A multi-disciplinary approach to understanding Hong Kong's past: bioanthropological, biomolecular, and zooarchaeological methods

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Abstract

The past of Hong Kong has been extensively explored through close to a century's systematic archaeological surveying, investigations, and excavations. These efforts mostly included landscape, artefactual, and rescue archaeology. This article highlights the potential of a largely underutilized subfield of archaeology in Hong Kong: archaeological science. Focusing on three main areas of archaeological science: bioanthropology, bio-molecular archaeology, and zooarchaeology, the main objective of this paper is threefold: 1) to provide an overview of recent developments in bioarchaeological techniques; 2) to showcase successful applications of bioarchaeological techniques in deriving archaeological information in the region's past; and lastly, 3) to provide a roadmap for future archaeological research in Hong Kong. We hope that this review will help to promote the use of archaeological science in Hong Kong, and enrich the current archaeological and historical narratives we can tell.

概要

近一個世紀以來，考古學家透過嚴謹而有系統的調查和發掘方法，在香港發現無數考古遺址，揭露了香港自史前時期便是古人類繁衍生息的重要地區。可是，過往的考古研究主要集中在括景觀、文物範疇，以及搶救性考古，惟忽略科技考古的應用。本文主要介紹科技考古學的其中三個領域：生物人類學、生物分子考古學、和動物考古學。我們主要有三個目標：1) 概述科技考古學的最新發展； 2) 展示以上三個研究領域在本港以及鄰近地區的實踐和案例；最後，3) 香港未來的考古研究提供發展路線圖。我們希望這篇文章可以推動科技考古學在香港的應用，以豐富我們目前對香港遠古史的認知。

Keywords

Bioarchaeology; South-East Asia; Bioanthropology; Biomolecular archaeology; Zooarchaeology

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Introduction

The territory now known as Hong Kong has a rich and diverse history dating back to at least the middle Neolithic period (~7,000 BP) (W. Meacham 2009), although there are (highly disputed) claims of detectable human activities dating to as early as 35,000 BP (Wu et al. 2006). Located at the mouth of the Pearl River Delta, the region is well-connected to other parts of Asia. Therefore, the past of Hong Kong has always been deeply intertwined with that of its surrounding neighbours, sharing environmental conditions and cultural elements with many different groups within the modern territories of the People's Republic of China, Vietnam, Laos, and the Kingdom of Cambodia (Higham 1996; Tang 1997). Thus, the significance of Hong Kong's past is far beyond local interest, and can help us better understand the immense socio-cultural dynamics amongst people living in the larger region during prehistoric and historical times.

Just like most parts of Southeast Asia, the warm and humid climate, as well as acidic topsoil that is characteristic of the region make the survival of organic remains rare at most archaeological sites in Hong Kong. While the poor preservation of organic remains certainly makes it a challenge to carry out more in-depth reconstructions of past lives using direct evidence, in the following we will demonstrate with examples that it does not mean nothing can be done. This paper intends to describe three well-established bioarchaeological subfields or approaches that are less practiced in Hong Kong: human osteoarchaeology (or biological/physical anthropology), stable isotope analysis, and zooarchaeology. These three different areas of archaeological science can help answer questions about the past, from reconstructing personal experiences over the course of an individual's life history, to larger-scale aspects of social dynamics such as demographic change, migration, trade networks, subsistence economies, and many more.

Archaeological science

Over the past few decades, archaeology has become an increasingly interdisciplinary field, both in terms of theory and methodology. By incorporating these scientific methods, the field has been completely transformed, with input from biologists, medical professionals, physicists and engineers, chemists, geologists, mineralogists, experts in computer modelling, etc. In terms of theory, archaeologists also borrow frameworks from fields such as social anthropology, political geography, and economic theory to help better describe and understand past human societies. Equipped with these new approaches, archaeologists are no longer limited to asking the standard set of questions we have always asked, such as our attempts to derive an artefact's function or to date a human skeleton. We are now able to probe deeper and answer "bigger" questions surrounding social change, kinship structures, migratory activities, and subsistence strategy. As practiced in the Philippines, Japan, Singapore, India, elsewhere in Asia, and in the archaeology of the 'Global North', archaeological sciences are helping researchers gain insights into many previously underexplored facets of past human life.

Human osteoarchaeology and biological anthropology

Human osteoarchaeology comprises the scientific interpretation of biological (and sometimes even occupational or sociocultural) information from skeletonised human remains (CS Larsen 2015; Rivera 2018). Depending on the state of preservation, it is possible to estimate information such as biological sex, age (of death), height, health status, the degree of physical activity, etc. A brief overview of these methods is provided below.

Human osteoarchaeology is a part of biological anthropology, the scientific study of humankind, using evolutionary theory and understanding about human evolution, biology, anatomy, endocrinology, and/or genetics. Scholars in this overarching field view human skeletal evidence as a source of information about human adaptation to different environments, physiological or genetic responses to various human cultural practices/social behavior, and variation among/between human populations in body form and function.

Estimations of sex and age (of death) in humans

In examining skeletonised remains, sex is mostly estimated by observing features that typically exhibit sexual dimorphism, most commonly on the skull and/or pelvis. On the skull, these include regions on the cranium and mandible (see Figure 1). Sex differences also can be observed in areas of the pelvis (Phenice 1969; Klales, Ousley, and Vollner 2012), including the greater sciatic notch of the pelvis (see Figure 2). To acquire a biological sex estimation, some osteologists prefer to score traits from 1-5, then combine both the mean skull trait and mean pelvic trait scores. These methods can give diagnostic accuracy above 80% (Walker 2005, 2008; Klales, Ousley, and Vollner 2012). In cases where the pelvis and skull are pathological, too fragmented, or missing altogether, other elements that can be used for sexing include the clavicle, scapula, and long bones, but these are generally considered to be less accurate than sex estimation using the pelvis and/or skull. Where the sex of individual skeletons is uncertain (yielding a '3' on the 1-5 scale), such cases are typically excluded from sex-divided analyses, but still included in pooled analysis and investigation. The biological sex of older or younger individuals is harder to estimate, as the sexual dimorphic traits are either too worn or not yet developed, respectively. In these cases, biochemical methods such as aDNA analysis (Gibbon et al. 2009), or more recently, proteomics (Parker et al. 2019) are possible ways to determine sex.

When assessing the age of death, examination of skeletal materials can involve one or more of the following: tooth eruption/tooth attrition, epiphyseal union, state of fusion of cranial suture, and the development of the pubic symphysis (Brothwell 1981; Brickley and McKinley 2004; Buikstra and Ubelaker 1994). The presence of wisdom teeth (i.e., third molars) and fused long bone epiphyses will indicate individuals of adult status (McKern and Stewart 1957; Ubelaker 1999). Observations of the pelvis may be combined with interpretations of the cranium to allow adult individuals to be further classed into 'young adult', 'middle adult' and 'older adult' categories (Lovejoy et al. 1985; Meindl and Lovejoy 1985; Buckberry and Chamberlain 2002; White, Black, and Folkens 2012). Recent research has also shown that sex and age estimation equations should be derived that are more specific to population and subsistence economy, as such factors influence sexual dimorphism and any one method is not universally applicable (see (Go, Tallman, and Kim 2019) for a review of the latest advances in biological profiling methods). Archaeologists (and even forensic anthropologists) may look to develop sex and age estimation formulae being developed in future work using reference skeletal collections curated in Hong Kong/Southeast Asia. Population-specific studies will allow us to make more accurate claims about differences in diet or past divisions of labor, for instance, with greater certainty about the age and sex profiles of individuals making up a given population sample.

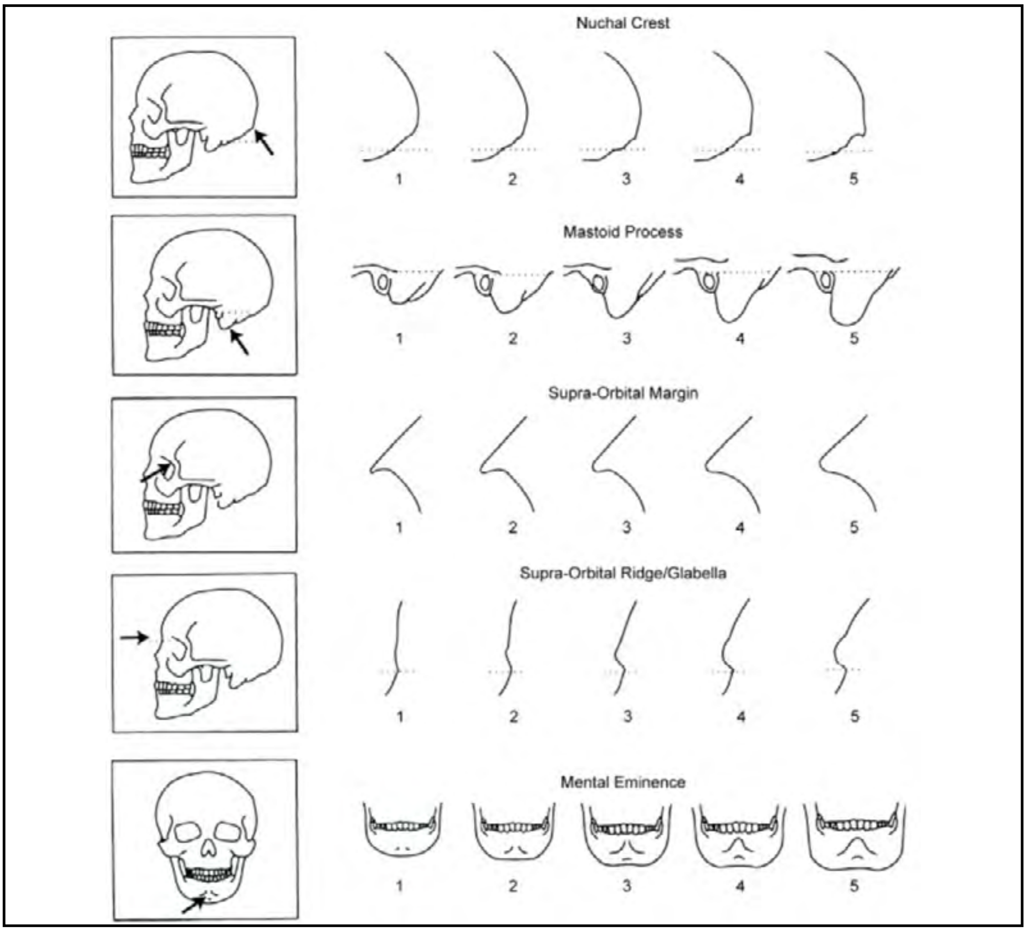

Figure 1 Standard visual method of sex estimation using cranial traits (from Walker (2008), adapted from Buikstra and Ubelaker (1994)). Numbers below the diagrams indicate the scores assignable to skulls that exhibit similar morphology

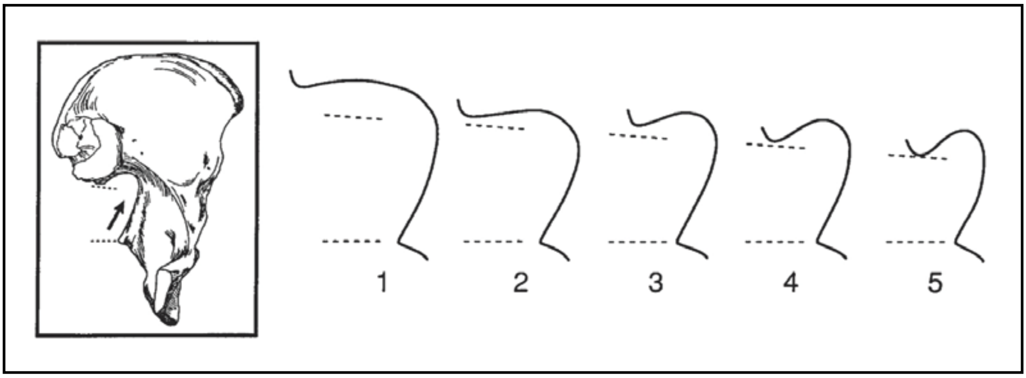

Figure 2 Method developed by Walker (2005) for scoring the greater sciatic notch of the pelvis, adapted from Buikstra and Ubelaker (1994).

Health profiles of past humans

Certain diseases, pathologies, and conditions cause visual, microscopic, and molecular changes throughout the human body. Those observable changes among human remains make up the primary evidence used in the study of the origin, development, and process of diseases known as 'palaeopathology'. Palaeopathologists derive most information relating to health and disease from skeletons or mummified remains, then supplement the skeletal record with historical records, environmental data, and knowledge derived from medical researchers and other archaeological specialists. Thus, it is possible to reconstruct whether a prehistoric person suffered an issue with their health, and if so, derive a differential diagnosis listing the possibilities of what may have caused certain lesions or pathological conditions observed on their bone or teeth (Cohen and Armelagos 1984; Cohen and Crane-Kramer 2007; Roberts and Manchester 2012). Indicators of bony or dental growth interruptions, such as Harris lines (on bones) and enamel hypoplasia (on teeth), can show that there were distressing events or periods of time as a tissue was being formed during early development (CS Larsen 2015). Other signs of nutritional deficiency include cribra orbitalia and rickets, which suggest whether iron and vitamin D intake, respectively, was deficient in a person's diet. Shorter than average stature may also suggest poor nutrition during childhood and adolescence. Signs of trauma, fracture and injury can signal physical accidents, or exist as indicators of interpersonal violence. Other topics of interest concerning past health and disease may include the prevalence and lived experiences of joint disease, neoplastic diseases, congenital diseases, other metabolic and endocrine diseases, dental disease, and infectious disease (this final topic may be particularly relevant in the tropical environment within and surrounding Hong Kong).

Activity patterns of past humans

Repetitive, intense, or prolonged activities can lead to modifications in our bodies, especially in our skeleton and musculature. In bioarchaeology, as shown in Figure 3 and Figure 4 for instance, cross-sectional geometric data of human long bones provide a useful, quantitative means of studying habitual activity (CS Larsen 1995; CS Larsen and Ruff 2011). Measures of bone midshaft thicknesses and shapes reflect the intensities, frequencies and even the directions of physical forces acting on a person's skeleton (CB Ruff et al. 1993; Stock and Pfeiffer 2004; Stock 2006). Measures of bone cortical thickness and subperiosteal area are particularly indicative of mechanical loading when bones are still developing throughout the juvenile 'growth period' and in young adulthood as well (CB Ruff and Hayes 1983; Forwood and Burr 1993; C Ruff 2003). Even handedness can be estimated by comparing the bone cross-sectional morphology between a person's two arms, as the robustness of one's dominant arm should be increased proportional to their activity (Sládek et al. 2007; Sparacello et al. 2011; Macintosh, Pinhasi, and Stock 2014).

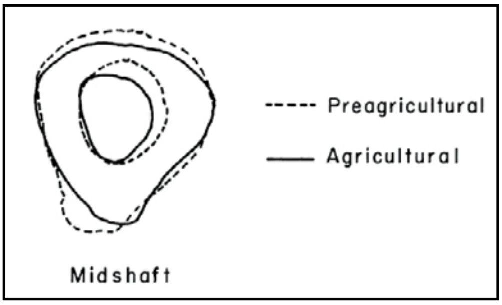

Figure 3 Cross-sectional shape variation in the femoral diaphysis between preagricultural and agricultural groups derived from the coast of Georgia in North America (from (CB Ruff, Larsen, and Hayes 1984)).

Figure 4 Bone cross-sections extracted from 3D bone models at different points along the shaft of a left femur (Rivera 2019).

Frequent or intense use of weaponry (such as spear-throwing or archery) or tools (as in metalworking and farming) will also leave characteristic markings on one' s upper and lower skeleton. These are studied as skeletal indicators of activity, comprising musculoskeletal stress markers and osteoarthritic lesions (Hawkey and Merbs 1995; Waldron 1995; Villotte et al. 2010; Molnar, Ahlstrom, and Leden 2011; Henderson et al. 2013). Certain pathologies can also indicate the working environment around past individuals. For instance, air pollution may cause bony changes to occur as signs of sinusitis (CS Larsen 2015). Other examples are auditory exostoses—small, rounded, often bilateral bony growths or hypoplasias occurring in, or just outside, the earhole—possibly initiated by aquatic activities such as swimming and diving, or exposure to the cold, windy environments near coasts where some prehistoric groups spent a lot of their time exploiting lake, river, and seaside resources (Okumura and Eggers 2005; Villotte and Knüsel 2016).

Previous archaeological work in Hong Kong gives us some understanding of the human biological experience over the last 10,000 years, such as the investigations at Sham Wan that revealed some skeletal indications of malnutrition among a few Neolithic individuals and not much more remarkable concerning their teeth and bones (Lisowski 1978; Walters 1978). There is skeletal evidence from Tung Wan Tsai in Ma Wan, but there remain significant gaps in our knowledge of how their diets and/or their ways of life altered the form of their bones/teeth (Han and Dong 1999). Even more so, the skeletal variation of populations of Hong Kong across/time and space could be viewed through a larger evolutionary lens. We may still explore what effect changing climate, nutritional quality, and population histories would have had on body sizes and health throughout Hong Kong' s prehistory and historical periods. Among this tropical, coastal climate, it is uncertain whether skeletal shape and size variability reflects overall trends observed in the environmental and artifactual evidence. In the past, did the people who inhabit the land now known as Hong Kong engage in region-specific lifestyles that produced unique biological responses and skeletal adaptations?

Biomolecular archaeology – Stable isotope analysis

Biomolecular archaeology examines organic matter extracted from archaeological remains at the chemical level (Pollard 2001). Some of the more widely applied approaches include aDNA analysis, radiocarbon dating, stable and radiogenic isotope analysis, proteomics, and residual analysis. Each of these techniques focuses on different types of biomolecules, and can help to answer different aspects of past lives. This paper will focus on discussing one of the most long-standing, well-established biomolecular archaeological techniques: stable isotope analysis.

Stable isotope analysis is a method that is routinely applied in archaeology for the reconstruction of palaeodietary and palaeomobility practices. This technique is based on the premise that chemical signatures in the environment are transferred to organisms through biological processes such as digestion and respiration. Therefore, organisms living in a particular environment and eating a particular diet should have isotopic signatures that reflect their lifestyle and environment – hence the adage "you are what you eat". It is possible to relate an organism to its living environment and/or diet through stable isotope analysis (Katzenberg 2008; Nehlich 2015; Schwarcz, White, and Longstaffe 2010). Of all isotope systems, the most commonly used isotope systems in archaeology are those of carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), oxygen ($\delta^{18}O$), strontium ($^{87}Sr/^{86}Sr$)[4] , and increasingly sulfur ($\delta^{34}S$). Generally, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ values relate to diet, while $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ values are useful for reconstructing mobility.

The analytical technique of stable isotope analysis is relatively straightforward. Skeletal remains (bone or teeth) consist of organic and inorganic components. Collagen, for example, is an organic component of the skeleton (Figure 5), while hydroxyapatite (or bioapatite) is an inorganic substance. In bones, collagen is the substance that gives bones flexibility, where hydroxyapatite gives structure and strength to bones. In teeth, collagen is mostly found in dentine, where enamel is almost entirely consists of hydroxyapatite. The isotopes $\delta^{15}N$ and $\delta^{34}S$ values are only measured in the organic component, while $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ values are usually measured in the inorganic component, and $\delta^{13}C$ values can be measured in both. Depending on the component required, samples are chemically treated to remove the unwanted component (e.g., using hydrogen peroxide to remove organics or hydrochloric acid to remove inorganics), and then analysed with an isotope ratio mass spectrometer (IRMS). These technologies and standard protocols are similar in other fields that employ isotopic chemistry, such as geology, sedimentology, paleontology, and (paleo)environmental studies.

4. ^{87}Sr is radiogenic, thus, strontium isotope analysis is technically not "stable" isotope analysis.

Figure 5 Extracted collagen from archaeological bones, photographed next to a proximal hand phalange from the left hand

Here, we focus on stable carbon and nitrogen isotope analysis, as it is arguably one of the most well-established biochemical methods used in archaeology. Figure 6 presents a schematic overview of how the two isotopic systems can be studied to understand past human experiences, using real archaeological data as examples[5] (summary of sites presented in Table 1). Generally speaking, $\delta^{13}C$ values can be used to help identify the consumption of food from different ecosystems (e.g., marine vs. terrestrial) and plants using different photosynthetic pathways (e.g., C_3 vs. C_4). C_3 terrestrial foods include crops such as wheat, rice, potato, and most leafy vegetables, as well as all animals that are dependent on these crops. C_4 terrestrial foods include crops such as corn, millet, and sorghum, as well as all animals that are dependent on these crops. Marine protein refers to the various animals, including fish and shellfish, coming from the marine systems. In most temperate regions, C_3 plants dominate the landscape, while only a handful of C_4 plants are exploited intensively by humans. $\delta^{15}N$ value mostly reflects an organism' s trophic position, where organisms higher on the food chain typically have higher $\delta^{15}N$ values. Aquatic systems tend to have much longer food chains, therefore human groups that rely heavily on marine resources have higher $\delta^{15}N$ values than those predominantly relying on terrestrial resources. Figure 6A presents the expected $\delta^{13}C$ and $\delta^{15}N$ values of three major food systems: C_3 terrestrial, C_4 terrestrial, and marine protein. Figure 6B plots the bone collagen $\delta^{13}C$ and $\delta^{15}N$ values of different groups of humans relying on these three food sources. As demonstrated, $\delta^{13}C$ and $\delta^{15}N$ values can clearly distinguish groups with different dietary behaviours.

5.Note that even though the data are real, extreme case studies have been chosen to showcase the maximum variability in the isotopic ranges. In actual archaeological studies, patterns are often more nuance and "messier".

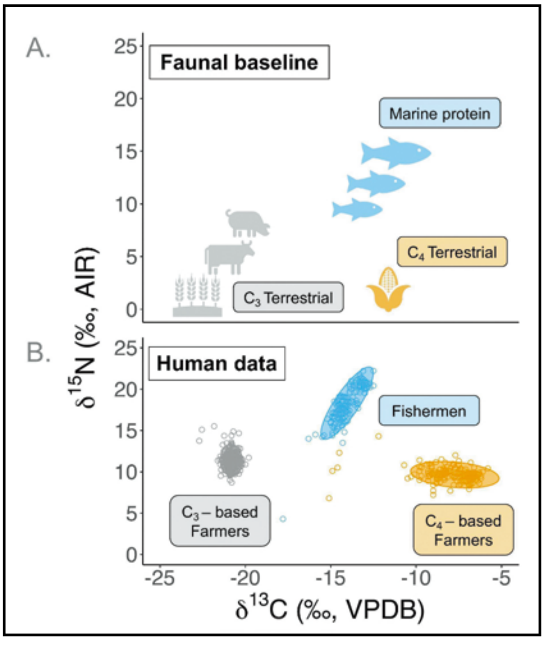

Figure 6 Examples of how different isotope systems can help to understand past dietary patterns. A: an illustrative biplot showing the expected δ ^{13}C and δ ^{15}N values of three major food groups B: biplot of bone collagen δ ^{13}C and δ ^{15}N values, showing distinct clustering of the three major subsistence economies. Values for the faunal baselines are approximations. Values for the human data come from actual archaeological sites as listed in Table 1.

Table 1 Data used in Figure 6B

Subsistence economy type	Period and region	No. of sites	No. of samples	References
Fishermen	Prehistoric, Canadian Arctic	7	164	(Coltrain 2009; Coltrain, Hayes, and O'Rourke 2004)
C_3–based farmers	Neolithic, northern France	8	253	(Cheung et al. 2021; Rey, Goude, and Rottier 2017; Rey et al. 2021)
C_4–based farmers	Bronze Age,Central Plain of China	4	172	(Cheung, Jing, Tang, and Richards 2017; Cheung, Jing, Tang, Yue, et al. 2017; Gong 2016; Hou et al. 2013; Li et al. 2020)

These isotope systems are rarely used on their own. When combined with other archaeological evidence, stable isotope analysis (C, N, S, O, and Sr) can reveal so much more than just past dietary and mobility patterns; they can also help us to explore other fascinating aspects of past human experiences associated with food production and consumption, such as animal husbandry regimes (e.g. free-range, penned, or transhumance) (Chen et al. 2016; Merrett et al. 2021; Vaiglova et al. 2018) and overall subsistence economy (e.g. hunter-gatherer, pastoral, or horticulture societies) (Atahan et al. 2011; Cheung, Jing, Tang, and Richards 2017). When coupled with funerary archaeology, stable isotope analysis has also been shown to help identify differential dietary practices among those in different socioeconomic classes (Cheung, Jing, Tang, Weston, et al. 2017; Cheung, Jing, Tang, Yue, et al. 2017). Sex-based mobility patterns can also help us understand marital practices in past societies, such as patrilocality (i.e., non-local females marrying into males' residence) or matrilocality (i.e., non-local males marrying into females' residence) (Eerkens et al. 2014; Knipper et al. 2017; Toyne et al. 2014). Another interesting topic is that of ancient weaning practices – as breastfeeding infants are technically one trophic level above their nursing mothers, it is possible to identify weaning patterns using stable isotope analysis. The timing of which weaning began can provide unique insights into social issues such as general health of the community, demographic and socioeconomic structures, differential treatment of male and female infants, and birth spacing (Eerkens and Bartelink 2013; Miller et al. 2020; Xia et al. 2018). Thus, all these can then help to further enhance our understanding of past social structures, organisations, and dynamics.

The applications of stable isotope analysis in Southeast Asia are rather limited, but not impossible. Early in the 1980s, the archaeologist Chisholm analyzed the bone collagen of humans and animals from several sites in Hong Kong, including Sham Wan, Pui O, and Chek Lap Kok (Chisholm n.d.; W. 秦 . Meacham 1990). At that time, only δ13C values were obtained, and the results suggested the earliest inhabitants of Hong Kong relied on marine resources in variable amount. More recently, $\delta^{13}C$ and $\delta^{15}N$ values were obtained from 10 humans dated to the middle Neolithic period from Tung Wan Tsai, Ma Wan (Cheung, Schwarcz, and Chisholm 2022). This result not only revealed that the humans at Tung Wan Tsai subsisted heavily on marine protein, but that they also specialized in high-trophic resources, hence they were targeting bigger fish[6]. This example shows how stable isotope analysis can reconstruct more than just what people ate, but in this example, it showed that the Tung Wan Tsai humans had the required knowledge and skills to acquire larger catches, thus provided valuable insights into the livelihoods of these Neolithic humans.

It is true that organic preservation in Hong Kong is generally poor, and that well preserved skeletal remains such as those found at Tung Wan Tsai and Sham Wan are extremely rare. There are still many opportunities for other types of biomolecular analyses to be conducted. For example, cremated remains are found throughout Hong Kong but are largely overlooked. In recent years, a growing body of research has shown that isotopic analyses on cremated remains are possible (Harbeck et al. 2011), and can provide many new and exciting stories regarding past human mobilities, burial rites, and ritual practices in many parts of the world (Snoeck et al. 2016; Snoeck et al. 2018; Grupe et al. 2020). Residue analysis is another method that should be tested in Hong Kong. By characterizing and analyzing absorbed organic residues in archaeological pottery, residue analysis can provide significant insights into how humans utilized and processed food resources in the past (Copley et al. 2003; Evershed et al. 2008; Hansel et al. 2004; Evershed 2008). A recent study has successfully retrieved and analysed lipids from Lapita period pottery from Vanuatu (Leclerc et al. 2018). Considering Vanuatu' s tropical climate, the study has demonstrated that organic residue could very well be preserved in pottery in Hong Kong. Both pottery and cremated remains are found abundantly throughout most prehistoric and historic periods in Hong Kong (W. Meacham 2009). Therefore, these remains presented a cache of unexplored opportunity, waiting to unveil aspects of past life experience in Hong Kong that would otherwise be lost to history.

6. In an aquatic system, trophic levels tend to correlate positively with body sizes (Potapov et al., 2019).

Non-human Organic Remains – Zooarchaeology

Besides human remains, non-human organic remains from the archaeological context, including those of animals and plants, can also contribute greatly to our understanding of the human past.

To date, the only in-depth analysis concerning animal (faunal) and plant (botanical) remains in Hong Kong comes from the multi-period site (Middle Neolithic to early Historic) site of Sham Wan (W. Meacham 1978b), where the relatively well-preserved organic remains, particularly from the Middle Neolithic Period shell midden, allowed for the reconstruction of ancient human exploitation of natural resources. While Hong Kong is situated in a subtropical climatic zone where the humidity and acidic topsoil can adversely affect the preservation of organic remains, a significant number of archaeological sites in Hong Kong, such as Po Yu Wan (Atha and Yip 2016; Williams 1981), Tung Wan Tsai (Chau 2003; Rogers et al. 1995), Sha Po Tsuen (W. Meacham 1992), Sha Tsui (Ho and Ng 1974), Pak Tso Wan (Shang and Ng 2010), Sha Ha (Lu, Zhao, and Zheng 2005), Lo So Shing (W. Meacham 1978a), and Tai Long (W. Meacham 1981) also yielded non-human organic remains. However, noted that most of the collections are not comparable in quantity and preservation conditions to those from Sham Wan, and they are only preliminarily reports without in-depth analysis. The limited remains nonetheless demonstrate a potential for our understanding of not only subsistence economies and practices in the early (pre)history of Hong Kong, but also of early cultural development and potential local and/or long-distance trade and exchange networks in Hong Kong and beyond (Crawford 1988). Given that most of the non-human organic remains yielded from archaeological sites in Hong Kong belong to those of animals, and that it is in more infrequent occasions that plant remains are excavated and studied (either due to preservation or sampling strategies), with the exception for the pollen and phytolith analyses conducted at the sites of Ho Chung and Sha Ha (Shang and Ng 2010; Huang and Pei 2001), we see the need to briefly introduce zooarchaeology to Hong Kong archaeology so to encourage studies that can enrich our understanding of the human-animal relationships through time in the history of Hong Kong.

Zooarchaeology concerns the relationships between humans and animals in the archaeological context. Although zooarchaeological research occasionally utilizes animal depictions (e.g. figurines or rock art), hunting tools (e.g. fish hooks, spearheads), and fatty acids left behind in ceramic remains, this subfield deals primarily with faunal remains yielded from archaeological excavations. These archaeofaunal remains are not limited to those from vertebrates such as mammals, birds, reptiles, amphibians, and fish, but often also include non-insect invertebrates, such as molluscs and crustaceans. And while mineralised tissues such as bone, teeth, horn cores, antlers and shell are the most frequently recovered animal remains from archaeological sites, in certain conditions, other soft tissues may be preserved and studied by zooarchaeologists, such as scales, hides, animal hair/fur/feathers, and even faeces (we refer to these remains as ‘coprolites’).

By examining faunal remains at an archaeological site, zooarchaeologists aim to understand past human-animal relationships by reconstructing how and why ancient populations exploited various species of animals available in, or beyond (through trade, exchange, migration, and gifting), their immediate ecological environments (Laffoon 2018; Sharpe et al. 2018; Crabtree 1990). While one of the more evident contributions of animals to humans is as a subsistence source, many animals are valued beyond mere nutritional provision and can be charged with different cultural, ideological, and even political significance (Russell 2011). As such, zooarchaeological studies can help to answer more than just ‘what people ate’. From helping to reconstruct whole food production processes, including procurement, management, distribution, and consumption, zooarchaeology also provides insights into other non-diet related roles animals played in past human societies, such as utility (e.g., traction labour), the provision of raw materials for tool production, the sourcing of secondary products (e.g., milk, wool, leather) (Greenfield 2010; Mulville and Outram 2005; Bartosiewicz, Van Neer, and Lentacker 1997), as well as involvement in sociocultural and religious/ritual practices. All these contribute to the understanding of not only the animals, their ecological environments and how different animals contributed to the socio-cultural development of past societies, but also the symbiotic relationships between those of humans and animals (deFrance 2009).

The discussion below will focus on the study of mineralized remains of animals, as they are the most commonly found faunal remains in archaeological sites. Some of the aspects zooarchaeologists focus on are similar to those accessed in the study of skeletal remains of human osteoarchaeology (such as age and sex), albeit to answer different archaeological questions.

Body element and species identification of animal bones

To identify what body elements and species are represented in a faunal assemblage, zooarchaeologists use various taxonomic guides and modern reference collections (Figure 7) for specimen comparisons (Lyman 2019; Broughton and Miller 2016). The most ideal scenario for a zooarchaeologist is the presence of complete and articulated remains. However, besides animals found at ritual contexts (i.e., sacrificial animals), animal remains were heavily processed before deposition and not easily identifiable at most archaeological sites (Figure 8). It is important that the first task of a zooarchaeologist is an attempt to identify the bone elements (e.g., femur, mandible, canine tooth, etc.). And then by comparing the bone or tooth with those from a reference collection, it is sometimes possible to identify the species. In cases where the bone remains are too heavily fragmented for identification, biochemical methods such as aDNA or ZooMS (Buckley 2018; Matisoo-Smith 2018; Pilaar Birch et al. 2019) can be employed to help identify the species. Sometimes, when a bone fragment cannot be identified on a species level, zooarchaeologists may still be able to place the fragment in a general taxonomic group such as 'medium-sized mammal', or "artiodactyl".

Figure 7 Comparing an archaeological specimen (upper specimen) with a modern comparative specimen (lower specimen), both are pig femurs

The identification of species found at/near a site can tell us a great deal about the past. For example, the transition from hunting-gathering to an increasing reliance on animal management can be told through the difference in composition of wild and domestic species (Vigne 2008). Moreover, the discovery of non-local species at a site usually connotes trading or gift exchange activities with groups from outside the immediate ecological zones, and helps illustrate the extent of a group' s sociopolitical networks (Crabtree 1990). However, sometimes, finding remains from species that are unexpected in the current environment may not be indicative of past trading activities, but instead indicate a change in the environment. For example, in one study, the abundance of bivalve and fish remains at a site in the arid Eastern desert of Sudan revealed that the region during the Neolithic period was once a lush shrubby savanna with a running stream (Tahir 2011).

Figure 8 Common fragmentation pattern of animal bone remains from an archaeological site.

Quantification of animal bones

Apart from knowing what species of animals were represented in the assemblage, it is also crucial to quantify taxonomic abundance and body-part representation. This is not only to evaluate the relative importance of different groups of animals and their body parts at a site, but it can also help answer questions related to subsistence practices and even access to distribution of meat resources based on social status or occupation. There are several approaches to quantify animal remains, the most common being MNI (minimum number of individuals) and NISP (number of identified specimens). MNI accounts for the most commonly present unique element (e.g. left femur) and therefore provides an estimate for the fewest possible number of individual presence. NISP accounts for the total number of bones (or fragments of bone) identified for each species. The former approach tends to underestimate the total abundance, while the latter tends to overestimate. Therefore, it is important that the zooarchaeologist states clearly which approach is used and communicates the potential bias to the readers. For a more detailed discussion of these methods please see Lyman (1994).

An example of how quantification of animal remains can shed light into past social organisation is demonstrated by a study conducted by Schulz and Gust (1983), where they examined the faunal assemblages from different urban contexts in 19th century Sacramento. Schulz and Gust discovered that despite similar amounts of cattle bones were being recovered at all locales, the quality of the cuts was markedly different between the site of the Golden Eagle Hotel (a luxury hotel) and the site of the city' s jail. The study reported that over 50% of the bone assemblage from the Golden Eagle Hotel consisted of fine steak sections, such as T-bone cuts, while the jail assemblage consisted mostly of soup bones. This gave insights into the differences in diets consumed by the different social groups in the city.

Estimation of sex and age (of death) in animals

The principles of sex and age estimations in animals are fairly similar to those in the study of human remains. For age estimation, the most commonly used methods are tooth eruption/attrition, as well as epiphyseal fusion in long bones (Grant 1982; Silver 1969). For the most part, age estimation is mostly performed using the remains of domesticated animals, as most of the modern comparative data derive from reference samples of domesticates. For sex estimation, zooarchaeologists look for elements with sexual dimorphic characteristics, such as pelvic morphology, the presence of certain features such as canine teeth in musk deer, baculum (i.e. penis bone) in dogs or antlers in deer, and the shape of canine teeth in certain animals including pigs. Looking at the age and sex profile of domesticates is important, as it can allow us to reconstruct the mortality profile, or the ‘kill-off pattern’, at a site. These provide insights into specific animal management practices, in which careful considerations were made to decide which animals to keep alive and which to exploit for their offered resources. For example, for cattle and/or sheep, the preferential culling of very young animals may suggest dairying was the key economy, while herds being killed as young adults were likely exploited for meat (Marom and Bar-Oz 2009; Payne 1973; Gillis et al. 2017; Brunson, He, and Dai 2016).

Pathological traits and other anomalies on animal bones

Evidence of pathologies and processing marks on animal bones may provide further insights into the relationship between how past humans interacted with animals. Many identified paleo-pathologies on animals are a result of the domestication process; animal husbandry places stress on the natural growth of an animal (Upex and Dobney 2011). For example, deformities found on cattle limb bones sometimes indicate that these animals were exploited for traction (Bartosiewicz, Van Neer, and Lentacker 1997; Lin et al. 2018). Cut marks left behind from the butchering process can indicate whether the bones were processed for food or other secondary products, or both (Lee Lyman 1987; Charles 1995).

A final note about the recovery of animal remains at archaeological sites concerns the issue of taphonomic and preservation biases. One big difference between human and animal remains is that animal bones are usually found disarticulated and in a very fragmentary state, as the majority of the bones were likely processed from activities such as food preparation and/or tool making, and the animal carcasses were butchered and discarded in different locales within and/or around a site. At most archaeological sites, zooarchaeological assemblages are dominated by bones from larger animals, such as cattle and pigs. Bones from smaller and younger individuals, especially those from birds and fish, tend to be poorly preserved and overlooked if finer recovery methods with dry screening, smaller mesh size, flotation/water sieving are not employed. Therefore, when designing research projects, and sampling and interpreting zooarchaeological data, it is important to take this preservation bias into consideration.

The study of archaeofaunal remains from Sham Wan demonstrates a lot of potential for zooarchaeological research in the region (W. Meacham 1978b). Remains from terrestrial mammals, fish, and shellfish suggest that the earliest inhabitants of Hong Kong engaged in hunting, fishing, and shellfish gathering activities. In addition to describing what was presented in the faunal assemblage, the research goes further to discuss the ancient fishing and shellfish collecting practices at Sham Wan. For example, based on the behaviors and spawning seasons of the fish species, including two marine fish species of grunt and catfish, identified from the site, specific information about fishing strategies were postulated (Chan 1978; Morton 1978). Interestingly, the results from the zooarchaeological studies corroborated with those from the isotopic study (see section above on Biomolecular Archaeology) that suggests larger fish individuals were preferentially exploited by the early peoples of Hong Kong. Thus, the studies have provided critical insights into how the unique ecological settings at these sites have helped shape their subsistence modes.

In recent years, there has been growing interests in zooarchaeological research in Southeast Asia. Examples include case studies in northern Vietnam (Jones 2017), the peninsular Thailand (Marwick et al. 2017), the northern Pearl River Delta (Lei 2016; Zhang and Huang 2019), as well as Macau (Lei 2021). These zooarchaeological studies have improved our current understanding of the roles animals played in supporting the survival of ancient populations, as well as how different species of animals contributed to early cultural and technological developments in different parts of Southeast Asia. Unfortunately, for Hong Kong, after the immense success of the Sham Wan case study, there has been a dearth of zooarchaeological research since then. As pointed out at the beginning of this section, animal remains are commonly yielded from archaeological sites in Hong Kong. Lu (2007) has also demonstrated, by summarizing the non-human organic remains from archaeological sites in Hong Kong, the potential to amalgamate zooarchaeology, paleobotany, and biomolecular (isotopic) studies to reconstruction the changes in relationships between humans and their environments through the (pre)history of Hong Kong. In addition, examples such as the seashells in burials from Tung Wai Tsai (Antiquities and Monuments Office and（中國社會科學院考古研究所）1999) and the anthropogenically modified mammal bones from Po Yu Wan (Williams 1981) demonstrate that many species of animals contributed to early Hong Kong societies beyond their subsistence values. All these factors provide an argument for developing zooarchaeological research as part of the archaeological research repertoire in Hong Kong. And one of the first steps is to encourage finer excavation and sampling strategies in future excavations for the collection of both macro- and micro-organic materials.

Towards a future of Hong Kong bioarchaeology

With our best efforts, recent attempts to study the earliest inhabitants of Hong Kong through bioarchaeology methods has painted a vibrant picture, where different groups have adapted to the challenges of this environment, establishing for themselves reliable methods of food production, shelters and settlements, relationships with neighbouring groups, and lifestyles that worked for them. Thus, archaeologists in Hong Kong should continue to exploit the recent advances in archaeological science, embrace more collaboration with researchers and practitioners from a larger range of fields, and routinely incorporate more of these approaches into their research. These areas of bioarchaeology will allow us to locate Hong Kong in the variation that exists worldwide in how different human groups adapted to various circumstances such as various farming and animal husbandry practices, metal-working, greater trade networks, and track its development into the Hong Kong we all know today.

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