and Colonial populations ($n = 77$) in Lambayeque, Perú (CE 900 to 1750). The macroscopic analysis revealed variation in PD and PL presence and severity, especially in the late pre-Hispanic era, where the population of Jotoro showed the highest severity for both conditions. This pattern seems to have persisted and intensified into the Colonial era, especially in the people at Mórrope. Ten samples from PD and PL lesions in four individuals with different severity (and 23 control rib samples) detected

immune response-linked proteins such as dermcidin and immunoglobulins in the lesion-sourced samples. These proteins correlated with macroscopic severity scores, suggesting a link between inflammatory protein presence and lesion severity. We propose combining macroscopic skeletal analysis with proteomics to enhance paleopathology's ability to reconstruct various disease states at the molecular level. Ultimately, this research considers how systemic immunological changes affect health and mortality variation during adaptive transitions.

Intersectionality, stress, and frailty in Post-Medieval London: estimating group-specific risks of mortality and resilience.

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Indices for estimating frailty and resilience in past individuals are increasingly being used in paleopathology. Recently, novel approaches have been proposed for estimating frailty and resilience that incorporate both hazards-based and indexical methods. Here, we develop resilience indices from skeletal biomarkers (presence/absence) associated with increased survival and decreased risk of mortality, specifically from four Postmedieval (16th-19th centuries) London cemeteries: generally high socioeconomic status (SES) Chelsea Old Church and St. Benet Sherehog, and low-SES St. Bride's Fleet Street and Cross Bones. Kaplan-Meier survival and Cox proportional hazards analysis suggest increased resilience associated with osteoarthritis, periodontal disease, trauma, and the absence of vitamin C deficiency. We applied this group-specific 4-biomarker resilience index to a subgroup of estimated adult female ($n = 119$) and male ($n = 163$) individuals from ascribed high- and low-SES burial contexts, and compared these indices to assess impacts of sex, status, and their intersections. Results showed that high-SES individuals exhibit significantly lower average resilience index values and older ages-at-death relative to low-SES individuals. Although resilience indices differed significantly between high- and low-SES males, no such differences were observed between high- and low-SES females. Within status groups, resilience indices did not vary significantly. While measures of cumulative stress, the indices here reflect distinct embodiments of resilience according to status; resilience in low-SES contexts translates into physiological weathering (e.g., degenerative lesions), while resilience in high-SES contexts conveys fewer pathological conditions. Ultimately, these findings demonstrate how Postmedieval socioeconomic systems preferentially benefited high-SES individuals, notably high-SES males.

Piecing together an osteobiography of childhood at Amarna: what we learn from linear enamel hypoplasia.

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This project examines the frequency of linear enamel hypoplasia presence and age-at-formation among the South Tombs Cemetery (STC) skeletal sample from Amarna, Egypt (c. 1353BCE) to examine severe stress events during childhood and their potential cause(s) among the relatively understudied non-elite children in the New Kingdom. The sample includes all individuals excavated from the STC for whom the six anterior permanent teeth are represented on at least one side ($n_{subadult} = 19$; $n_{adult} = 81$). Ninety 90% of individuals exhibit at least one LEH. LEH height (distance from cemento-enamel junction) was used to calculate the age at which individuals experienced severe stress event(s). The mean age-at-first-stress-event for individuals with 1–2 stress events is 3.48 years, whereas for individuals with 3+ stress events it is 2.09 years ($p < 0.001$; *t*-test). Inter-event timing is consistent, regardless of the number of stress events experienced, and the mean spacing is 0.86 years (10.3 months). This study demonstrates high stress events during childhood were a common experience in New Kingdom Egypt and the inter-event timing suggests a near annual cycle of stress. This may correspond to the annual Nile inundation and differences in mean age-at-first-stress-event suggest differential exposure to stressors early in life. Limitations of this project include potential population level differences in tooth formation timing affecting age-at-insult estimates, an under-enumeration of the last stress event for non-survivors (subadults), the exclusion of deciduous dentition to examine early health status, and recording a maximum of three LEH per tooth. Future research will address the latter two elements.

Skeletal inflammatory phenotypes and biohistorical transitions in medieval populations from Sant Pere churches, Terrasssa, Catalunya, Spain.

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The Late Antiquity (LA) to Early Middle Age (EMA) transition in the Northeastern Iberian Peninsula was a historical period of cultural, social, and political change. Germanic and North African peoples settled in this region in successive migratory waves. These cultural and social transitions impacted the biology of local populations over generations. This project aims to study periodontitis (PD) and periostosis (PL-tibia) severity and co-occurrence as osteological proxies to reconstruct skeletal inflammatory phenotypes in 49 individuals from the medieval necropolis (4th to 11th centuries CE) of the churches of Sant Pere de Terrassa, Spain. PD severity (PDS) was determined by a combined score from cemento–enamel–alveolar crest distance and interseptal bone texture and shape (scores 2 to 9). PL severity (PLS) was determined by a combined score considering severity and coverage (scores 2 to 8). Our results show greater PDS and PLS scores in males (score 6) than in females (score 4). Interestingly, PDS showed higher severity (score 6) in individuals buried inside the church complex (proxy for higher social status) when compared with those buried outside the church complex (score 4). PD and PL co-occurrence showed a higher correlation (Spearman's rho correlation) in females ($R = 0.35$), individuals outside the church complex ($R = 0.44$), and individuals from EMA (0.40). These results show that the complex local sequence of historical changes observed in the Sant Pere Medieval population, when comparing the LA and EMA transition, generated heterogeneous inflammatory phenotypes landscapes that ultimately could explain hidden heterogeneities associated with ill health or increased mortality risk.

Osseous changes associated with hallux valgus deformity: a cadaver study.

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Hallux valgus (HV) is a condition where the first metatarsophalangeal joint becomes progressively subluxed. This abnormal lateral deviation of the great toe can cause osseous changes that can be identified in skeletal assemblages. However, the exact relationship between the observable pathological changes and the severity of HV deformity remains unknown. This study seeks to identify and classify the osseous changes associated with HV severity (defined by the hallux valgus angle (HVA)) with the aim of devising a refined method to identify and assess HV in skeletal assemblages. To do this, 62 feet from 31 formalin embalmed cadavers were assessed. Simulated weight-bearing radiographs were used to assess HVA. In this study, HV was characterized by a HVA $\geq 20^{\circ}$. Each foot was dissected and disarticulated to allow for the tarsals and metatarsals to be assessed. A total of 18 features were recorded and explored using various statistical tests. HVA was correlated with the size

of exostoses on the medial aspect of the first metatarsal head, and the amount of lateral deviation of sagittal ridges on the distal articular surface of the first metatarsal. Flattening of the intersesamoidal ridge was present only in those with HV. Though additional research is needed, these findings suggest that certain osseous features can be used to determine HV severity in skeletal assemblages. As mild and moderate cases of HV have been under-recorded, the application of this method may enable more accurate prevalence rates of HV to be calculated in archaeological populations.

Tooth loss patterns as an indicator of quality of life in ancient populations.

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Aiming to reconstruct the quality of life, this study analyzed age and biological sex patterns of tooth loss in 7th to 9th century CE, northern Serbian populations (South-eastern Europe). This study only included skeletons older than 17 years ($n = 98$). To assess toothlessness patterns in all the examined skeletons, the well-established Kennedy classification was applied. Partial or total edentulism was observed in 41.8% of individuals, with a predominance of Kennedy Class III. In the maxilla, toothlessness patterns showed an increasing trend across age cohorts, from the youngest to the oldest, with no significant difference between the mature adults (45–60 years) and the old adults (60+ years). A similar trend was noted in the mandible, although a difference was recorded between the middle-aged adults (26–44 years) and the mature adults (45–60 years). A significant difference between sexes was found in the maxilla ($p = 0.017$), with males exhibiting higher tooth loss rates. Among males, Kennedy Class III was the most common, while in females, Kennedy Class I was predominant. No significant difference between the sexes was observed in the mandible. Partial edentulism can be attributed to many factors, some being inevitable, especially in ancient populations, like caries, periodontitis, and trauma. Edentulous areas result in compromised chewing and speech, negatively affecting quality of life. This is the first study to apply a well-established clinical approach to investigating edentulism in an ancient population, aiming to enhance our understanding of their oral health and its implications.

Capturing cancer: visualization methodologies in skeletal analysis.

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Cancer-induced bone lesions provide critical insights into the biological impact of cancer on skeletal structures, yet their documentation presents significant challenges. This preliminary study analyzed skeletal remains from the USF Donated Skeletal Collection at the University of South Florida, focusing on one individual with a confirmed cancer diagnosis, exhibiting metastatic cancer with secondary lesions affecting both the axial and appendicular skeleton, and non-cancerous skeletal elements for comparison. Three 3D scanning methodologies: structured light scanning with the Artec Space Spider, laser scanning with the FARO ScanArm, and triangulation scanning with the NextEngine Desktop Scanner, were evaluated for their ability to document cancer-related skeletal changes. High-resolution digital models were analyzed using macroscopic diagnostic criteria such as lytic, blastic, and mixed lesion patterns. Scans were assessed for resolution, surface accuracy, and edge clarity, with a focus on their capacity to document lesion morphology, porosity, and surface texture. Qualitative comparisons highlighted differences in the scanners' ability to capture subtle pathological features, while quantitative metrics included measures of model fidelity and consistency across scanning methods. Results show all scanners successfully documented these features, but their performance varied in handling porous regions and intricate lesion margins. This research demonstrates the potential of 3D scanning technologies to standardize the documentation and analysis of skeletal pathologies, including detailed assessments of lesion morphology, texture, and porosity, as well as evaluations of resolution and model fidelity. Findings contribute to developing protocols that enhance precision and reproducibility, though further studies are needed to expand lesion types and refine methodologies.

A case of concha bullosa from Baucina, Sicily (ca. 7th-5th centuries BCE) and a review of the literature.

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Concha bullosa (CB) refers to the partial or total pneumatization of the nasal turbinates. Albeit considered a common anatomical variant of the ostiomeatal complex rather than a pathology *per se*, its presence may predispose to diseases, such as chronic rhinosinusitis. However, CB remains understudied in the bioarchaeological record. Here is a review of published results and a case study uncovers the factors leading to its invisibility. Our review of bioarchaeological CB cases yields 268 cases recorded globally and diachronically, but most reports did not indicate the CB type, a critical factor in understanding how it affected the individual with condition. A case of CB found in a skull from the commingled human remains ($MNI = 50$) from the 7th–5th centuries BCE necropolis of Baucina (Palermo, Sicily), provides an example of how this condition can be recognized and properly categorized. The skull belonged to an adult male individual based on cranial sutures and morphological features. The CB was assessed through gross anatomical examination and radiology (CT-scan imaging), revealing the presence of a pneumatization (length = 2.52 cm) of the right middle turbinate, of the lamellar CB type, and a deviation of the nasal septum to the left side of the nasal cavity. We conclude that the scarcity of published CB cases relates to three essential factors: fragility of nasal structures, limited knowledge of CB and interest in it. More systematic research on this condition will be necessary in the future by assessing large skeletal samples.

A possible case of Hansen's disease (leprosy) in Avar-period Austria.

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Hansen's disease (leprosy) is an infectious disease caused by *Mycobacterium leprae* or *Mycobacterium lepromatosis*. It was common during the later medieval period in Europe, and remains a concern particularly in Southeast Asia, South America (Brazil), and parts of Africa. Early presence of the disease in Europe prior to the 10th century has been identified through a handful of cases, but the disease is far less commonly reported for this period. The Avar populations that moved into and settled in Austria from the 6th-9th centuries CE were a semi-nomadic culture. Only a few Avar-period cases of leprosy have been identified from Hungary, Austria, and Italy. Here, we describe a 17–21-year-old male with probable borderline lepromatous leprosy from the Avar-period cemetery of Vienna-Hirschstetten with a diagnosis based on macroscopic osteological assessment. The individual was buried within the cemetery, without any differentiating mortuary characteristics. They showed marked postcranial osteological changes that include periosteal new bone formation on the fibula, tibia, carpals and tarsals, and penciling and fusion of phalanges. Only minimal rhinomaxillary changes are observable but minor disruption of anterior maxillary dental root formation consistent with leprogenic odontodysplasia is present. Independently, porotic changes to the cranial vault (*porotic hyperostosis*) and orbits (*cribra orbitalia*) are shown, suggesting metabolic stress and a history of health challenges. The osteological changes are

consistent with non-adult onset of leprosy, marking the youngest example of the disease yet identified for the Avar period in Austria and providing insight into this disease in a highly mobile, semi-nomadic population.

Social determinants of head trauma? A study of nineteenth-century male prisoners in Graz, Austria-Hungary.

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This research investigates whether social factors influence patterns of head trauma in a bioarchaeological population sample of known identity. By examining the relationship between individual-level social variables (age, legitimacy status at birth, language and occupation) and head trauma, it is hypothesized that social determinants shape behaviors leading to injury. The skulls of 135 male convicts who died in Karlau Prison in Graz, Styria, Austria-Hungary, between 1858 and 1908 were analyzed. Their bodies were anatomized at Karl-Franzens University, where their skeletal remains (primarily skulls) were included in the anatomical collection. To investigate the relationship between social environment and trauma, biographical information in documented records is linked to the palaeopathological evidence. Head trauma in 23% of the individuals was diagnosed from predominantly healed fractures, affecting the skull base (2%), the cranial vault (20%) and the face (6%). Regression analysis revealed that the tested social variables were not significant predictors of head trauma. The social backgrounds and life experiences of the prisoners were diverse, and the results highlight those studies of social complexities in bioarchaeology are not straightforward. It is postulated that the seemingly random pattern may relate to the environment of the prison, which may have resulted in additional injuries that obscure any potential social determinants outside the institution. As cranial fractures are generally the cause of severe trauma, the study is limited to mostly grave head injuries and therefore not able to detect any nuances of exposure to violence that these individuals may have experienced in life.

Granular impressions on the endocranial surface as a marker of tuberculous infection: an investigation on a Medieval population from Tuscany, Italy.

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Recent palaeopathological studies have suggested that granular impressions (GIs) on the endocranial surface may be pathognomonic of tuberculous meningitis (TB meningitis). The objective of this study is to investigate the presence and significance of GIs in relation to tuberculosis in an osteoarchaeological assemblage. The endocranial surface of 212 skulls (38 non-adults and 174 adults) from the medieval rural site of Pieve di Pava (10th-12th century CE, Tuscany, central Italy) was analyzed. The examination was conducted through macroscopic and stereomicroscopic observation. GIs were observed in 52.6% of non-adults and 54% of adults, with no statistically significant difference between adult males and females. The findings challenge the interpretation of GIs as an indicator of TB meningitis, a rare complication affecting the central nervous system. Instead, based on the current clinical data, it seems more reliable to consider GIs as the result of the long-lasting pressure on the endocranial surface of the tubercles produced by the immune system during the stage of bacteremia; therefore, they can occur even in the absence of skeletal signs of TB disease. A detailed differential diagnosis excluded that GIs could be related to other diseases. GIs are thus a proxy for TB infection that reached the central nervous system, but it is not possible to determine whether the tubercles had ruptured, resulting in TB meningitis. A limitation of this study is the underrepresentation of non-adults. Further screening of GIs in other large skeletal assemblages could provide valuable data on the spread of TB infection across different archaeological contexts.

Comparative isotopic weaning data from Medieval European urban and rural cemetery populations.

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Breastfeeding and weaning practices in Medieval Europe (500 to 1500 CE) remain poorly understood, with sources limited to written records that traditionally reflect only one part of society. A few studies have enhanced these historical narratives using stable isotope analysis, a method that provides a precise age range for weaning and offers a window into ancient breastfeeding norms. We analyze previously collected ($\delta^{13}C$ and $\delta^{15}N$) incremental dentine and bone collagen data from 8 urban and 10 rural Medieval cemetery populations, mainly in Central Europe. Combined, the rural and urban cemetery contexts include a total of 506 individuals. A Welch's *t*-test was used to determine if there was a significant difference in mean weaning age between the rural ($n = 223$) and urban ($n = 283$) populations. Our results indicate that Medieval females from rural contexts breastfed their infants for an average of 2.2 years ($SD = 0.65$), while Medieval females from urban contexts breastfed their infants for an average of 2.4 years ($SD = 0.72$) ($p = 0.50$). Our findings imply that breastfeeding practices were relatively similar across Medieval urban and rural contexts and that environmental or cultural factors may not have had a significant influence on breastfeeding duration and weaning age. This study does not take into account the presence of disease or malnutrition, which may have affected C/N ratios. Future research will include analysis of $\delta^{13}C$ and $\delta^{15}N$ isotopic values from Neolithic, Iron Age and Industrial period populations to examine temporal and geographic trends surrounding weaning age and child-rearing practices that existed in ancient populations.

Traumatic injuries in medieval Southern Portugal: a comparative study of rural and urban Christian populations.

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Analysing trauma in skeletal remains may reveal daily hazards, including interpersonal violence, across societal contexts. This study historically contextualizes bone trauma from two medieval Christian settlements in southern Portugal: Cacela, an early rural site under the military, religious Order of Santiago ($n = 43$), and Silves, a major urban centre scene of battles during the medieval period ($n = 82$). Macroscopic analysis of the individuals over 12 years old, along with field report data, revealed a significant difference in fracture frequency between the individuals from Cacela and Silves, with 37.2% (16/43) and 18.3% (15/82) with traumatic lesions, respectively. Fractures, possibly from interpersonal violence, are also more frequent in Cacela. Males have more fractures in both sites but there are no statistically significant differences between sexes; however, injury location differs by sex and age-at-death of the individuals. Multiple fractures were observed in seven individuals from Cacela (one female, five males, one indeterminate sex) and in three males from Silves. Rib fractures were the most common in both sites, followed by skull, hand, and fibula in Cacela, and upper limb (humerus, ulna, hand) and clavicle fractures in Silves. Most appeared well-aligned and with no signs of infection, suggesting possible medical treatment. This study suggests that the individuals from rural Cacela suffered more single and multiple fractures, including those resulting from interpersonal violence, than those buried in the urban centre of Silves. Further

research with larger samples would enable the verification of this assumption.

Fibro-osseous processes in the frontal sinus and their differential diagnosis.

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Osteomas in the frontal sinus are an incidental finding in clinical imaging. These are mainly benign, rarely symptomatic tumors of unknown etiology (e.g., chronic inflammation, traumatic, developmental). Applying radiography and computed tomography, they might be radiopaque or show a ground-glass appearance. A tumor obstructing the frontal sinus is visible from the outside in two adult males from Bronze Age (2000-1500 BCE) Slovakia, and Iron Age (800-400 BCE) Iran. These tumors are up to 10mm large and show a fine porous surface. In one individual, the tumor is accompanied by a slight thickening of the orbital roof, while three more similar lesions can only be seen radiographically within the frontal bone. The frontal bone of the second individual shows a porous thickening of the external frontal lamina in the area of the frontal sinus tumor and a malformation with a porous surface of the zygomatic process of the right frontal bone. Radiography and computed tomography show well-circumscribed lesions with ground-glass appearance. While the tumors in the frontal sinus seem to match the diagnosis of paranasal osteoma, their distribution within the frontal bone is unusual. Giant osteomas of the paranasal sinuses are known to extend into the intracranial or intraorbital cavities but are not described as invading the cranial bones in multiple locations. Cemento-ossifying fibromas tend to expand the bone without cortical breach. Therefore, fibro-osseous processes seem to be the most likely differential diagnosis. Applying radiography is inevitable to detect further lesions within the cranial bones and consequently, is crucial for diagnosis.

“We are all formed of frailty and error”: childhood health and development in early medieval England and the Isle of Man (c.5th-11th centuries CE).

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The early medieval period (c.5-11th centuries CE) was tumultuous for people on the British Isles with significant migration, the spread of Christianity, and the rise and fall of kingdoms. However, the impact of these societal changes on child and adolescent health is understudied despite young people's remains being important indicators of environmental conditions. This study analyzed 150 early medieval individuals (aged 3-25 years) for frailty, a proxy for morbidity and mortality risk, from five sites in England and the Isle of Man to investigate their embodied experiences of physiological stress. Preliminary results using a novel 12-biomarker frailty index show early medieval young people scored on average 2.22 out of 12. Frailty varied across sites and males had slightly higher average frailty than females. The most common biomarkers included *cribra orbitalia*, Schmorl's depressions and dental enamel hypoplasia suggesting chronic childhood malnutrition and potentially high axial loading undertaken from a young age were likely commonplace risks during this period. This is the first project in palaeopathology to apply a frailty index to early medieval non-adults and young adults and has created detailed early life health histories to provide nuance in our interpretations of their growth and development. Excellent preservation is usually required for this method but alternative ways to apply the frailty index to incomplete remains will be discussed to tackle this. Future research includes comparison to mid-late medieval and post-medieval individuals, in addition to high-resolution stable isotope analyses to detect nutritional stress and explore more broadly, growing up medieval.

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Detailing cranial traumas by coupling macroscopic and 3D imaging analyses.

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Traumatic cranial lesions provide valuable insights into the cultures and lived experiences in past populations. Analysis of cranial traumas can offer insights into population-specific day-to-day hazards or risk of interpersonal violence. Gross observations have traditionally helped advance our understanding; however, integrating 3D imaging techniques can significantly enhance the precision and visualization of cranial trauma analysis. Twenty crania and one mandible with traumatic injuries from different contexts (Kerma period Nubia (Sudan): Kerma, and Abu Fatima) were analyzed and scanned using an Artec Space Spider 3D scanner. The resulting 3D models vividly captured the surface topography of traumatic lesions, facilitating more nuanced measurements of area and depth. Additionally, lesions obscured by taphonomic alterations were revealed, and reconstructions of broken skulls displayed the full extent of fragmented lesions. The 3D models demonstrated the effectiveness of supplementing macroscopic analysis with digital imaging, allowing for visibility of subtler lesions a more nuanced mapping approach. Future research can utilize such scans to offer insights into the biomechanics and possible sources of injuries where objects may have been involved. To ensure reliability of models in trauma assessments, further research is recommended to establish a baseline for normal variations in cranial morphologies and topographies. Assessment of possible obfuscations from scanning and post-processing, especially when subtle or small-scale lesions are being analyzed, is also proposed.

A case study of childhood metabolic stress in 11th – 12th century Giecz, Poland.

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Several different sites dated to the 11th – 12th century Poland document the occurrence of metabolic diseases among juveniles. The high prevalence of metabolic diseases can be the result of several causes including malnutrition, poor maternal health, poor living conditions, malabsorption disorders, parasite load, chronic infections, and limited sun exposure. Therefore, a high prevalence of metabolic diseases is associated with periods of elevated stress on individuals during development. In this study, we offer a differential diagnosis of an individual from site Gz10, located outside the stronghold in Giecz, Poland. The remains were analyzed macroscopically to estimate age-at-death and identify non-specific skeletal markers of physiological stress and metabolic disease. An age at death of 3–5 years was estimated based on dental eruption and long bone measurements. Evidence of metabolic disease is present in the form of bilateral *cribra orbitalia*, hypoplasia on seven deciduous teeth, increased porosity throughout various regions on the skull and long bone epiphyses, and periosteal new bone formation on the left tibia and right femur. Differential diagnoses ruled out tuberculosis, treponemal disease, hypertrophic osteoarthropathy, and Caffey's disease. Skeletal markers suggest this child may have suffered from scurvy (vitamin C deficiency), rickets (vitamin D deficiency), iron deficiency anemia, and/or a non-specific infection. Although it is not possible to clinically diagnose the specific metabolic disease affecting this individual, this evidence from Giecz adds to existing data from other medieval Polish sites, which suggests that populations from that period were experiencing stressful environments affecting their growth and development.

Biocultural variables and their influence on vitamin D deficiency in the historic United States.

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A lack of detailed acceptance of the impact of biocultural variables has

hindered our current understanding of metabolic bone diseases like vitamin D deficiency. I address this by examining biocultural variables and their influence on vitamin D deficiency. The skeletal remains of 177 individuals living between the 1830s and 1940s in the United States were macroscopically analyzed and traced through the historical record. Skeletal results and biocultural variables were compared via chi-square and Spearman RS correlation (RS). Thirty individuals had confirmed vitamin D deficiency and twenty had potential vitamin D deficiency based on the appearance of post-cranial skeletal pathology. When comparing biocultural variables and vitamin D lesions, results indicate that there were trends in where an individual spent their childhood ($p = 0.006$; RS 0.92, $p = -0.008$), year of death ($p = 0.005$; RS 0.87, $p = -0.01$), and age ($p = 0.02$; RS 0.60; $p = 0.04$). There were also correlations between vitamin D deficiency and sex (0.61; $p = 0.04$), social race (0.74; $p = 0.04$), and occupation (0.50; $p = 0.05$). Individuals with residual rickets were likely to be working class white females, who grew up in the North during a post-war industrial period while both black males who moved to the North during the last 5-10 years of life living during wars or industrialization, and white males living in the North during industrialization were likely to have osteomalacia. Biocultural variables can influence vitamin D susceptibility, and the social history of the individual should be examined when possible. Future research should include increasing the skeletal sample size.

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Violent ends: Understanding violent death and trauma in northern England during the 18th and 19th centuries using a multidisciplinary approach.

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Violent deaths are those caused by forceful, accidental or interpersonal incidents. Osteological analyses of trauma records primarily ante-mortem trauma. This research aimed to study violent deaths as reported by the General Registrar's Office (GRO) in the 19th century and the evidence for violent incidents in life (skeletal lesions) within Northern England during the period. The osteological data from North Shields ($n = 236$), South Shields ($n = 204$), Sheffield ($n = 287$), Leeds ($n = 51$), Fewston ($n = 163$) and Blackburn ($n = 654$) were compared with GRO decennial reports via crude prevalence of fractures, logistic regression, and comparison between the two datasets. Males presented with more evidence of violence osteologically (23.2%) and in GRO recorded deaths (both interpersonal and otherwise; 74.5%), especially urban males, in comparison with females (7.6% and 25.6%, respectively). Deaths due to burns were more prevalent in females (37.4%) and children (41.4%), possibly due to domestic labor, which required the utilization of fire. Comparison of the two datasets revealed that the high prevalence of general accidental childhood death presented by the GRO is not reflected in the number of non-adult skeletal individuals presenting with evidence of trauma in the osteological record. This research revealed how the use of multiple sources of data with differing perspectives can provide a more holistic understanding of trauma in the past. The use of multidisciplinary methods presented in this research could be beneficial when studying violence and trauma in other populations in both England and elsewhere, and those associated with specific samples such as mining communities, rural settlements, and armies.

Resistance to oppression: the impacts of slavery and racism on the skeleton.

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Enslavement has created a violent environment through torture, abuse, rape, trauma, and forced hard labor. Racism, particularly during enslavement, equally created a horrific environment for African Americans in the United States. Evidence of this abusive environment can manifest in the skeleton, which can be used to understand their lived experiences. This research aims to explore skeletal indicators of stress, violence, and disease on the remains of African Americans living in New York during the 18th century, buried in the New York African Burial Ground ($n = 107$). As the remains have been reinterred, photographs and documents were used to record skeletal indicators, including fracture prevalence, enamel hypoplastic defects, evidence of disease, metabolic disturbances, and musculoskeletal markers. Given the physical demands and the violent nature of enslavement and racism, it was hypothesized that the remains interred in this cemetery would demonstrate high prevalences of skeletal fracture, stress, disease, and evidence of hard labor. However, analyses indicate low levels of fractures across the cranial vault and postcranial skeleton (ranging from 3 to 8% depending on location), except for the radius (19%) and ribs (11%). Conversely, evidence of metabolic disturbances (16%) and periostitis (42%) illustrates a stressful environment. Additionally, skeletal remains yielded evidence of mechanical wear; 100% of adults (20+ years) present enthesopathies in the upper and/or lower appendage. Results indicate varied responses to enslavement and racism. This research aims to reveal a more accurate description of the lived experiences of African Americans during enslavement in the United States, as told by their own skeletal remains.

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Physiological and social evaluation of an adult individual with sagittal craniosynostosis from Late Bronze Age (Mycenaean) Greece.

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Craniosynostosis is a condition with few case studies in paleopathological literature, likely due to the rarity of the condition and archaeological sampling bias. This research situates the lived experience of one adult in Late Bronze Age (Mycenaean) Greece (1100-1050 BCE), buried in a tholos (beehive-shaped) tomb, who exhibits cranial deformation. Differential diagnosis considered cultural cranial deformation, but found the obliteration of the sagittal suture and the occipital protrusion were more consistent with non-syndromic sagittal craniosynostosis. A biological profile for the individual used standard bioarchaeological methodology and a literature review focused on modern and historical cases of craniosynostosis, as well as physical, psychological, and neurological outcomes associated with the condition. The individual is a probable male adult with no other observed pathological changes other than asymmetric dental attrition. Background research found that sagittal craniosynostosis may produce cognitive and developmental deficits, including visuospatial, verbal/language, and behavioral impacts. Although severe cognitive deficits may not be expected, the individual may have presented issues in communication, fine motor skills, or learning. Additionally, the uneven dental attrition may indicate that these motor skills unilaterally affected facial musculature. This research adds an example of an individual whose lived experience with craniosynosis as an adult did not restrict their inclusion for burial in an ancestral tomb. Limitations of this study include modern medical literature that primarily discusses subadults and surgical methods, as well as skeletal preservation and incompleteness. Future research including aDNA and isotopic analyses, may reconstruct genetic relatedness or kinship with other individuals buried in the tomb.

Building a framework for cranial lesion analysis: a case study of trauma and care from Ras Shamra (Ugarit).

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This study develops a framework for categorizing cranial lesions in paleopathology, focusing on identifying evidence of potential therapeutic interventions. It addresses the lack of paleopathological research on health and medicine in the Bronze Age Levant, using remains from Ras Shamra (Ugarit) housed at the Musée de l'Homme as a case study. Partial and complete crania from 49 individuals from Middle and Late Bronze Age contexts were examined, 16 of which (35.5%) display pathological lesions. The collection, excavated during the early 20th century, presented preservation and documentation challenges. Lesions were analyzed using a systematic four-phase framework synthesizing recent advances in cranial healing research, forensic methodologies, and concepts in bioarchaeology of care to build a catalog of discriminating criteria for cranial pathologies in the Levant. Phase one integrated anatomical mapping, fracture typologies, and preservation grading to address taphonomic biases. Phase two applied a structured system to evaluate lesion characteristics through a composite score. Healing stages were then contextualized to estimate injury timing and infer care practices, based on lesion-specific functional risks. The final phase compared findings with neighboring sites to identify potential variability, supporting a replicable regional catalog. Results revealed a range of cranial pathologies, including evidence of healed trauma, suggesting therapeutic interventions. The study highlights the potential for such practices in the ancient Levant while emphasizing the need for cautious interpretation. It advocates for renewed focus on early excavations in the Levant and suggests biomolecular analyses and integration of archaeological and historical evidence to refine our understanding of health in these populations.

An additional osteological indicator to assess menarche status in osteological remains.

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Menarche indicates that an individual is approaching the physiological capacity to reproduce. For this reason, menarche often holds social and cultural significance today and probably also in past communities. Since the timing of menarche is an easily recognizable developmental milestone, it has been studied in a clinical context to research growth and secular trends in adolescence. Osteological indicators are used to assess adolescent development in past societies, where the age at menarche is assessed by scoring the ossification of the iliac crest and the hand phalanges. Unfortunately, unfused iliac crests and small finger bones are rarely recovered from burials. Therefore, additional indicators are needed to better assess menarche status from the skeleton. However, the fusion of the triradiate cartilage (TRC) connecting the innominate bone has been linked in clinical studies to the time around peak height velocity right before menarche. Therefore, an unfused innominate bone indicates that menarche has not yet occurred. In a sample of 130 medieval adolescents between the ages of 10 and 25 years, all nine genetically determined females with fully fused distal phalanges – an indicator that menarche had passed – had a fully fused TRC. Similarly, of the individuals with an ossified but unfused iliac crest – suggesting they died around the time of menarche – 8 out of 9 (89%) had a fully fused TRC. Adopting the fusion of the TRC into studies on past adolescence can add to the assessment of growth velocity stages and tell us about the sexual maturity in female individuals from the past.

Pits, plaques and pores: using high-resolution imaging to distinguish porous lesions caused by vitamin deficiencies.

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Porous lesions of the skull are commonly observed within archaeological skeletal assemblages, ranging in appearance from individual scattered pits to gross porosity or plaques of new bone overlying the surface of the skull. The etiology of these lesions has been greatly contested and attributed to several nutritional deficiencies and/or metabolic disorders. This project utilises the current understanding of disease processes combined with high-resolution digital microscopy (Keyence VHX7000) and micro-CT cross-sectional imaging (Zeiss MetroTom 1500 micro-CT) to investigate the formation processes and etiology of these varied lesions. For this exploratory study, 20 skulls were examined from three sites in England (St James and St Mary Magdalene, Chichester (12th-17th century); St Peter's, Wolverhampton (19th century); and Raunds Furnells, Northamptonshire (10th-12th century). Surface changes were observed in all 18 skulls (excluding the two controls) including two cases where plaques of woven bone were visualized that could not be observed macroscopically. Pits were observed in 7 skulls and 12 displayed perforating lesions, including four cases, previously observed by eye lens as pits, which were shown to be lesions that perforated through, exposing the underlying trabecular bone. This approach could aid in distinguishing pits and porosity caused by an inflammatory response, versus those that are a consequence of marrow expansion. Assessment of the direction and length of the porous lesions (i.e., from the inside out versus from the outside in) may be possible with microscopic methods; however, mixed lesions and co-morbidity of deficiencies and/or metabolic disorders will still make differentiation of the causal factors difficult.

The skeletal effects of lead toxicity in classical antiquity: a report from Laurion, Greece.

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The impact of lead toxicity on past populations has been studied through chemical and isotopic analyses of human remains and associated metabolic diseases. The osteological effects of lead poisoning are less well known in paleopathology. Skeletal effects of living in a lead-impacted environment during the Archaic and Classical periods (6th-5th centuries BCE) in the Laurion region, Greece, are investigated. The area has been recognized since prehistoric times for its mining of silver-rich lead ores and the exploitation of thousands of enslaved people. At Laurion, mines, ore-washeries, and furnaces were situated close to habitation areas, directly affecting living conditions. The remains of ten infants and young children from the Thoricos site at Laurion were examined macroscopically and radiographically for lesions that are due to lead toxicity, including lead bands and metaphyseal hypertrophy. Only one infant displays clear bone lesions, particularly in the distal femur, which was also examined with CT microtomography. Additionally, lesions associated with anemia, scurvy, and rickets were found to coexist in the same individual. These findings mark the first evidence of lead's effects on human remains from classical antiquity. Differential diagnosis helps distinguish lead-induced lesions from those due to specific conditions, such as scurvy, and non-specific pathologies, such as growth arrest and recovery lines. This case informs the diagnosis of lead toxicity from the human skeleton, its impact on morbidity and mortality, and the history of this environmental contaminant. Further research on human remains from Laurion using chemical methods is needed to assess population toxicity over time.

Should we use Fisher's exact test in paleopathology? Fisher's tea drinker and the fixed marginals assumption.

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Analyzing contingency tables of prevalence data in order to help test methodological or biocultural hypotheses is one of the most common applications of statistics in paleopathology. It is often said that when numbers are small (>20% of expected cell frequencies <5 in a table) Fisher's exact test (FET), or extensions of it, should be substituted for chi-square. The use of FET has attracted long-running (>80 years) controversy in scientific and social science disciplines. However, this has not penetrated the paleopathology literature. Much of this centers around the fixed marginals assumption, which underlies the probability

calculations in FET. In this presentation, I will explain this assumption using examples from cognate disciplines and consider, by analogy, the extent to which paleopathology data satisfies it. Analogy with studies in biomedicine and other disciplines suggests that our data probably violates this assumption. We thus need to be cautious before applying FET. For each dataset, this will involve thinking about factors including the magnitude and direction of error in p-values that may occur in FET, versus other inferential tests (e.g., chi-square, Monte Carlo methods) that we might apply to sparsely populated contingency tables. The application of FET raises subtle issues, and the continuing debate in other disciplines indicates that it may take time to address them thoroughly in paleopathology. Paleopathologists should routinely go beyond standard statistical textbooks and consult the primary literature in applied statistics in order to effectively carry out their research.

Challenging human 'wacrifice' through tuberculosis: an update from Abydos, Egypt.

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The site of Abydos, Egypt, is the primary location of one of the most controversial debates in Early Dynastic scholarship: did the kings of the 1st Dynasty (c. 3050-2900 BCE) practice retainer sacrifice at the occasion of their death? Twentieth-century excavations concluded that several hundred individuals were sacrificed over the nine reigns of the 1st Dynasty rulers and that the sacrificed individuals were interred in graves surrounding the rulers' monuments. Proponents of the human sacrifice theory argue 1) that sacrificed individuals were meant to serve the ruler in the afterlife and 2) that the sacrifices eliminated potential competitors to the throne. 21st-century reinvestigations have cast serious doubt on the plausibility of human sacrifice. The Meret-Neith Project has re-excavated the tomb of Queen Meret-Neith, the only woman buried at the 1st Dynasty royal cemetery with 42 subsidiary burials. Several lines of data from the project have refuted the assumptions that led to the conclusion of sacrifice, including the excavation of a section of a spinal column (T9-L1) affected by a severe case of tuberculosis (Pott's Disease). If the bone belongs to one of the subsidiary burials, an individual with the symptoms of active tuberculosis and the kyphosis of five vertebrae would face severe challenges in serving the ruler or presenting a legitimate challenge to rulership. The presence of advanced, active tuberculosis in this ancient population nuances long-standing assumptions about absolute power and state formation in 1st Dynasty Egypt. This paper exemplifies the value of using paleopathology to inform socio-political history.

Non-adult frailty in Middle to Late Bronze Age and Early Iron Age central Greece.

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Mycenaeans in Greece had centralized palaces with expansive trade during the Late Bronze Age (1680 – 1070 BCE). The end of this period is marked by the economic collapse of the Mycenaean palaces, the cause of which is unclear. Frailty of non-adults from pre-Palatial (1680 – 1400 BCE) and post-Palatial (1190 – 1070 BCE) Mycenae will be compared to examine the effects of a dramatic economic transition on health. Frailty scores were developed for 59 non-adults (perinatal – 15 years) using an adjusted Biological Index of Frailty. Assessed frailty characteristics include linear enamel hypoplasia, rickets, *cribra orbitalia*, periosteal new bone formation, trauma, porotic hyperostosis, and caries. Non-adults come from two archaeological sites in Greece, Mitrou ($n = 50$) and Eleon ($n = 9$). The Mitrou sample contains pre-palatial and post-palatial individuals, while the Eleon sample only contains pre-palatial individuals. Non-adults were placed into pre-palatial and post-palatial categories for analysis. The average frailty score and age of individuals in each period were then compared using Cochran-Armitage and Kendall's tau-b tests. Frailty scores were higher and non-adults died at older ages in the pre-palatial period. It is possible that children were frailer with more pathological conditions in the pre-palatial period. Given historical and archaeological data, it is more probable that children were frailer in the post-palatial period because they died before skeletal lesions could manifest. The limitations of this study include sample size and quality, hidden heterogeneity of risk, and selective mortality. This study is significant for understanding Mycenaean collapse and economic transitions.

Periodontal disease and the embodiment of colonial oppression: variable expressions of structural violence within Muchik communities of the North Coast of Peru (1535–1750 CE).

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Periodontal disease (PD) has long been considered a paleopathological marker of health, but less work has surrounded its interpretive potential. This research examines PD in Colonial northern Peru, where Indigenous peoples experienced dramatic biocultural transformations. Here, various chronic diseases were driven by structural violence endured by the Muchik communities of Mórrope and Eten in the Lambayeque Valley Complex. PD prevalence and severity serve here as indicators of how colonial exploitation, material deprivation, and social instability were biologically internalized, reshaping Indigenous health on a physiological level. To assess impacts, we analyzed skeletal remains from 64 individuals in Mórrope and 115 in Eten (including only individuals aged 18+), utilizing measurements of CEJ–alveolar margin distance and indicators of alveolar bone porosity and recession as markers of periodontal health. Contrary to our hypotheses predicting higher PD prevalence in economically distressed Mórrope, odds ratios (OR) indicated a higher prevalence in Eten (59% vs. 36%; $\text{OR} = 0.38$; $p = 0.01$), with no significant variance in severity between the two towns ($\text{OR} = 0.61$; $p = 0.01$). These findings suggest a complex, non-linear relationship between colonial stressors and biological responses, wherein local adaptive mechanisms or differential resource access may mitigate broader physiological impacts of structural violence. The high prevalence of antemortem tooth loss and alveolar remodeling observed in Mórrope is likely consequence of their consumption of carbohydrate-rich fallback foods that generated worse oral health than in Eten. This study advances understanding of PD as a biocultural artifact, reflecting both structurally violent relationships and how pathways of inequality become physiologically encoded within Indigenous bodies.

Macroscopic and micro-CT assessment of a rare case of osteoid osteoma from an Avar necropolis in Serbia (700–900 CE).

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Osteoid osteomas (OO) rarely occur in the facial region of the skeleton. The impacts of these ovoid-shaped tumors in this region, despite their small size (<1 cm) and benign nature, can be severe, including pain and functional limitations. To understand how a facial OO can impact the quality of life of an individual, specialized microscopic documentation is necessary. Here we present a macro-morphological and microstructural study of a rare case of a zygomatic OO from an archaeological context. The analyzed sample derives from grave No.62/2, site 40 - Potes Gornje Sajlovo, northern Serbia, dated to between the 7th and the 9th century CE. The analyzed skeleton belongs to an old adult male. A high-resolution micro-computed tomography examination of the entire zygomatic

bone with the OO was performed. Micro-CT analysis showed that the lesion was well circumscribed, with a central nidus of 3.7 mm in length (along with surrounding sclerotic bone), confirming the macro-morphological findings and diagnosis of the OO. The location and extent of the OO suggest this person suffered daily from persistent facial pain, swelling, and functional limitations (chewing and/or speaking). This case represents a rare example of a benign facial tumor documented in an archaeological population, emphasizing the use of micro-CT analysis in the differential diagnosis process and understanding the impact of the tumor. Further research into benign tumors and the application of state-of-the-art methodologies will certainly contribute to expanding our knowledge of neoplastic lesions in paleo-oncology.

Intestinal parasites in the Ottoman Period coastal town of Ainos (Türkiye).

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Little is known about parasite infection in populations of the Ottoman Empire from the 14th to the early 20th centuries. Our aim was to learn more by analyzing five sediment samples taken from the excavation of a stone-lined cesspit excavated from a house in Ainos, a harbor on the coast of northwest Türkiye. Radiocarbon dating shows the cesspit was in use from the 1600s to the 1800s. Digital light microscopy was employed to detect the eggs of intestinal helminths and ELISA was used to identify protozoan parasites that cause diarrhea and dysentery. We found the eggs of roundworm and whipworm in high concentrations in all samples, and three of the five samples were positive for the protozoan parasite *Giardia duodenalis* that causes diarrhea. This shows that sanitation at the site was ineffective at separating human feces from food and drink, therefore allowing reinfection. The eggs of the Lancet liver fluke (*Dicrocoelium sp.*) were also found in multiple samples. This parasite typically infects the liver of herbivores such as cattle and sheep, thus likely indicates that the population was eating the liver of these animals but not becoming infected themselves. This is only the second cesspit from the Ottoman Empire to be analyzed for parasites, so it provides a good comparison with past research from Israel. In order to better understand intestinal infectious diseases during the Ottoman Period, further analyses are needed in other regions of the empire, such as North Africa, the Middle East and Eastern Europe.

Paleogenomic insights into the history of tuberculosis in South America across diverse cultural contexts.

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Despite abundant skeletal evidence of pre-Hispanic tuberculosis (TB) in South America, genomic data of the *Mycobacterium tuberculosis* complex (MTBC) strains circulating at that time remain limited to the northwestern (Colombia) and western (Peru) regions. This is partly due to challenges in recovering, authenticating, and analyzing MTBC DNA from archaeological remains. Here, we provide new genomic evidence of MTBC distribution in pre-Hispanic times and its reach to the Southern Cone (Argentina) through application of a thorough screening method and a novel authentication approach for MTBC DNA. Targeted analysis of seven individuals presenting pathology consistent with TB, coupled with the ongoing exploratory screening of over 300 individuals absent of TB pathology, revealed MTBC DNA in five individuals, including morphologically invisible cases. A biologically male individual with signs of TB yielded a high-coverage (66x) MTBC genome from ~1090 years ago in Lomitas de Saujil. Phylogenetic analysis places this strain within the *M. pinnipedii* subclade, extending the known range of the phylogroup to Northwest Argentina. Additionally, our novel approach for low-coverage data confirmed four cases of TB in individuals with no skeletal signs from geographically dispersed sites. This includes a hunter-gatherer dated to ~1700 BP, offering the oldest genetic evidence of MTBC in South America and the first detection in a non-agricultural population. Despite its antiquity, this strain is not phylogenetically basal to more recent cases, suggesting dynamic host range and broader MTBC diversity. This study extends genomic TB identification by 700 years and highlights its widespread impact across ecologically and culturally diverse contexts.

Analysis of DISH in a modern population.

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Diffuse idiopathic skeletal hyperostosis (DISH) is the ossification of ligaments with a "melting candlewax" appearance to the spine and has been found in 10-25% of ancient and modern populations. The disease can leave individuals deformed with limited mobility. The etiology is poorly understood, but biological sex, age, obesity, and diabetes are considered the main contributing factors. The purpose of this study was to determine if the association and interaction with select disease processes and life history variables predict the prevalence and severity of DISH. A modern anatomical sample, the USF Donated Skeletal Collection ($n = 108$) was analyzed. The disease severity was scaled 1-4. In total, 57% (62/108) of the sample was found to have DISH, with no significant difference found in the prevalence between males ($n = 36$) and females ($n = 25$), aged 44-96 years. Logistical regression and chi-square analysis were completed to test for the significance of age, sex, weight, occupation, socioeconomic status, cancer, diabetes, smoking, alcoholism, and osteoporosis in the prevalence and severity of DISH. The DISH severity was significantly influenced by being male ($t = 4.017$; $df = 60$; $p < 0.001$; $d = 0.819$), having diabetes ($t = -2.154$; $df = 58$; $p = 0.035$; $d = 0.890$), and/or greater body weight ($R = 0.473$; $R2 = 0.224$; $p < 0.001$; $y = 0.010$ (log x) -0.985). The observed patterns differ from much of the published clinical literature and provide new pathways for understanding the pathophysiology of the condition with important implications for both ancient and modern populations. This study highlights information gained from researching modern populations along with archival data to better understand correlates of diseases in the archaeological record.

Lead poisoning and subadult health in Roman period (1st-7th c. CE) populations from Croatia.

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In modern contexts, the effects of lead poisoning are well-known: decreased fertility, higher rates of miscarriage, failure to thrive in infants, and increased rates of some pathological changes. The main aim is to present preliminary results of a lead poisoning study conducted on several Croatian sites to see if lead concentrations in teeth increased during antiquity, and to check for the possible correlation between lead poisoning and deteriorated subadult health evident in increased frequency of *cribra orbitalia*/porotic hyperostosis, periosteal inflammation, scurvy and rickets. We used bioarchaeological analysis of the bony pathologies and age-at-death of 150 individuals from 18 prehistoric and Roman period sites, along with chemical analysis to establish lead concentrations that have been deposited in primary core tooth enamel. We specifically chose to study subadults under the age of 20 years (70% of the sample) to correlate age-at-death and pathological conditions with lead concentrations. In general, lead values for nine prehistoric

sites (31 samples) are well below 1 ppm, while they are much higher for the nine Roman period sites (119 samples; averaging 5.59 ppm per site), thus showing a significant increase in lead contamination from prehistory to Late Antiquity. Individuals with higher lead levels (over 1 ppm) had a lower age-at-death (one year on average) compared to those with low lead levels, and higher frequencies of *cribra orbitalia*/porotic hyperostosis, periosteal inflammation and scurvy suggesting that lead poisoning had a negative impact on general subadult health during antiquity in the studied region.

Inextricable links: the study of impacts of toxicants in past and present environments.

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At the Summer 2024 ONE Palaeopathology Workshop, our working group explored the intersection of environmental toxicants and human and animal health impacts, identifying key research avenues to elucidate historical and contemporary effects of toxicant exposures. This presentation delivers a concise literature review of completed research on toxicant exposures and health outcomes, highlighting successful approaches and future directions framed within the One Palaeopathology concept. Ongoing work in bioarchaeology, including animals as sentinels and environmental studies, and prevalent toxicant exposures will be discussed, alongside geographical regions with notable human remains studies, baseline values, results, pitfalls, limits, and potential insights. We propose three primary axes to propel the field forward: (1) establishing standardized sample preparation protocols and analytical methods for comparable future studies, 2) developing community outreach strategies to engage local populations, and (3) exploring avenues for future work that stimulate interdisciplinary collaborative research and knowledge sharing on environmental toxicants' impact on human and animal health through time.

Oral health and social position in an early medieval site from Austria.

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We analyzed the oral health of 53 women with potentially different social positions from the early medieval cemetery of Leobersdorf, Austria (7th−8th century CE). Based on genetic relatedness, a six-generation aDNA-based pedigree with most individuals closely related (1st−3rd degree) was reconstructed by an interdisciplinary team. We identified mothers, non-mothers, and women not in the pedigree. The aim of the study is to test if these three groups represent different social positions and experienced different food and oral hygiene. Therefore, we compared caries prevalence, presence of periapical lesions and antemortem tooth loss to see if social differences could be deduced. The results indicate that the mothers had the highest percentage of permanent teeth affected by caries (72.,2%) as compared to the others with ~40% and 50%, respectively. Also, they were most frequently affected by antemortem tooth loss (60%) compared to zero non-mothers and ~30 % of those not integrated in the pedigrees. The percentage of periapical lesions in the mothers was also the highest (47.1%) compared to ~6% in the non-mothers and ~27 % for the women outside. Although mothers had the highest percentages overall, no statistically significant differences occurred. However, the median age was also higher for mothers than for non-mothers and women outside the pedigree (40.5, 23.5 and 35.5 years, respectively). So, we conclude that diet and oral hygiene were comparable between the three groups of women. This points to a good social integration of the "foreign" women into the rather tight "family bonds" shown by the genetic lineages.

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A syndemic approach to One Health in the past.

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The One Health approach highlights the importance of animal-human interactions to health and disease. Here, we discuss how this interdisciplinary approach, which incorporates socio-cultural, climatic, ecological, and economic factors, fits quite naturally with a syndemic model of disease by using previously published data. The syndemic approach (synergistic epidemic) was developed by Merrill Singer in the 1990s and refers to two or more diseases that interact in mutually intensifying ways and are driven by specific social and environmental determinants. Incorporating the One Health perspective shifts the focus of human-centered syndemics to considering how humans may impact animal health in a syndemic (or "synzootic") manner. Here we focus on two synzootics with One Health implications. Firstly, we highlight how the co-infection of bovine tuberculosis and helminths in African buffalo can reverberate through the ecosystem, including increasing chances for human cases of bovine tuberculosis. Secondly, the coexistence of avian influenza A and antimicrobial resistant bacteria in wild birds can result in new, potentially deadlier forms of influenza in domestic fowl, pigs, and humans. Highlighting these synzootics allows an explicit consideration of the intra-action between environmental, economic, and cultural factors that facilitate the coexistence of these diseases within a particular ecosystem. It also underscores how the management of animal diseases, just as with human diseases, must recognize and account for the multiplicity of confounding factors in order to achieve successful outcomes.

Commingled human remains from the former synagogue of Agira (Sicily): From excavation to reburial.

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This study examines commingled human remains recovered from the former synagogue site in Agira, a historic city in central Sicily. It also provides a model for ethical investigations of historical period humans recovered from burial contexts. Agira hosted a vibrant Jewish community until the diaspora of 1493, after which the synagogue was converted into a Catholic church. Recent archaeological excavations (2022–2023) uncovered three primary burials and three mass graves containing a minimum of 85 individuals (51 adults and 34 subadults between birth and 18 years), in use until at least the 19th century. Bioarchaeologists documented demographic and paleopathological data using feature-based digital recording sheets. Of the 32 adults with sufficient data for sex estimation, 14 were identified as male and 18 as female. Evidence of diffuse idiopathic skeletal hyperostosis (DISH) in primary burials may reflect a combination of genetic predisposition and high social status,

given its association with dietary practices. Other findings include metabolic (13.21%), degenerative (16.67%), and traumatic conditions (3.77%), which are commonly seen in rural agricultural communities. By reconstructing the living conditions of a rural Christian community in Agira, this research provides a nuanced paleopathological profile of the population and emphasizes the importance of professional and ethical approaches to analyzing commingled remains. These findings contribute to broader discussions on health, resilience, and social dynamics in historical populations.

Funding statement: This bioarchaeological study was supported by the City Council of Agira (Enna, Italy).

Stressing about stress: assessing relationships between dental enamel hypoplasia and dental cortisol concentrations.

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Physiological stress is a critical topic within paleopathology, where macroscopic skeletal stress indicators, such as dental enamel hypoplasia (DEH), are commonly assessed. Recent research has also begun to explore biochemical stress markers, including the stress hormone cortisol, which has been identified in human teeth. Although promising, dental cortisol analyses are new and have yet to be directly compared with typical stress indicators assessed in paleopathology. In this study, dental cortisol concentrations were analyzed in 10 teeth that displayed enamel hypoplastic defects. The selected teeth came from nine individuals buried in the 'Brno-Vídeňská Street' cemetery, dated to the 11th-12th century, and located in the present-day Czech Republic. Cortisol was assessed in dentine and enamel from each tooth through enzyme-linked immunosorbent assay. Six teeth generated detectable cortisol concentrations in multiple tissues, suggesting a possible relationship between cortisol and dental enamel hypoplasia. Although more research is needed, hypercortisolism, stemming from repeated or prolonged stress exposure, could be a direct causative mechanism in the formation of some enamel hypoplastic defects. Alternatively, heightened cortisol concentrations could underlie and/or exacerbate other factors contributing to DEH formation, such as increased risk of infection from a suppressed immune system. However, other factors and influences, including differential preservation and methodological limitations, need to be considered. With continued evaluation and development, dental cortisol methods may provide an additional tool for assessing stress in past, as well as present and future populations.

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Sacrifice or epidemic: further examination of data from La Cueva de los Muertos Chiquitos, Rio Zape, Durango, Mexico.

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La Cueva de los Muertos Chiquitos was occupied between 600 and 800 CE. The earliest feature at the site was an adobe floor that sealed a communal burial of seven subadults. Their ages range from 2 to 18 months with an average of 6. Archaeological evidence of nearly overlapping burials and the manufacture of burial cloths and mats from several large source textiles indicated an emergency interment. A disease outbreak was proposed by the archaeologists. More recently, a sacrifice hypothesis was proposed based on ethnohistoric and artifactual evidence including historic accounts of warfare and cached ceremonial artifacts including blades. Also, the authors of the sacrifice hypothesis cite the spread of a Mesoamerican Tláloc cult. We are summarizing the archaeological data supporting ritual sacrifice and presenting new molecular parasite data relevant to disease. Parasites are present in the burial sediments showing the presence of four roundworm parasites. New DNA bar coding analyses of coprolites in trash deposits overlaying the adobe floor show a diversity of infectious agents including several diarrhea-causing bacterial and protozoa species. We cannot associate these pathogens directly with the burials, but we can say that throughout the occupation of the site, people had a high exposures to a diversity of pathogens. This is an indicator of overall health risks, consistent with many pre-modern people lacking adequate sanitation. Certainly, mortality in early life is high under these conditions, across cultures and times and places. Thus, there is merit to both hypotheses.

Combining dental paleopathology and stable isotope analysis: an interdisciplinary approach to the reconstruction of pre-Roman foodways in Italy (7th-4th centuries BCE).

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Pre-Roman Italy was a diverse region with distinct populations, notably the Etruscans. Despite their prominence, their diet, nutrition, and oral health are underexplored. This study addresses this gap by examining the bidirectional relationship between nutrition and oral health through dentoalveolar pathologies (e.g., dental caries, ante mortem tooth loss, periapical lesions, periodontal disease, and dental calculus) and stable isotope analysis of $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ from human remains. The research analyzed 63 skeletons from six funerary contexts (7th–4th centuries BCE) across Etruria Padana (northern Italy), Etruria Propria (central Italy), and Etruria Campana (southern Italy). The burials represented elite and medium-low social classes, reflecting stratification of Etruscan society. Regional dietary patterns emerged: Etruria Campana exhibited a plant-dominated diet, while richer contexts showed greater consumption of terrestrial and marine protein. The analysis of oral pathologies revealed moderate-to-high true prevalence rates of dental caries (11.1%, 111/997) and periodontal disease (23%, 435/890), with crude prevalence of dental calculus at 78.2% (43/55). Interestingly, the study found associations between the high burden of dental caries and periodontal disease and increased reliance on pro-inflammatory diet based on carbohydrate-rich foods and animal proteins. The integration of macroscopic and biochemical analysis along with the contextualization of the findings within detailed archaeological frameworks highlights the socioeconomic and sociocultural complexities of food consumption in pre-Roman Italy. A limitation of this study was the unequal representation of sites, with northern Italy underrepresented compared to other areas. Future research should explore paleoproteomics of dental calculus for a more detailed characterization of individual dietary practices.

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Identifying caries intervention in ancient Maya teeth.

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Caries intervention in the form of scraping, chipping, probing, and drilling has been documented in several premodern societies around the world. The prevalence, variety, and nature of these behaviors can yield significant insights into ancient oral care. The dentitions of 329 individuals from 25 archaeological sites across the Southern Maya Lowlands were microscopically examined for evidence of caries intervention. The full sample comprises five regional sub-samples, with the largest ($n = 117$) from Central Belize. These individuals span the Late Preclassic to Terminal Classic (250 BCE – 900 CE) and include both adults ($n = 258$) and non-adults ($n = 71$). Each carious lesion recorded, as well as the surrounding dental surface(s), was inspected visually via digital video microscopy and any abrasions, grooves, cut marks, or other mechanical defects were carefully documented. Prevalence and patterns of these marks were assessed according to age group, archaeological

period, and biological sex. This poster presents evidence for direct mechanical intervention in and around caries, documented in 19 individuals (5.8%). Evidence for highly sophisticated dental intervention in the form of occlusal drilling was documented in two individuals (0.1%). These artificial defects are characterized by cut marks, scraping, and circumferential striations and are differentiated from aesthetic modifications by their location in the mouth and on the tooth. These results comprise previously undocumented therapeutic interventions in the Maya area. However, the formation of these mechanical defects may be multifactorial and further consideration of possible explanations is warranted. Further attention to these practices via microscopic examination by other researchers is encouraged.

A case of probable developmental hip dysplasia: paleopathology and differential diagnosis of a Late Moche Individual, North Coast of Peru (550–800 CE).

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Of the many types of paleopathological conditions, congenital or developmental errors have historically received less attention. This is particularly true of the skeletal record of the north coast of Peru. In this case study, we describe and conduct differential diagnosis involving a Late Moche adult (550-800 CE) from Huaca Santa Rosa de Pucalá in the Lambayeque Valley Complex. The individual featured asymmetrical pseudo-acetabula on the lateral surfaces of the ilia. The true acetabula are significantly reduced in size, abnormally shallow, and asymmetrical. Both femoral heads are malformed. Lower limb bones demonstrate abnormally low mass, suggesting habitual absence of normal locomotion. Diagnostic options include developmental dysplasia of the hip (DDH), Leggs-Calvé-Perthes disease, and trauma-induced bilateral hip dislocation. The most likely differential diagnosis is DDH, which is the first of its kind described on the pre-Hispanic north coast. Moreover, this individual would have severely compromised mobility. Without help, this life-long condition would constrain their abilities to obtain necessary resources for survival. Nevertheless, this person lived into the seventh decade of life (63 years old as estimated by Transition Analysis 3), indicative of some degree of long-term caregiving. Additionally, the individual was buried with several copper pieces and nine miniature ceramic vessels. This is notable at this site where most individuals had few to no grave goods. Considering that this individual would have limited ability to contribute physically to their community, these burial goods suggest that this person was not only cared for but mourned by their immediate community.

A comparison of dental versus skeletal age estimations in Nubian (Sudan) non-adults.

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Skeletal growth, being more susceptible to physiological and environmental stressors, is more likely to diverge from dental age-at-death estimates. This research compares dental and skeletal age-at-death estimations while integrating non-specific stress indicators (NSSI's) for a more context-sensitive understanding of the relationship between ontogeny and embodied inequality. Nine individuals (birth to ~7 years old) with preserved dentition and skeletal elements were analyzed from three Nubian sites (Abu Fatima, Attiri, and Hannek). Seven exhibited differences between their skeletal and dental ages varying by ~6 months to ~2 years, while two showed consistent skeletal and dental ages. NSSI's were observed in six individuals. Despite dental-skeletal age differences and a majority of individuals with NSSI's, no significant relationship was found between age discrepancies and NSSI's ($\chi 2$ (1, $N = 9) = 0.32$, $p = 0.571$), potentially due to the small sample size or normal population-level variation. It is also possible that in this sample of nine individuals there is no correlation between NSSI's and growth. These findings suggest that while there is variation in dental-skeletal age-at-death estimations in Nubian communities, there is no clear relationship between this difference and the presence of NSSI's. This research contributes to a more nuanced understanding of ontogeny in Nubian non-adults, while also pointing to the need for larger, population-specific datasets to better disentangle the interplay between physiological stressors and skeletal and dental development.

A historical influenza genome from Switzerland provides deeper insights into host adaptation during the 1918 flu pandemic in Europe.

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During 1918 and 1920, the “Spanish” flu pandemic spread globally causing between 20 million to 100 million deaths. While historical data can provide insights into the disease dynamics such as the occurrence and severity of the pandemic waves, details on the genetic structure of the causative agent, the influenza A virus, are still limited. Increased sampling of viral genomes from various countries can help to reveal patterns of host adaptation during the waves of the pandemic. A major source for ancient RNA recovery, in particular for ancient RNA viral genomes, is well-documented formalin-fixed wet specimen samples curated in medical and museum collections. However, to unlock the potential of these collections efficient ancient RNA processing protocols are required. Here, we present the first 1918 influenza genome from Switzerland, which we recovered with a new protocol for ancient RNA sequencing that uses a ligation-based approach and is efficient for the recovery of ancient viral RNA, in particular, small fragments. Our high-coverage genome, originating from the beginning of the first pandemic wave in Zurich already contains three mutations for human adaptation, whereas contemporary strains from Germany were not yet fully adapted to the human host. Therewith, our results reveal significant insights into the dynamics of human adaptation during the first European wave of the 1918 pandemic. Furthermore, we introduce an efficient workflow for ancient RNA recovery from formalin-fixed wet specimen samples that are particularly suitable for ancient RNA viruses.

Life and death by the sea: paleopathological insights from an Early Preceramic individual from the Paracas Peninsula, Peru (ca. 10,000 calBP).

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We present the bioarchaeological and paleopathological analysis of an Early Preceramic individual (10,299 - 9460 calBP) from Santo Domingo, Paracas Peninsula, Peru. Excavated by Frédéric Engel in the 1950s, these remains provide a rare glimpse into the life of a marine hunter-gatherer during early ecological and economic transitions on Peru's south coast. No in-depth paleopathological studies of Early Preceramic remains from this region exist to date, offering critical insight into early lifeways during a transformative and poorly understood period in Andean prehistory. The remains were re-evaluated macroscopically in 2024, establishing the biological profile of an adult male presenting a remarkable case of cranial modification, characterized by an unusual anterior-posterior compression. Predating known cases from Pernil Alto by several millennia, this may represent the earliest documented example of cranial modification in Peru. Extensive spinal pathological lesions were observed, including Schmorl's nodes, spondylolysis, sacroiliac joint fusion, symphyseal ligaments ossification, and severe spinal osteoarthritis. Additional findings include vertebral collapse, destructive lesions on T6-L5, considerable osteophyte and

syndesmophyte formation, and partial fusion of several thoracic and lumbar vertebrae. The pathological lesions suggest a diagnosis of prostate metastatic carcinoma; however, other conditions, including seronegative spondyloarthropathies or infectious diseases, cannot be disregarded. Future biomolecular and imaging studies are needed to provide additional lines of evidence and refine the pathological diagnosis. These findings offer valuable insights into the time depth of certain pathological conditions and cultural practices in South America, shedding light on transforming social identities and health challenges of early coastal populations in Preceramic Peru.

Paleopathological significance of murder investigation records of the Joseon Dynasty, Korea.

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Government records (n > 600) documenting death cases during the late Joseon period (19th to early 20th century) are preserved in the Gyujanggak Library of South Korea. In our project, these murder investigation records are analyzed by historians, paleopathologists, and forensic scientists to uncover the causes of death from that era. Our study recognizes that causes of death before the 20th century differ significantly from those of the 21st century, which presents challenges for accurate paleopathological interpretation. This report focuses on two specific cases. The first case concerns a widow, accused of promiscuity, who was enraged and ultimately poisoned herself. The second case examines how suspects, who initially denied their involvement, were eventually compelled to confess to beating and killing the victims after investigators secured crucial evidence. While poisoning and beating deaths still occur in modern times, these causes of death in the Joseon Dynasty were shaped by the unique social and cultural norms of the period, including societal views on women, crime, and justice. Traditional paleopathology typically relies on human remains from excavation sites to infer the cause of death, but interpreting the precise circumstances of death based solely on recovered remains is inherently challenging. Our study aims to offer valuable insights into the nature of death in the Joseon period by bridging the gap between modern forensic science and historical cases at the time. Funding statement: Our study is supported by the Seoul National University Research Grant (800-20220548) and the Education and Research Encouragement Fund of Seoul National University Hospital (2025).

Analysis of an unknown tumor-like bone pathology, Nileke, China (6th-3rd century BCE).

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Discovery and analysis of archaeological cases of cancer remains an under-investigated branch of paleopathological study today. In focusing on these historical cases, there is the potential for these discoveries to help provide modern-day researchers and physicians with a better understanding of the complete disease progression of various cancers and cancer-like conditions, particularly in the absence of medical intervention. The purpose of this paper is to identify the pathophysiological processes behind an unknown bone lesion observed in the skull of a Pazyryk individual found in the Altai mountains. The differential diagnosis was obtained using photographic analysis of the lesion and skull, and the most likely differential diagnosis of Parosteal Osteosarcoma was ultimately reached following careful consideration of the various characteristics and diagnostic features of the diseases included within the original differential diagnosis. Other conditions that were considered during the differential diagnosis of this condition include Conventional Osteosarcoma, Periosteal Osteosarcoma, Chondrosarcoma, Ewing's Sarcoma, Osteoid-Osteoma, Osteoblastoma, and Osteochondroma. Though this is only one individual case, it helps to serve as an example of how archaeological cases of cancer can potentially be applied to existing paths of inquiry within cancer research, such as by way of revealing environmental factors that may be relevant in the onset of cancer, amongst other topics.

Trauma, interpersonal violence, and climate change over 3000 years in the Lambayeque Valley Complex, Peru.

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Previous research at archaeological sites in the coastal desert of northern Peru suggests strong human behavioral responses to changes in precipitation. For example, at the Huaca de la Luna, Sicán, and the Huanchaquitos las Llamas sites, paleopathological and stratigraphic analyses suggest that sociopolitical elites organized mass human sacrifices between 550 and 1450 CE in response to sudden, intense increases in precipitation, possibly caused by El Niño Southern Oscillation events. However, there has not yet been quantitative research into the relationship involving regional non-ritualized violence and climate variation over the long durée. To investigate the role climate change may have had on driving violence in the Peruvian desert coast outside of episodic sacrifice events, we modeled the relationship between average precipitation, precipitation variability, and cranial trauma in the Lambayeque Valley. We pull paleoclimate data from the PaleoView TRaCE 21k simulations, and paleopathological data from the extensive work of the Lambayeque Valley Biohistory Project, yielding a sample size of 889 individuals from distinct archaeological cultures over 3000 years. Data were analyzed using a Bayesian statistical approach. Ultimately, we found little support for any relationship between mean precipitation or precipitation variability and cranial trauma (−1.7 – 4.75; 95% C.I.). This supports previous meta-analytical work in the South-Central Andes, which found similar results in coastal and middle elevation communities. This study not only reinforces our understanding of the range of human behavioral responses to climate change, but reinforces the hypothesis that mass sacrifice in the Lambayeque Valley Complex was politico-religious in nature rather than an adaptive strategy.

“Your majesty will perceive [sic] that every man by his card tells his own tale.”: Exploring the effects of heavy disease burden in young military men from Victorian Chatham, Kent (UK).

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Across a short nine years, the recently uncovered mid-19th century military burial ground of Whiffens Avenue, Chatham, Kent (UK), a major naval military port at the time, received the bodies of individuals growing up - and not very old – wedged between the Napoleonic and Crimean Wars, at a time of thriving colonialism, cholera epidemics, famines, and medical advances alike. This paper presents first insights into this assemblage of c. 120 individuals with so far 40 skeletons analyzed macroscopically and comprising almost exclusively adolescent (18% of skeletons) to young males (78% of skeletons) who may have enlisted to serve but ended their short lives as convalescents in the adjacent Fort Pitt Military Hospital, a rising star in the treatment of tropical diseases. Most likely rank-and-file soldiers, their skeletons reveal a multitude of palaeopathological indicators for non-specific infectious diseases, treponemal infection, metabolic and respiratory conditions, a response to deplorable living conditions in the barracks and revealing the hidden costs of possible overseas deployment. Coupled with medico-historic evidence from necrological registers, their dissected skeletons, evidence for a push in medical training coinciding with the recent introduction of the Anatomy Act 1832, permit us to particularly explore the acquisition of treponemal disease as well as skeletal evidence of intense infectious bone reaction in relatively young individuals. With another 60 skeletons still to be investigated, we anticipate illuminating new research avenues for investigating skeletal

evidence for infectious and tropical diseases, as well as providing biological evidence contributing to the picture of 19th-century military life.

The bioarchaeology of tobacco use: a pilot study of nicotine and cotinine in tooth dentine.

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Tobacco use has been evident in human populations throughout history. However, the detection of tobacco use, e.g., the presence of nicotine and cotinine, a byproduct of nicotine, originating from tobacco usage, in archaeological human skeletal remains is challenging due to the breakdown of organic material over time. This research attempted to detect tobacco use from dentine in skeletal remains from archaeological contexts. Adapting a method for analyzing dentine by Badillo-Sanchez and colleagues, eight tooth dentine samples were extracted from five skeletons excavated from a Napoleonic battlefield (19th century) in Austria. All five individuals had external signs of tobacco use (e.g., pipe facets and tobacco staining). Dentine samples from the pre-tobacco period (Avar Period) in Europe and modern samples from smokers were also tested as positive/negative controls. After the dentine was extracted and purified, the substrates were run through an ultra-performance liquid chromatography system directly coupled to tandem mass spectrometry. Nicotine was not detected in the archaeological teeth; however, cotinine was identified and quantified in one of the eight samples from the early 19th century. Difficulties of nicotine detection above the Signal-to-Noise levels were also seen in one of the positive modern tooth dentine samples and could be linked to the half-life of nicotine in the body. This extraction detected cotinine in one archaeological sample and all three modern control samples. This indicates that cotinine is a viable proxy for the detection of tobacco use in archaeological remains. These results enable us to further study tobacco's impact on past human populations.

What are the odds of OCD? Osteochondritis dissecans distribution in non-adults from an urban post-medieval (1650–1850 CE) Dutch population.

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Conditions arising from osteochondral fractures, such as osteochondritis dissecans (OCD), straddle the line between trauma and joint disease. The known etiology of OCD makes it a highly informative lesion when observing activity-related paleopathology, as it can be directly linked to trauma to the joint caused by either singular or repetitive excessive force. This study assessed the manifestation and distribution of OCD in 28 individuals between the ages of 3 years (±1 year) and 18 years (±1 year) at death from the urban post-medieval (1650-1850) Dutch community of Arnhem, a population with low socio-economic status and documented child labor practices. Preliminary analysis found that 60% of individuals presented with at least one instance of OCD in either the upper or lower limb, with 25% of individuals having two or more lesions. OCD prevalence in the upper and lower limbs was similar, with 36% of individuals having lesions in the upper limb and 39% having lesions in the lower limb. As expected, lesion presence was correlated with age ($\chi2 = 7{,}295$, $p = 0.026$), but the presence of multiple lesions was not ($\chi2 = 4.188$, $p = 0.123$). Assessing the distribution of OCD between different age categories in this population sheds light on the areas of the skeleton that were frequently affected by the activities these individuals were participating in. Considering that Arnhem has a known history of child labor, these data provide valuable insight into the lived experiences of these children and the types of labor they may have participated in.

Insights across time and oceans: a One Paleopathology approach to the spread of *Toxoplasma gondii*, yellow fever and *Cryptococcus gattii*.

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Shared human and animal pathogens have been transported across oceans to new continents. This study considered what facilitated the expansion of three pathogens: *Toxoplasma gondii*, *Cryptococcus gattii* and yellow fever virus. Historical records, pathogen life cycles, patterns of disease susceptibilities, vector ecology, human activities and natural disasters were considered. The distribution of *T. gondii* was facilitated by domestic cats commonly being used as rodent control aboard ships, which effectively spread its definitive host to all continents. Shipping routes enabled by the Panama Canal, dumping of ship ballast and a tsunami have been tied to the outbreak of the tropical fungus *C. gattii* along the Canadian/American Pacific NW coast. European ships carried enslaved peoples and water containers with the yellow fever virus vector *Aedes aegypti* from areas where the pathogen was endemic to the Americas. Once the yellow fever virus and its principal vector were established in human settlements, the virus was able to adapt to native primate-mosquito sylvan systems, where it exists in a complex dynamic between sylvatic-agricultural/rural-and urban socioecological systems. Although the specific factors that facilitated establishment and maintenance of these pathogen on new continents varied, all were imported on ships and were initially established along land-sea interfaces, areas that have been profoundly impacted by both human activities and natural disasters. Increased susceptibility of previously unexposed hosts also enhanced their spread. Identification of factors enabling human and animal pathogens to cross oceans and become established in new areas is complex and is best investigated through the One Paleopathology approach.

Examining frailty relative to persistent late-stage acquired syphilis infection in pre-antibiotic era individuals.

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The many complexities of clinical and microbiological research on acquired syphilis mean that scientific understandings of its pathogenesis, especially heterogeneity in frailty or susceptibility to persistent, tertiary (late) stage infection relative to human host characteristics, have lagged behind that of other common bacterial infections. In order to quantify frailty to persistent syphilis and build on previous research, an 11-biomarker Skeletal Frailty Index (SFI) (porotic hyperostosis, *cribra orbitalia,* rickets/osteomalacia, osteoporosis, linear enamel hypoplasia, periodontal disease, neoplasms, osteoarthritis, intervertebral disc disease, rotator cuff disease, fracture) measured chronic physiological stress and nutrition. SFIs were calculated for individuals from the pre-antibiotic era, the early 20th century Robert J. Terry Anatomical Collection and the Hamann-Todd Osteological Collection ($N = 56$) with antemortem syphilis diagnosis. The group was split into those with early-stage ($n = 18$) and late-stage ($n = 38$) infection. Results show that the mean between-group SFI varied between early-stage (3.72) and late-stage (4.26) individuals. The difference is not statistically significant, likely due to small early-stage group size (Mann-Whitney *U* test $p = 0.3151$), but may indicate an association between early and later-life stress and undernutrition and vulnerability toward persistent infection. Future work will focus on increasing the group of early-stage individuals

to detect whether this association is meaningful. A deeper understanding of frailty relative to destructive and debilitating late-stage syphilis may improve reconstructions of syphilis's past disease burden but also, via translational science, contribute to refined prognostic, diagnostic, and screening criteria in public health and clinical settings.

Association between dental pathologies and cardiovascular disease in an ancient Egyptian population.

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The global health burden of both dental/periodontal and atherosclerotic vascular disease is well established, as well as their known association. Given such known associations between dental/periodontal disease and an increased risk of cardiovascular disease in modern populations, we aimed to evaluate the association between dental/periodontal disease and atherosclerotic vascular disease in Ancient Egyptian mummified remains. Computed tomography (CT) scans of mummified remains were initially acquired and examined for evidence of atherosclerosis, characterized by calcified plaque in artery walls or calcifications along an artery, by the Horus Project team. From this initial group of mummified remains, 42 Egyptian mummified individuals were assessed for dental/periodontal disease by three independent readers with expertise in bioarchaeology and/or imaging. For the purposes of this study, dental/periodontal disease was defined by periapical lucencies and dental caries. RStudio v4.4.0 was used for all statistical analyses. Age was positively associated with the number of dental caries ($p=0.047$) and periapical lucencies ($p=0.041$). For periapical lucencies, there was no significant association with atherosclerotic vascular beds when including age as a covariate; however, there was a significant positive relationship between periapical lucencies and atherosclerotic vascular beds when age was excluded ($p=0.024$). When considering the presence of periapical lucencies (excluding age as a covariate), the odds of having a higher number of atherosclerotic vascular beds more than doubled (OR = 2.58). Our findings show that the known modern association between dental/periodontal disease holds true in a subset of mummified individuals from Egypt, particularly for periapical lucencies when confounding variables were removed.

A severe case of osteomyelitis of the lower limb from Byzantine Catania (Sicily, ca. 9th century CE): morpho-radiological analysis and lower-limb disability assessment.

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Recent clinical research on lower-limb osteomyelitis shows that the long-held paradigm that chronic antibiotic therapy and/amputation are the only available options is not true; instead, "limb salvage" procedures are emerging. Considering this, how would lower-limb disability impact a person's well-being in ages past? To this end, this presentation illustrates the skeletal remains of *Burial T2* from the 2015 Rotonda Baths excavation in Catania (Sicily, 9th century CE, Byzantine era). The remains only consist of the lower limbs, excluding femora, with the rest of interred skeleton removed during construction for a 19th-century wall. The remains, anthropologically assessed using Buikstra and Ubelaker and Silva, belong to a young adult individual based on epiphyseal union and a probable female based on talar measurements. The well-preserved bones recovered allow for a paleopathological examination of their cortical surfaces using gross morphological visual inspection and paleoradiological investigations (X-ray and CT scan imaging). In the right lower limb, abnormal bone proliferation and ankylosis were observed in the tibia, fibula and talus. Trauma and congenital anomalies were excluded on morphological and radiological examination. This anomaly most likely resulted in a deforming morphology of the lower limb and a disabling impairment suffered by the individual in the form of walking problems. The unfortunate loss of the remaining anatomical districts of this skeleton represents the major limitation of this study in that it makes it difficult to extrapolate a broader interpretation of the global disability suffered by this ancient individual, especially in light of her ultimate, unknown cause of death.

Dietary isotopes and metabolic diseases in 18th to 19th-century Montreal-area nonadults.

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Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope ratios, usually used for dietary reconstruction in bioarchaeology, can be affected by pathophysiological processes. In paleopathology, this has led to increased interest in using isotopic data for disease diagnosis. This study explores the relationship between intra-individual variation in $\delta^{13}C$ and $\delta^{15}N$ and skeletal lesions diagnostic of three metabolic diseases, anemia, scurvy, and rickets, in 18th to 19th-century nonadults from the Montreal area, Canada. The sample consists of nonadults with isotope data from at least four dentine samples formed at different ages. Anemia diagnosis required evidence of orbital marrow hyperplasia; scurvy diagnosis was based on the Ortner criteria, and rickets was based on micro-CT data and core macroscopic lesions. No statistically significant differences emerged in $\delta^{13}C$ intra-individual variation between nonadults with or without rickets (n = 21), scurvy (n = 21), or anemia (n = 16). In contrast, individuals with rickets and anemia had significantly more $\delta^{15}N$ intra-individual variation. For co-occurrence (n = 15), there was no significant difference in $\delta^{13}C$ between individuals with zero, one, or two conditions, although the single individual with three conditions had substantially more variation in $\delta^{13}C$ and $\delta^{15}N$. Individuals with one or two conditions had greater $\delta^{15}N$ variation than those without. This suggests it is reasonable to expect greater $\delta^{15}N$ but not $\delta^{13}C$ variation within nonadults who experienced metabolic disease, supporting the utility of $\delta^{15}N$ in paleopathology investigations. However, the influence of dietary variation, whether contributing to or resulting from the metabolic condition(s), cannot be accounted for, limiting the power of nitrogen isotopes in disease diagnosis.

Tracing the legacy of malaria: integrating paleopathology, ecology, and modeling to inform modern malaria trends.

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Malaria transmission depends closely on environmental conditions

suitable for the primary mosquito vector, *Anopheles* species, to develop, feed, and complete its life cycle. This concept is used in conjunction with the analysis of nonspecific skeletal lesions to infer the disease's presence in regions where it was once endemic. Because environmental and climatic conditions can change significantly over time, advanced modeling to reconstruct ancient environments, and disease vector habitat specifically, can inform our understanding of past risk and transmissibility. Utilizing a One Paleopathology framework, this paper broadly explores the potential for integrating bioarchaeological methods with paleoclimate and disease ecology modeling to understand trends in risk, infection, and adaptation to malaria with a deep-time perspective. Referencing historical and archaeological evidence, we also consider how fluctuating environmental conditions interact critically with human behavior, culture, and identity to produce unequal health outcomes in malaria-endemic areas. We highlight Phaleron Cemetery, an emerging locus of malaria research in the ancient Mediterranean, as a case study. We use open-source paleoclimate data and paleogeographic maps to reconstruct *Anopheles* habitat around the Athenian Basin, including ancient Athens, from the Late Geometric to the Classic periods (750-320 BCE). We compare fluctuations in predicted risk against increasing rates of cranial lesions over time, comparing the non-elite people of Phaleron to elite cemetery populations from the same region. Our exploration highlights how integrated methods can reveal more precise information about shifting risk and long-term health outcomes, in response to environmental and temperature change, with implications for current predictions of malaria's resurgence.

Destigmatizing ancient to contemporary emerging infectious disease origins: a One Paleopathology approach.

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Pre-colonial to contemporary academic, popular, and geopolitical discourses surrounding ancient to contemporary epidemic and pandemic infectious diseases frequently stigmatize associated regions, populations, and cultures, often precipitating discrimination and violence. Throughout history, this stigmatization is often caused by poor understanding of the complex ecosocial structures and processes that drive disease emergence and spread, creating long-term geographical and temporal patterns in emerging infectious diseases (EIDs), past to present. Here, we propose that One Paleopathology represents a valuable pedagogical and interpretive tool for uncovering the contingent social, economic, and ecological contexts underlying past to present EID origins and therefore deconstructing, denaturalizing, and combating harmful narratives surrounding them. We present five 15th-21st century case studies employing genomic, archival, and skeletal evidence; these focus on colonialism and social determinants within the origins and spread of syphilis/treponematosis, tuberculosis, HIV/AIDS, and ecology and reservoir distribution in coronaviruses and pandemic influenza. These demonstrate paleopathology's vital role in empirically revealing context-specific drivers of ancient to contemporary EIDs. They further evidence these data's applicability to clinical medicine and public health interventions, education, and surveillance, partially through translation science. Finally, they reveal how paleopathology can be used to destigmatize disease origins, burden, transmission and cultural and geographical patterning (e.g., global South) in classroom, research, and popular arenas. Potential implications span paleopathologically informed tailored epidemiologic surveillance of human-environmental-animal-plant-pathogen interactions (HEAPP) (e.g., bats, coronaviruses) to reducing motivations for hate crimes against socially marginalized communities (e.g., AAPI racism, COVID-19), and we conclude with concrete suggestions for achieving these (e.g., classroom exercises, monitoring strategies).