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Wang, H. (2003a) 'Cong Menbanwan chenghao juluo kan Changjiang chongyou diqu chenghaoquluo de qiyuan yu gongyong (The development and function of moats in the middle Yangzi River area)', *Kaogu*, 9: 61–75.

Wang, Y. (2003b) 'Prehistoric walled settlements in the Chengdu Plain', *Journal of East Asian Archaeology*, 5: 109–148.

Wang, Y. (2005) *Zhongguo yuangu renlen wenhua de yuanliu (The roots of Pleistocene hominids and cultures in China)*, Beijing: Kexue Chubanshe.

Wu, X., Zhang, C., Goldberg, P., Cohen, D., Pan, Y., Arpin, T. and Bar-Yosef, O. (2012) 'Early pottery at 20,000 years ago in Xianrendong cave, China', *Science*, 336: 1696–1700.

Yang, X., Ma, Z., Wang, T., Perry, L., Li, Q., Huan, X. and Yu, J. (2014) 'Starch grain evidence reveals early pottery function cooking plant foods in North China', *Chinese Science Bulletin*, 59: 4352–4358.

Yao, A. (2010) 'Recent developments in the archaeology of southwestern China', *Journal of Archaeological Research*, 18: 203–239.

Yu, S., Zhu, C., Song, J. and Qu, W. (2000) 'Role of climate in the rise and fall of Neolithic cultures on the Yangtze Delta', *Boreas*, 29: 157–165.

Yuan, J. (2007) 'Dongwu kaoguxue jiemi gudai renlei he dongwu de xianghu guanxi (Zooarchaeology reveals the mutual relations between ancient humans and animals)', *Xibu Kaogu*, 2: 82–95.

Yuan, J. and Flad, R.K. (2002) 'Pig domestication in ancient China', *Antiquity*, 76: 724–732.

Zeder, M.A. (2015) 'Core questions in domestication research', *Proceedings of the National Academy of Sciences*, 112: 3191–3198.

Zhang, C. and Hung, H.C. (2008) 'The Neolithic of Southern China: origin, development, and dispersal', *Asian Perspectives: Journal of Archeology for Asia & the Pacific*, 47: 299–329.

Zhang, J.F., Wang, X.Q., Qiu, W.L., Shelach, G., Hu, G., Fu, X., Zhuang, M.G. and Zhou, L.P. (2011) 'The Paleolithic site of Longwangchan in the middle Yellow River, China: chronology, paleoenvironment and implications', *Journal of Archaeological Science*, 38: 1537–1550.

Zhang, X. (2006) *Longshan Wenhua (The Longshan culture)*, Beijing: Wenwu Chubanshe.

Zhao, C. (2009) 'Xinzhai juluo kaogu de shijian yu fangfa (Archaeological methods and practice in research on the settlement of Xinzhai)', *Kaogu*, 2: 48–54.

Zhao, Z. (2011) 'New archaeobotanic data for the study of the origins of agriculture in China', *Current Anthropology*, 52: S295–S306.

Zheng, Y.F., Sun, G.P., Qin, L., Li, C.H., Wu, X.H. and Chen, X.G.(2009) 'Rice fields and modes of rice cultivation between 5000 and 2500 BC in east China', *Journal of Archaeological Science*, 36: 2609–2616.

Zhejiang Sheng Wenwu Kaogu Yanjiusuo. (2004) *Kuahuqiao*, Beijing: Wenwu Chubanshe.

Zhejiang Sheng Wenwu Kaogu Yanjiusuo. (2005) *Fanshan*, Beijing: Wenwu Chubanshe.

Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo. (2003) *Guilin Zengpiyan (The Zengpiyan site, Guilin)*, Beijing: Wenwu Chubanshe.

Zhongguo Shehui, Kexueyuan Kaogu Yanjiusuo. (2010) *Zhongguo Kaoguxue: Xinshiqi shidai Juan (The Archaeology of China: The Neolithic volume)*, Beijing: Zhongguo shehui kexue chubanshe.

Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Shanxidui. (2005) 'Shanxi Xiangfen Taosi chengzhi 2002 nian fajue baogao (Report on the 2002 year excavations at the Taosi site, Xiangfen, Shanxi)', *Kaogu Xuabao*, 3: 307–346.

Zhongguo Shihui Kexueyuan Kaogusuo Yanjiu Guangxi Gongzuodui. (1998) 'Guangxi Yongning xian Dingsishan yizhi de fajue (Excavations at the Dingsishan site, Yongning County, Guangxi)', *Kaogu*, 11: 11–33.

2

OF MILLETS AND WHEAT

Diet and health on the Central Plain of China during the Neolithic and Bronze Age

Kate Pechenkina

This chapter takes a bioarchaeological approach in examining how human diet and health changed on the Central Plain during the time preceding the unification of China by the Qin dynasty (秦朝) in 221 BC. Using the analysis of human skeletons as our starting point, we aim to reconstruct how people's lives changed from the time of the Neolithic Yangshao to that of the Eastern Zhou dynasty, which witnessed agricultural intensification, introduction of new domesticated plants, the development of animal husbandry, population growth, and the rise of social inequality.

The Central Plain (中原) of China is formed by deposits of the Yellow River and spans the fertile agricultural lands of Henan, southern Hebei, southern Shanxi, and the western portion of Shandong. In a broader sense, the Central Plain is frequently amplified to include the adjacent territories of the Guanzhong Plain surrounding the Wei River valley, the northwestern part of Jiangsu, and parts of Anhui and northern Hubei, as human communities of this entire territory shared many aspects of their sociocultural development in the past. The northern center of Chinese agriculture developed in the region of the Central Plain during the Neolithic, independent of the southern agricultural center of Yangzhe, where rice was the main staple cereal (Zhao 2011; Liu et al. 2012). On the Central Plain, broomcorn millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*), cereals characterized by superior resistance to drought and cold, were the two principal crop plants. Between 5000 and ca. 3000 cal. BC this region was occupied by settlements of the Yangshao (仰韶) archaeological tradition, best known for its black on red painted pottery produced by coiling and painted with zoomorphic, anthropomorphic, and, later, geometric motifs (Yan 1992; Ren and Wu 1999; The Institute of Archaeology Chinese Academy of Sciences 2010). The Yangshao was succeeded by the Longshan (龙山) cultural phase and then the early Chinese dynasties. Following the conquest and consolidation of territories by the Qin dynasty, led by Qin Shi Huang (秦始皇), the Central Plain became the core of an expanding Chinese empire (Li 2013).

Development of agriculture and animal husbandry on the Central Plain

The trajectory of early agricultural development on the Central Plain is unusual, as the repertoire of cultivated plants changed considerably during the Bronze Age. The earliest evidence of domesticated millet in this area dates back to more than ~11,000 cal BP (Lu et al. 2009, Yang et al. 2012). Millet agriculture flourished during the Yangshao, when the two species of millet became predominant in the paleobotanical record of the region. A flotation study conducted at the Yangshao tradition Yuhuazhai (鱼化寨) site (Figure 2.1), located in Shaanxi Province, found that millets accounted for almost 90% of the total number of recovered seeds (Zhao 2011), underscoring their economic importance. The ubiquity of the two species of millet was similar: 67% for *Panicum miliaceum* and 63% for *Setaria italica*. Other economically important plants recognized at this site from paleobotanical remains included *Brassica* (cabbage), *Papaver* (poppy), *Vitis* (grapevines), and *Oryza* (rice), the latter represented by only four charred grains (Zhao 2011). Similarly, analysis of plant remains at the nearby Yangshao site of Didong (底董) revealed that the two species of millet accounted for 81% of all plant remains (Wei 2014). Remains of acorns and wild legumes, as well as some plants that couldn't be identified, accounted for the rest. Stable isotope studies of human and animal bones from Yangshao sites confirm that millets served as the major calorie sources for humans as well as for their domesticated animals, i.e. pigs and dogs, during the Yangshao (Pechenkina et al. 2005; Guo et al. 2011; Zhang et al. 2011). Recovery of millet-based noodles from the Late Neolithic Lajia (喇家) archaeological site, dating to around 4,000 BP (Lu et al. 2005), indicates that millets served as a foundation of indigenous cuisine through the end of the Neolithic. Evidence of both millet- and rice-based fermented beverages dating back to the Neolithic was identified by McGovern and colleagues based on pottery and bronze vessel residue analyses (Mcgovern et al. 2004).

Largely provisioned with millet, pigs served as essential domesticated animals during the Neolithic. In the earlier phases of the Yangshao, hunting still made a substantial contribution to the human diet, as suggested by zooarchaeological assemblages. At the Early Yangshao site of Jiangzhai (姜寨), with radiocarbon dates ranging from 6790 to 5360 cal BP (Institute of Archaeology 1991), bones of domestic pigs comprised only 22% (674 out of 3096 identifiable animal bones) of the total faunal assemblage by count (Xi'an Banpo Museum 1988). Different species of deer, including sika deer (*Cervus nippon*), water deer (*Hydropotes inermis*), musk deer (*Moschus moschiferus*), and unidentified deer comprised 60% of the faunal assemblage. Other faunal remains identified from that site included the bones of macaque (*Macaca mulatta*), mole rats (*Myospalax fontianieri*), dhole (*Cuon alpinus*), raccoon dog (*Nyctereutes procyonoides*), wild cattle (*Bos sp.*), Mongolian gazelle (*Prodorcas gutturosa*), and indeterminate *Artiodactyla*, as well as single bones of other wild animals. Pig bones dominate the faunal assemblages of Middle and Late Yangshao sites. For instance, at Xipo (西坡) pig bones comprised 84% of the faunal assemblage by number, while dog bones were 1.3%. Wild animal bone altogether comprised 14.7% of the Xipo assemblage and included the remains of sika deer (*Cervus nippon*), water deer (*Hydropotes inermis*), and musk deer (*Moschus moschiferus*), along with a few fragments of mollusks, fish, and birds (Ma 2003: 129–148). Similarly, more than 80% of animal bones recovered from Xishan (西山), a Miaodigou (庙底沟) phase Yangshao site, belonged to pigs. The remains of twelve species of wild mammals were also identified at Xishan, including those of sika deer (*Cervus nippon*), tufted deer (*Elaphurus cephalophus*), Père David's deer (*Elaphurus davidianus*), water deer (*Hydropotes inermis*), leopard (*Felis pardus*), panther (*Panther tigris*), fox (*Vulpes sp.*), raccoon (*Nyctereutes proycyonoides*), and a number of small mammals (Chen 2006). Domesticated chickens were present in the area as early as 10,000 BP (Xiang et al. 2014), although assessment of their ubiquity is complicated by the difficulty of species diagnostics (Yuan 2001).

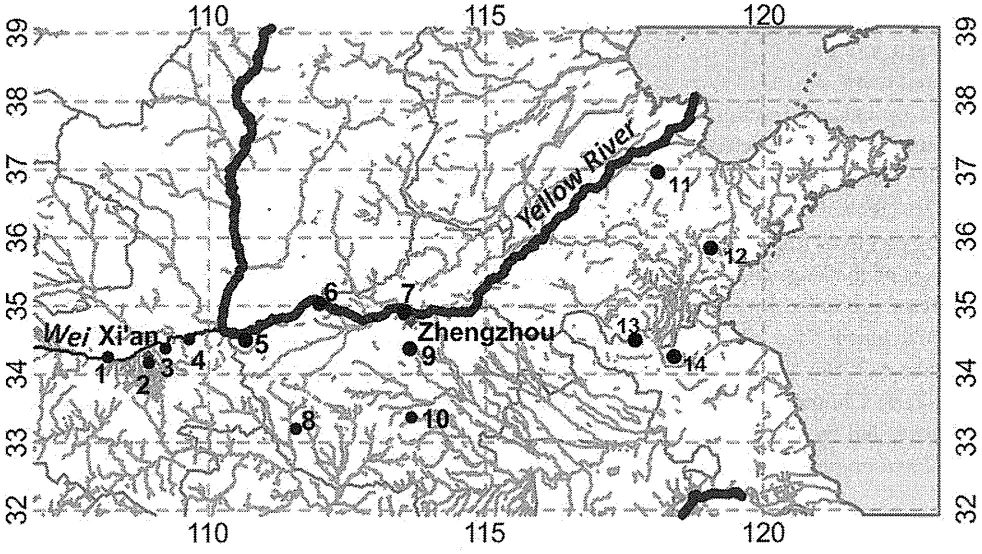

Figure 2.1 Location of archaeological sites discussed in the chapter: 1 – Shijia, 2 – Banpo and Yuhuajai, 3 – Jiangzhai, 4 – Baijia, 5 – Xipo, 6 – Guanjia, 7 – Xishan, 8 – Gouwan, 9 – Ancient Zhenghan city associated sites: Xiyasi, Xinghong, Chanxinyuan, Thermal Power Plant, 10 – Jiahu, 11 – Fujia, 12 – Dongjiaying, 13 – Liangwangchen, 14 – Huating

Development of millet agriculture in China overlapped in time with the Holocene Megathermal, which manifested in this territory as higher mean annual temperatures and greater precipitation between ca. 7900 and 4450 cal yr BP (Xiao et al. 2004; Peng et al. 2005). This favorable episode was followed by the rapid onset of a cool and dry climatic episode around ca. 4450 to 3950 cal yr BP and a generally cooler and drier climate between ca. 4450–2900 cal yr BP, which likely resulted in lower agricultural outputs. The period of climatic instability and colder climate coincided in time with the introduction of new cereals and the expansion of domesticated herbivores into the area.

Wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) first appeared in paleobotanical assemblages from northern China ca. 4600–3900 years ago, during the Late Neolithic (Crawford et al. 2005; Zhao and He 2006; Li et al. 2007; Flad et al. 2010; Dodson et al. 2013). Domesticated soybeans (*Glycine max*) also first appeared in this area during the Late Neolithic and became progressively more important over time (Fuller et al. 2014). Initially and through much of the Bronze Age, the proportion of these new grains remained miniscule, as compared to those of millets, but they seem to have gained in importance after 2500 BP (Fuller and Zhang 2007; Lee and Bestel 2007; Lee et al. 2007; Lan and Chen 2014).

Domesticated herbivores were introduced into the region during the Late Neolithic and early dynasties. Domesticated cattle (*Bos taurus*) appeared on the Central Plain between 4500 and 4000 BP (Lv 2010). Sheep and goats also first appeared in the region during the Late Neolithic and became widespread during the Erlitou (二里头 3900–3500 BC) (Li et al. 2014). Sheep were predominantly raised for wool, as inferred from the advanced age of sheep in several faunal assemblages from this region (Dai et al. 2014), although it is suggested that at Yinxu (殷墟), an archaeological site in Henan, the sheep slaughter pattern was consistent with their utilization for meat (Li et al. 2014). The presence of domesticated horses in the region dating to around 3300 BP has also been documented at Yinxu (Yuan and An 1997). Domesticated water buffalo (*Bubalus bubalus*), used as draft animals, were introduced to China from South Asia as late as 3000 BP (Liu et al. 2006).

How, why, and when wheat supplanted millets, which had servedas the core of indigenous cuisine on the Central Plain of China through the Neolithic, remains enigmatic. Strictly pragmatically, wheat is more productive than millets per cultivated area of land. Although millets are a better source of dietary iron than wheat, they are extremely deficient in protein (FAO 1972). Yet millets had long been established as the foundation of an elaborate cuisine, while wheat and barley don't seem to be appreciated initially. Historic records dating to the Han dynasty consistently refer to wheat, as well as beans, as a poor person's diet, fall back or starvation food, plentiful, yet not very palatable (Yu 1977). Millets were priced at 2.5 times more than wheat or beans during the great famine of AD 194 (Yu 1977). Beans were likely prepared as congee (gruel), but it is not clear how wheat and barley were initially cooked. No technology yet existed for converting these much tougher cereals into thin flour for noodle production. Bray (1984) proposed that they could have been roasted and then pounded down and mixed with oils in the manner of Tibetan tsamba (Bray 1984: 462). Only at the end of the Han dynasty, when the development of hand-mills, as well as large water and animal powered mills, allowed converting wheat into fine flour for noodle production, were these new cereals finally appreciated in the area (Bray 1984: 461).

Stable isotope perspective on Yangshao diets

Stable isotope method

The two stable isotopes of carbon, ^{12}C and ^{13}C, accumulate at different rates in plants using the C3 and C4 pathways of photosynthesis (Farquhar et al. 1984; O'Leary 1988). The overwhelming majority of plants, close to 95% of known species, follow the C3 pathway, which can be utilized only when plant stomata are open. In hot and arid climates, some plants developed a water-conserving C4 pathway of photosynthesis that is more efficient than C3 and can proceed even when stomata are closed allowing plants to conserve moisture during the hot periods of the day. This latter pathway discriminates against heavier isotopes of carbon, including proportionally fewer atoms of ^{13}C into the sugars produced. The consequent $\delta^{13}C$ isotopic signatures of C4 plants are less negative than those of the C3 plants. The two types of plants can be recognized based on leaf anatomy, as C4 plants display a Kranz leaf structure, with bundle sheath cells possessing chloroplasts.

The two millet species were the only C4 domesticates grown in early China. *Setaria viridis*, the wild progenitor of *Setaria italica*, also follows the C4 pathway of photosynthesis. It is a weedy plant that grows on the Central Plain and beyond. Its consumption would certainly shift isotopic signatures in human and animal bones towards less negative $\delta^{13}C$. However, it seems unlikely that humans would consume large quantities of this particular species, as *Setaria viridis* is always found in patches interspersed with other plants in the wild. Besides, isotopic signatures obtained from the bones of wild animals suggest that the overwhelming majority of wild grasses growing in the vicinity of Neolithic settlements in the area were C3.

The C4 pathway results in $\delta^{13}C$ isotopic values averaging around −12.5‰, as opposed to the −26.5‰ typical for C3 plants (van Der Merwe 1982; Schoeninger and Moore 1992; Ambrose 1993). Analysis of modern *Setaria italica* millet grain produced $\delta^{13}C$ values averaging −11.81‰ (Pechenkina et al. 2005). Thus, consumption of millets can be detected by the stable isotope analysis of human and animal bone collagen, which preserves the isotopic composition of the diet plus an approximately 5‰ trophic level enrichment.

Nitrogen isotopic composition ($\delta^{15}N$) for terrestrial food-webs is a reliable indicator of animal product consumption (Ambrose 1991), as $\delta^{15}N$ undergoes a trophic level enrichment of 2–6‰ with every step of the food chain (Minagawa and Wada 1984; Schoeninger and Deniro 1984; Bocherens and Drucker 2003). In human communities where terrestrial diets are inferred from the geographic location and zooarchaeological evidence, higher $\delta^{15}N$ values generally reflect greater proportions of animal products in the diet. Aquatic food-webs, where nitrogen is repeatedly recycled, display very high $\delta^{15}N$ signatures. Therefore, $\delta^{15}N$ in human bone collagen provides an estimate of the amount of animal protein in the diet as well as the degree of dependence on aquatic animal resources (Ambrose 1991). Heavy reliance on legumes (e.g. beans) can considerably depress bone $\delta^{15}N$ values, because legumes maintain colonies of nitrogen-fixing bacteria in their roots and hence have $\delta^{15}N$ values close to 0‰ (Deniro and Epstein 1981).

Brief summary of the archaeological background for Yangshao sites in the analysis

Shaanxi sites

Jiangzhai (姜寨) is an Early Yangshao archaeological site located in Lintong County of Shaanxi Province, south of the Wei River, on the northern bank of the Lin River (Xi'an Banpo Museum 1988) (Figure 2.1). Five radiocarbon dates obtained from charcoal, as well as animal and human bones, range from 4790 to 3360 cal BC (Institute of Archaeology 1991: 262). Jiangzhai had a settled area of approximately 5 hectares, demarcated by a substantial ditch (Xi'an Banpo Museum 1988). During phase I, the living community consisted of about 120 houses. These surrounded a central plaza encompassing circular structures interpreted as animal pens. Five of the largest houses, with a floor area of up to 124 m² each, were initially interpreted as gathering centers for large clans. Each of these houses was associated with a number of medium-size houses of 20–40 m² interpreted by the archaeologists as representing the activity areas of smaller matrilineal clans, each in turn with an aggregate of small houses of its own, each with living space sufficient for a small family of 2–5 people, or possibly a pair of families (Xi'an Banpo Museum 1988: 352–357). Based on the layout of the Jiangzhai site, Shelach (Shelach 2006) argued that its people were communally sharing oriented because its houses were arranged facing inward in circles, while storage pits are all located outside of the houses. Similarly, Lee (Lee 2007) concluded that the Jiangzhai community relied on communal food sharing.

Among 376 excavated burials, 174 were single burials, whereas the rest contained multiple individuals. Burials contained grave goods typical for the Neolithic, including a variety of pottery, stone implements, and arrowheads, as well as jewelry made of stone, bone, and shell (Xi'an Banpo Museum 1988).

The Shijia (史家) site from Weinan County in eastern Shaanxi is the type site for the Shijia phase of Early Yangshao culture in Shaanxi Province, which in this region succeeded the Banpo phase and was followed by Miaodigou. The site is situated on the western bank of the Qiu River, 12 kilometers south of the Wei River (Museum 1978; Wang 1993). A single radiocarbon date obtained for a human bone from Shijia is calibrated to 3779–3526 BC (Institute of Archaeology 1991: 264). Radiocarbon dates associated with the Shijia phase fall between 6140 and 5935 calibrated radiocarbon years ago, or 4190–3985 BC (Wang 1993). The overwhelming majority, 40 out of 43 burials at Shijia, represent multiple secondary interments with individual bodies that apparently partially decomposed before being packed in tight bundles. Multiple bundles were arranged in rows next to one another, with each grave containing multiple rows of funerary bundles (Gao and Lee 1993). Based on a craniometric analysis of Shijia individuals, Gao and Lee (Gao and Lee 1993) proposed that Shijia society was organized in patrilineal clans.

Yuhuazhai (鱼化寨) is a 40,000 m² Yangshao village site located in the western suburbs of Xi'an on a mound located 300 m from Yuhuazhai Village (Zhang and Guo 2003). The site is in close proximity to Banpo (半坡) (Institute of Archaeology 1963), surrounded by moats, and is strikingly similar to Banpo in its layout, features, and artefacts. The site dates to between 7000–6000 cal BP (Zhao 2011). Therefore, paleobotanical remains from Yuhuazhai can be used as proxies for the Banpo assemblage (Zhao 2011). Many of the human bone samples analyzed come from urn burials of juvenile individuals (Zhang et al. 2011).

Henan sites

Xipo (西坡) is situated in the upper Sha River valley, about 3 kilometers north of the Qinling Mountains, in the western corner of Henan Province (Ma 2003; Ma et al. 2005, 2006). Radiocarbon dates obtained from the human remains place Xipo burials toward the end of the Yangshao (5300–4900 BP). This was a relatively large settlement (40 hectares), surrounded by a moat, and with an estimated population of 640–900 people (Ma 2003: 85). A three-level size hierarchy among the houses, as well as the presence of several larger labor-intensive structures, suggests incipient social inequality. The biggest structure may have served as a gathering place for ritual or public functions (Ma 2003: 100). A cemetery outside the moat yielded 22 burials, all single interments. Associated grave goods ranged widely in number, suggesting a degree of status heterogeneity.

Guanjia (关家), the other Middle Yangshao site, was a smaller settlement (9 hectares). It is located along a narrow terrace on the south bank of the Yellow River, about 70 kilometers northeast of Mianchi (Fan 2000). The major occupation at Guanjia was contemporaneous with that at Xipo, but Peiligang and Early Dynastic remains were also present. Ditches demarcate the western and southern limits of the site, where it is not bounded by the Yellow River. Only seven of the 52 burials unearthed had associated artifacts, limited to small personal adornments, such as beads and hairpins. Pottery fragments were recovered from one burial (Fan 2000).

Xishan (西山) is a large Neolithic site in the northwestern suburbs of Zhengzhou City (Liu 1986). The site was initially excavated in 1984, and later for four consecutive years between 1993 and 1996. The total area of the site is 34,000 m². The site has three distinct layers of occupation. Yangshao culture layers were dated to from 6500 to 5000 BP. Its major phase of occupation and the majority of burials correspond to the Miaodigou phase of Yangshao culture (*ca.* 6500–5800 BP).

Gouwan (沟湾) is a Neolithic site located in southwestern Henan, Xichuan (淅川) county, in the Zhangying (张营) administrative district, approximately 800 m west of the Fengzi Mountain (Fu et al. 2010). Three layers of Yangshao occupation are recognized at the site, including Early, Yangshao 1 (7000–6600 BP); Middle, Yangshao 2 (6600–6000 BP); and Late, Yangshao 3 (6000–5500 BP). Yangshao occupation was succeeded at the site by the Qujialing (屈家岭) Culture (5000–4600 BP). Its location in the southern part of Henan suggests that rice cultivation, along with millet agriculture, could have been practiced at the site.

Dietary variation during Yangshao

A considerable quantity of stable isotope data from human and animal bone samples obtained from Neolithic archaeological sites of the Central Plain and adjacent territories has been accumulated in recent years (Cai and Qiu 1984; Pechenkina et al. 2005; Hu et al. 2006, 2008; Barton et al. 2009; Guo et al. 2011; Zhang et al. 2011). These data indicate that domesticated millets became the principal caloric source for humans of the Central Plain during the Yangshao (Table 2.1). Based on published data and our research, Figure 2.2 shows the distribution of the stable isotope values from the Yangshao collagen bone samples.

Several aspects of isotopic variation in Yangshao bone samples are noteworthy:

Table 2.1 Stable isotope values in human bone collagen samples from the Yangshao archaeological sites

site[1]	*sex*	$\delta^{13}C$ ‰				$\delta^{15}N$ ‰				*N*
		mean	*SD*	*median*	*MAD*[2]	*mean*	*SD*	*median*	*MAD*	
Yangshao (7000 BP to 4800 BP):										
Banpo	Total	−14.84	1.93	−14.2	1.19	9.05	NA	9.05	0.0	5
Jiangzhai	F	−9.8	0.9	−9.9	1.3	8.4	0.3	8.4	0.3	12
Jiangzhai	M	−10.1	1.5	−9.9	1.5	9.0	0.6	9.1	0.5	8
Jiangzhai	U	−9.7	NA	−9.7	0.0	8.6	NA	8.6	0.0	1
Jiangzhai	Total	−9.91	1.12	−9.8	1.33	8.63	0.55	8.5	0.58	21
t-test (females–males)		$t = 0.63, p = 0.54$				$\boldsymbol{t = -2.79, p = 0.02}$				
Shijia	F	−10.2	1.0	−10.2	1.4	8.2	0.3	8.2	0.4	3
Shijia	M	−10.0	0.6	−10.2	0.4	8.0	0.6	8.1	0.5	5
Shijia	U	−10.0	NA	−10.0	0.0	7.7	NA	7.7	0.0	1
Shijia	Total	−10.04	0.69	−10.15	0.53	8.07	0.46	8.08	0.52	9
t-test (females–males)		$t = -0.35, p = 0.74$				$t = 0.55, p = 0.59$				
Guanjia	F	−8.3	0.5	−8.3	0.7	6.1	0.8	6.2	1.0	8
Guanjia	M	−7.8	0.6	−7.6	0.5	6.3	0.6	6.2	0.3	13
Guanjia	U	−8.0	0.1	−8.0	0.1	6.5	0.2	6.5	0.2	2
Guanjia	Total	−8	0.58	−7.96	0.61	6.21	0.64	6.23	0.55	23
t-test (females–males)		$t =-1.79, p = 0.09$				$t = -0.56, p = 0.58$				
Xipo	F	−9.6	1.2	−9.5	0.9	9.5	0.7	9.3	0.4	12
Xipo	M	−9.5	1.1	−9.7	1.0	9.3	1.2	9.3	0.8	28
Xipo	Total	−9.55	1.11	−9.62	1.02	9.35	1.04	9.26	0.63	40
t-test (females–males)		$t =-0.18, p = 0.85$				$t = 0.67, p = 0.50$				
Xishan	F	−8.2	1.2	−7.9	0.1	8.8	0.6	8.6	0.3	10
Xishan	M	−8.3	1.6	−7.6	0.6	9.0	0.5	8.9	0.5	18
Xishan	U	−8.2	1.6	−7.8	1.0	9.3	1.3	9.0	1.4	11
Xishan	Total	−8.21	1.47	−7.82	0.53	9.01	0.81	8.8	0.65	39
t-test (females–males)		$t = 0.12, p = 0.90$				$t = -1.06, p = 0.30$				
Yuhuazhai	Total	−8.43	1.31	−8.14	0.88	9.37	0.71	9.24	0.74	22
Gouwan	Total	−14.30	1.92	−14.2	1.63	8.34	1.1	8.3	1.33	39

[1] Sources: Banpo (Cai and Qiu 1984; Pechenkina et al. 2005), Jiangzhai (Pechenkina et al. 2005; Guo et al. 2011), Shijia (Pechenkina et al. 2005), Guanjia (Dong et al. 2017), Xipo (Gong 2007; Zhang et al. 2010), Xishan and Yuhuazhai (Zhang et al. 2011), Gouwan (Fu et al. 2010).

[2] median absolute deviation

Statistically significant p values are in bold.

Isotopic values vary considerably among Yangshao sites, albeit that all Yangshao human bone samples suggest a very heavy reliance on millets. Banpo and Gouwan are the two Yangshao sites where the remains stand out as having more negative $\delta^{13}C$ values and hence evidencing a mixed C3/C4 diet. Only five bone samples were analyzed from Banpo, one by Pechenkina *et al.* (2005) and four more by Cai and Qiu (1984). Based on these samples, carbon isotopic values at Banpo range from −18.8 to −13.3‰, largely overlapping with the isotopic values from the chronologically earlier Baijia site of the Dadiwan culture (Table 2.2).

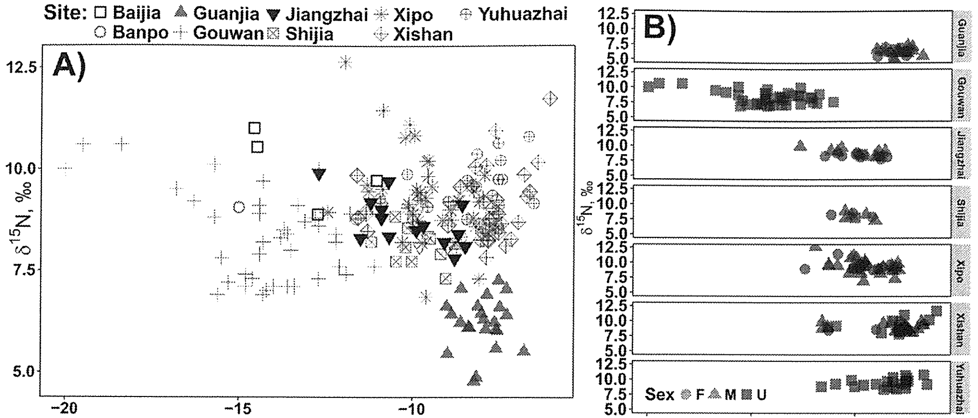

Figure 2.2 δ^{13}C and δ^{15}N values of human bone collagen samples from Yangshao sites. Values from the Baijia site of the Dadiwan culture are included for comparative purposes: A. intersite comparison; B. sex differences within each site.

Notwithstanding the contextual similarity and geographic proximity of the Banpo and Yuhuazhai sites, isotopic values of human bone samples from these two sites are quite different. Yuhuazhai δ^{13}C values average −8.4‰, and their range doesn't overlap with that from Banpo. Several explanations are possible for the disparity between Banpo and Yuhuazhai isotopic values. Given the small number of specimens analyzed from Banpo, it is possible that these are not representative of Banpo general diet and perhaps came from the earlier part of the Banpo occupation. Because of the high proportion of specimens from infant urn burials in the Yuhuazhai sample, its δ^{13}C and δ^{15}N values might be more reflective of juvenile diet and may be enriched by the consumption of breast milk, as well as by a high proportion of cereals in the weaning diet.

The Gouwan site is in the southern part of the Yangshao range. More negative δ^{13}C values of human bone samples from this site likely reflect a considerable proportion of cultivated rice in the human diet, as well as the presence of other C3 plants. Fu and colleagues (2010) estimated that millets constituted only half of the human diet there. The presence of a few migrants from the southern rice agricultural area at this site, seen as outliers with highly negative δ^{13}C values, has been also considered possible (Fu et al. 2010). Comparing isotopic values between the three Yangshao phases represented at the site, Fu and colleagues noticed a considerable overlap of δ^{13}C values, while δ^{15}N increased during the two later phases of the Yangshao, perhaps due to greater availability of domesticated animals.

A similar trend of increased rice contribution to the human diet in the south has been reported for the Dawenkou (6100 to 4600 BP) culture of Eastern China (Dong 2013). Bone samples from northern Dawenkou sites, Dongjiaying and Fujia, display isotopic values similar to those observed for the majority of Yangshao sites, suggesting strong reliance on millet and some contribution from millet-foddered domesticated animals (Table 2.2). Samples from southern Dawenkou sites are characterized by more negative δ^{13}C values, likely because of a greater proportion of rice in the diet.

Aside from the more negative δ^{13}C values at Banpo and Gouwan, there seems to be a slight increase in δ^{13}C values from earlier Yangshao sites of the Wei River area, i.e. Jiangzhai and Shijia,

Table 2.2 Stable isotope values in human bone collagen samples from the Neolithic and early dynastic archaeological sites

site[1]	*sex*	*δ ¹³C ‰*				*δ ¹⁵N ‰*				*N*
		mean	*SD*	*median*	*MAD*	*mean*	*SD*	*median*	*MAD*	
Peiligang culture (southern Henan, 9000–7000 BP):										
Jiahu	F	−20.65	0.37	−20.6	0.37	8.78	0.49	8.75	0.44	4
Jiahu	M	−20.47	0.06	−20.5	NA	8.1	0.52	7.8	NA	3
Jiahu	U	−22	2.79	−20.62	0.66	5.49	6.95	8.67	1.62	28
Jiahu	Total	−21.66	2.5	−20.51	0.43	6.3	6.06	8.68	1.24	35
t-test (females-males)		$t = -0.97, p = 0.39$				$t = 1.74, p = 0.17$				
Dadiwan culture (Shaanxi, 7900–7200 BP)										
Baijia	M	−12.73	NA	−12.73	0	8.88	NA	8.88	NA	1
Baijia	U	−13.33	1.25	−13.3	1.78	10.83	1.15	10.8	1.63	3
Baijia	Total	−13.18	1.06	−13.02	0.89	10.35	1.35	10.25	1.42	4
Houli culture (Shandong, 8500–7500 BP)										
Xiaojingshan	Total	−17.77	0.32	−17.85	0.35	8.99	0.56	9.15	0.25	10
Dawenkou culture (northeastern China, 6100–4600 BP):										
Liangwangcheng	F	−11.95	2.69	−11.4	2.97	9.03	0.86	8.9	0.74	15
Liangwangcheng	M	−10.49	1.42	−10.4	1.33	8.82	0.6	8.75	0.59	12
Liangwangcheng	Total	−11.3	2.3	−10.9	2.08	8.94	0.75	8.8	0.59	27
t-test (females-males)		$t = -1.8, p = 0.09$				$t = 0.77, p = 0.44$				
Huating	F	−14.35	0.49	−14.35	NA	8.66	0.41	8.66	NA	2
Dongjiaying	Total	−10.41	5.36	−7.6	1.33	3.83	6.91	6.7	1.93	21
Fujia	F	−7.6	0.45	−7.6	0.44	9.1	0.45	9.1	0.44	11
Fujia	M	−7.59	0.5	−7.4	0.59	9.15	0.41	9.2	0.44	11
Fujia	U	−7.8	NA	−7.8	0	9.8	NA	9.8	0	1
Fujia	Total	−7.6	0.46	−7.6	0.59	9.16	0.43	9.2	0.44	23
t-test (females-males)		$t = -0.04, p = 0.96$				$t = -0.30, p = 0.77$				
Qujialing culture (5000–4600 BP)										
Gouwan	Total	−14.6	0.85	−14.6	NA	7.0	0.85	7.0	NA	2
Qinglongquan	Total	−15.73	0.88	−15.9	0.60	8.69	1.12	9.10	0.80	7
Shijiahe (4600–4200 BP)										
Qinglongquan	Total	−14.18	1.1	−14.20	1.1	8.89	1.20	9.2	0.70	17
Xia dynasty (4070–3600 BP)										
Niedian	F	−7.2	0.39	−7.2	0.44	10.31	0.59	10.5	0.59	17
Niedian	M	−7.07	0.33	−7	0.3	10.51	0.82	10.55	0.67	22
Niedian	U	−7.18	0.32	−7.1	0.3	10.52	0.75	10.6	0.44	21
Niedian	Total	−7.14	0.35	−7.1	0.3	10.46	0.73	10.6	0.59	60
t-test (females-males)		$t = -1.11, p = 0.28$				$t = -0.92, p = 0.36$				

[1] Sources: Jiahu (Hu et al. 2006; Gong 2007), Xiaojingshan (Hu et al. 2008), Dawenkou sites (Dong 2013), Baijia (Atahan et al. 2011) and unreported data, Qinglongquan (Yunxian County, Hubei Province) (Guo et al. 2011), Niedian (Wang et al. 2014)

to the chronologically later sites located in Henan province, i.e. Xipo, Guanjia, and Xishan (Figure 2.2 A). Whether this slight increase in the δ^{13}C values reflects ecological differences between the Wei River area and the middle reaches of the Yellow River or a chronological trend related to a steady increase in the contribution of millet to the human diet over the Neolithic requires further investigation. Given even less negative δ^{13}C values in the Taosi human samples of the

Longshan culture (Zhang et al. 2007) and at the Niedian site of the Xia dynasty (Wang et al. 2014) than in Yangshao samples, the temporal trend explanation seems more likely.

Another important aspect of Yangshao isotopic variation, which is clearly seen in Figure 2.2, is that isotopic values of bones from the same site tend to cluster together, often forming spherical clouds that overlap only partially with those of the other sites. For instance, Guanjia samples are characterized by relatively high $\delta^{13}C$ and unusually low, for the Yangshao, $\delta^{15}N$ values. Thus, all Guanjia data points occupy the lower right part of Figure 2.2A. Xishan $\delta^{13}C$ values largely overlap with those of Guanjia, while its $\delta^{15}N$ values are considerably higher.

Such clustering can be explained by fairly consistent and uniform dietary preferences and/or choices at each site. In addition, different ecology and soil composition, as well as use of fertilizers, could be driving these differences. This clustering also suggests the fairly low long-distance mobility of Yangshao people. A general lack of outliers seems to suggest that most people whose bones were tested for stable isotopes were local to the settlement. In this respect, the Xipo series seems to be an exception, with considerable scattering of isotopic values. The observed variation in isotopic values of human bone samples from Xipo is consistent with a regional centre status for this settlement, as was proposed by Ma Xiaolin and colleagues (2005, 2006).

Male-female differences during the Neolithic

Discussions of the development of agriculture-based food production and male-female inequality have been intertwined in Chinese archaeology for over half a century (Shelach 2004, 2006; Chen 2014). In the Marxist archaeological thought of socialist China, F. Engels' "The Origin of the Family, Private Property, and the State," (1884) served as the interpretive framework describing basic stages of human social development, starting from the Paleolithic. Engels, building on the observations and ideas of Morgan and Bachofen, suggested that familial ties in early human societies could be described as Bachofen's "*Mutterrecht*" – a female dominated commune that traced relationship through maternal lineages, as paternity was generally unknown or uncertain. In this formulation, early agricultural communities were organized around matrilineal clans controlling communal property, with related women performing necessary agricultural tasks cooperatively.

> The communistic household, in which most of the women or even all the women belong to one and the same gens, while the men come from various other gentes, is the material foundation of that predominancy of women which generally obtained in primitive times.
> (Engels 1891 [2004])

The dispossession and hence disempowerment of women followed a shift in gender contributions to food production with cattle domestication and the husbandry of large herds of domesticated animals.

In archaeological interpretations derived within this framework, early agricultural communities of the Neolithic were generally assumed to be matriarchal, without rigorous testing of Engels' model (Jiao 2001; Chen 2014). Through the twentieth century, archaeological discussion of gender roles in early China didn't draw clear distinctions between matrilinearity, matrilocality, and matriarchy, oftentimes using these terms interchangeably and employing any evidence for – and against – the "*Mutterrecht*" to support or, conversely, reject all three. For instance, reports published on excavations at Banpo (Institute of Archaeology 1963; Museum 1975) referred to burials of females with infants and collective burials arranged according to sex and not in agreement with family units as an illustration of both matrilineage and matriarchy. Matriarchy was inferred for the Yangshao sites of Jiangzhai (Xi'an Banpo Museum 1988) and Yuanjunmiao (Zhang 1985), as well as for the Early Neolithic Houli Culture (Zhang and Lu 2004) from the presence of large communal houses that are ethnographically associated with matrilocality. Yangshao matriarchy was contested by Gao and Lee's (1993) craniometric study of Shijia burials that found greater morphological variation in a female skull series as compared to the male one, which the authors interpreted as evidence of patrilocality and, by extension, of patriarchy.

Because inequality usually goes hand in hand with uneven access to food resources, we compared male and female isotopic values for Yangshao sites. We used two-tailed Welch two-sample t-tests to evaluate the difference between male and female isotopic values (Tables 1 and 2). For the Yangshao samples, sex differences in isotopic values were minimal and generally didn't attain the level of statistical significance, suggesting that male and female diets during this period were generally similar. The only exception was at Jiangzhai, where males had a significantly higher $\delta^{15}N$ values: 9.0‰ vs. 8.4‰ for males and females respectively, suggesting a lesser proportion of animal products in the female diet (Dong et al. 2017). Other Neolithic sites for which sex differences in isotopic values have been reported show a similar absence of male-female dietary differences (Hu et al. 2008; Wang et al. 2014, also see Table 2.2). Although female $\delta^{13}C$ values were more negative than those of males in a sample from the Liangwangcheng site of the Late Dawenkou culture from Shandong (4800–4500 cal. BP) (Dong 2013), these differences didn't attain the level of statistical significance (Table 2.2) and seem to be driven by a few female outliers with unusual dietary signatures. Thus, isotopic data seem to provide little evidence for unequal distribution of resources during the Neolithic. The observed similarity in isotopic values among individuals from the same Yangshao sites seems to suggest a fairly equal distribution of resources among all community members.

Indicators of human health in Yangshao skeletal collections

Several papers have compared indicators of oral health and cranial/skeletal lesions among Yangshao skeletal collections (Pechenkina et al. 2002, 2007, 2013). I will briefly discuss whether dietary variation evidenced by stable isotopes translated into unequal distribution of skeletal health markers. To test whether the observed variation in the Yangshao diet had an impact on different aspects of human health we compared the frequencies of carious lesions and anemia indicators from site to site. Both of these skeletal health indicators are known to be diet dependent and tend to have increased in frequency throughout the world along with plant domestication and increased reliance on agriculture (Cohen and Armelagos 1984).

Dental caries

Caries is an infectious disease caused by bacterial pathogens including *Streptococcus mutans* and *Lactobacilli*. Reliance on domesticated cereals prompts the progression of caries for two reasons. First, sucrose, a disaccharide present in high concentration in many cereals, is necessary for *Streptococcus* to establish initial infection. Digesting sucrose, *Streptococcus* secretes a sticky matrix, hence forming a firm attachment with the dental surface. Cereals that contain low levels of sucrose, such as rice, are known to be less cariogenic (Tayles et al. 2000). Second, cariogenic bacteria require readily available water-soluble carbohydrates for their proliferation. Metabolizing sugars, both *Streptococcus mutans* and *Lactobacilli* produce acid that dissolves dental enamel, eventually leading to formation of a carious lesion.

The frequency of carious lesions considerably and statistically significantly increased from the Early Yangshao to the Middle/Late Yangshao. This pattern is in agreement with the trend indicated by stable isotopes, suggesting an increase in the dietary contribution of millet in later Yangshao sites and particularly at Guanjia and Xishan. Although the paleodietary signatures for Yangshao males and females overlap completely, the observed differences in caries frequencies between the sexes are not unexpected. Female physiology – specifically low saliva flow, different saliva composition, and physiological changes triggered by pregnancy – favors the initiation and progression of caries (Lukacs and Largaespada 2006).

Despite low δ^{15}N and high δ^{13}C values, which suggest a millet-rich diet with low amounts of animal products, caries frequencies from Guanjia were similar to those at other Middle and Late Yangshao sites (Figure 2.3). One peculiar aspect of Guanjia oral health is the notable frequency of caries on front teeth, incisors and canines. Samples from other Yangshao sites display carious lesions almost exclusively on posterior teeth. Crowns of anterior teeth are smooth and have no fissures. Regular saliva flow and mechanical pressures generated by drinking and chewing typically remove bacterial growth from the anterior teeth; hence caries on incisors and canines is very rare globally. Sugar-intense diets and habitual chewing of sweets have been known to lead to anterior carious infection. Nevertheless, there is no evidence of sweets consumption in early China. We can hypothesize that mushy and non-abrasive well-cooked millet could have caused anterior caries in Guanjia dentitions in the absence of more abrasive food products.

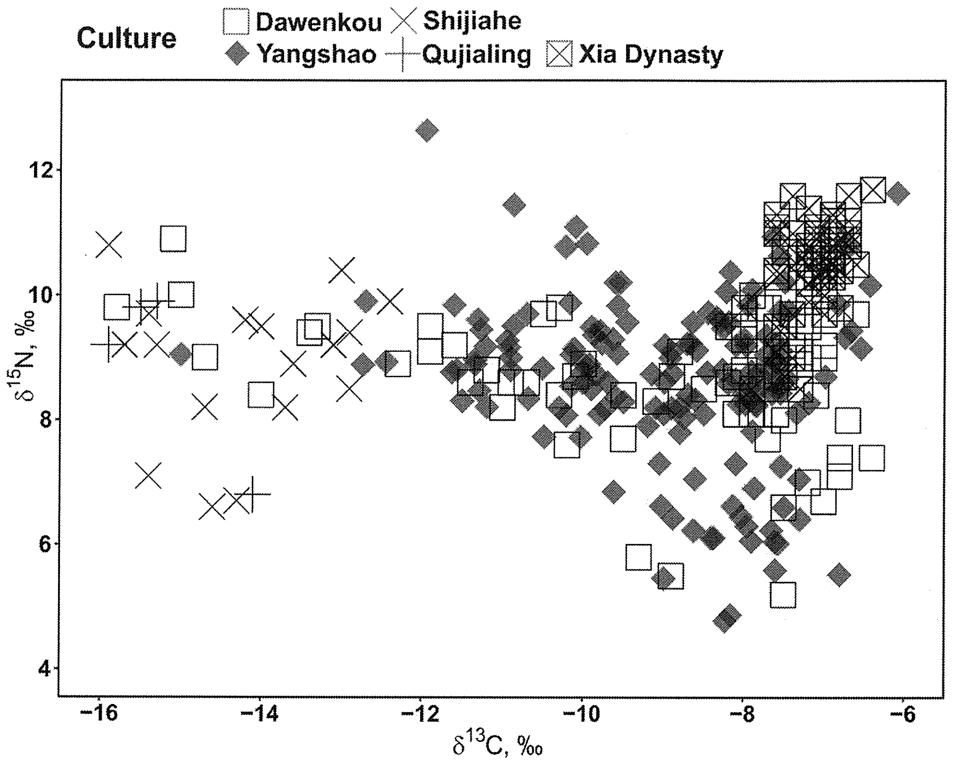

Figure 2.3 δ^{13}C and δ^{15}N values of human bone collagen samples from Yangshao sites compared to isotopic values of human collagen samples from other cultures and periods. Individuals from Jiahu and Dawenkou sites with δ^{15}N values below 4‰ were not included to improve resolution. Because rice consumption has likely affected Gouwan isotopic values, data from that site were not shown on this chart.

Table 2.3 Frequency of carious teeth in Yangshao skeletal collections

Site	*males*			*females*			χ^2	*p,*[1] *df*
	present	*affected*	*%*	*present*	*affected*	*%*		
Jiangzhai	262	5	2.0	174	6	3.4	1.09	.2975
Shijia	137	5	3.6	45	2	4.4	0.04	.8376
Guanjia	568	65	11. 4	446	102	22.9	**29.83**	**.0000**
Xipo	424	43	10.1	190	18	9.5	0.06	.7988
Xishan	695	98	14.1	989	173	17.5	**5.04**	**.0248**

[1] Based on (Pechenkina et al. 2013)

Table 2.4 Frequency of porotic hyperostosis and cribra orbitalia in Yangshao skeletal collections[1]

	Cribra orbitalia			*porotic hyperostosis*		
	present	*affected*	*%*	*present*	*affected*	*%*
Jiangzhai	28	5	17.9	28	0	0
Shijia	38	1	2.6	39	9	2.3
Guanjia	31	4	12.9	37	4	11
Xipo	21	3	14	23	2	8
Xishan	43	6	14	45	7	15.5

[1] based on (Pechenkina et al. 2013)

Porotic hyperostosis and cribra orbitalia

Hyperporosity of cranial bones associated with diploe expansion has been linked to childhood anemia by paleopathological research (Walker et al. 2009). Compensatory hyperplasia of the red bone marrow contained in the medullary cavities of the spongy bone leads to substantial expansion of the spongy region sandwiched between the cortical layers of the cranial bones, along with thinning of the cortical layer, giving cranial bones a porous, hair-on-end appearance. Such cranial lesions are referred to as *porotic hyperostosis* or *cribra cranii* when found on the bones of the cranial vault. Porous lesions on the cranial roof are called *cribra orbitalia*.

A transition to agriculture, agricultural intensification, and population growth have been known to lead to increasing frequencies of these anemia indicators in past human societies. Several contributing factors have been discussed in the literature. Overall, domesticated cereals furnish low amounts of dietary iron. Furthermore, absorption of iron from plant tissues is somewhat less efficient than of the heme iron found in animal tissues. Thus, cereal-rich diets are expected to cause iron-deficiency anemia. Overuse of cooked grains as the base for a weaning diet leads to increased anemia among infants. An increase in intestinal parasites in overcrowded settlements leads to considerable losses of iron through bloody diarrhea, further exacerbating iron deficiency. Similar to the trend observed for oral health markers, there is a significant increase in anemia indicators from the Early to Middle/Late Yangshao and a slight eastward trend toward an increase in these frequencies, although the latter is not statistically significant (Table 2.4). The easternmost skeletal series, from Xishan, displays the highest frequency of anemia indicators among the collections analyzed.

Isotopic evidence for a dietary shift toward wheat and barley agriculture

Wheat and barley first appear in the paleobotanical assemblages left on the Central Plain during the Late Neolithic (ca. 4600–3900 years ago). However, based on the human collagen stable isotope values from early archaeological sites, the dietary contribution of these new cereals to human diet was minimal until the late Bronze Age. Human stable isotope values from the Wei River valley suggest that dependence on millet was increasing until approximately 4000 years ago, whereas a clear shift toward reliance on C3 plants occurred around 2500 cal BP (Atahan et al. 2014). Figure 2.3 shows that the contribution of millets may have further increased from Yangshao levels during Longshan and the Xia dynasty (*ca.* 4070–3600 BP) (Wang et al. 2014).

The earliest clear evidence of the intrusion of plants utilizing the C3 pathway of photosynthesis into human diets in the Yellow River area comes from Eastern Zhou (770–221 BC or 2720–2171 BP) archaeological sites (Hou et al. 2012; Dong et al. 2017; Zhou et al. 2017). The range of variation in δ^{13}C values from Eastern Zhou sites tends to be greater than the range at each Yangshao site (Table 2.5, Figure 2.4). Thus, approximately a third of human bone samples from Eastern Zhou contexts display isotopic values completely within the range of Yangshao sites from the Wei and Yellow River valleys.

Male-female differences in isotopic values are more marked in Eastern Zhou samples, so that female skeletons on average display more negative δ^{13}C and lower δ^{15}N values. These differences attained the level of significance in the Changxinuan assemblage for both δ^{13}C and δ^{15}N, in δ^{13}C only for Xiyasi, and in δ^{15}N for Xinghong (Table 2.5). These sex-related differences in dietary signatures likely show that Eastern Zhou females had lesser access to animal products and an increased reliance on the less prized grains, such as wheat, barley, and beans. Observed unequal distribution of food sources between males and females suggest the rise of gender inequality (Dong et al. 2017). Alternatively, consumption of millet-based fermented beverages by males could have been responsible for the observed sex differences. Ligang Zhou (Zhou 2016) noticed that bone samples from more elaborate burials that included two nested coffins had less negative δ^{13}C values, suggestive of a greater proportion of millet in the diet of wealthier people, supporting the hypothesis that C3 cereals were less valued than millet during the Eastern Zhou.

Three skeletal series that show significant differences in isotopic values between males and females are associated with the urban population of the Ancient Zhenghan city and generally represent fairly wealthy urban dwellers. No such differences were observed for other Eastern Zhou sites, where people represented likely came from rural farming communities (Table 2.5). Thus, a gender divide in access to resources can be documented during the Eastern Zhou only in some settings and is associated with an overall wealthier population.

Carbon isotope values for human bone samples excavated from burials of the Han dynasty (206 BC – 220 AD) (Hou et al. 2012; Zhou 2016) suggest a further increase of C3 plants in the human diet. Development of mills allowed converting wheat into fine flour for noodle production and likely prompted a greater appreciation of wheat, apparently elevating its status to a more desirable cereal toward the end of the Han dynasty (Bray 1984: 461).

The animal story

The number of animal bone samples analyzed from the Central Plain remains low, yet there is better chronological continuity in the animal isotopic record (Table 2.6). As attested to by fairly high δ^{13}C values in pig and dog bone samples from early Neolithic contexts, millet was an important component of their fodder from the initial stages of its cultivation on the Central Plain (Barton et al. 2009; Atahan et al. 2011). When domesticated cattle became available in the region, millet seems to have assumed an important role in their provisioning as well, likely in the form of millet straw (Hou et al. 2013; Chen et al. 2016; Dong et al. 2017).

Pig bone samples from the Yangshao Xipo site, as well as from a number of Longshan sites, are characterized by very low δ^{15}N values, generally lower than those of humans from the same time periods (Pechenkina et al. 2005; Wu et al. 2007; Chen et al. 2012; Dai et al. 2016), suggesting that pigs were receiving food refuse with a high millet content and a low proportion of animal products. Pig bones from the Kangjia site of the Longshan period and from later dynastic sites show a marked increase in δ^{15}N values (Zhang et al. 2007; Hou et al. 2013; Ma et al. 2016). Combining pig sties with latrine areas would give pigs access to human feces and could increase their δ^{15}N values via tropic level enrichment due to consuming that fecal matter. Adding fertilizer to millet fields during the early dynasties could potentially have increased the δ^{15}N values

Table 2.5 Stable isotope values in human bone collagen samples from the Eastern Zhou archaeological sites

site[1]	*sex*	δ^{13}C ‰				δ^{15}N ‰				*N*
		mean	*SD*	*median*	*MAD*	*mean*	*SD*	*median*	*MAD*	
Xinzheng sites:										
Changxinyuan	F	−11.24	1.31	−11.29	0.76	7	0.61	6.84	0.71	8
Changxinyuan	M	−9.21	0.51	−9.02	0.62	8.57	0.63	8.71	0.64	7
Changxinyuan	Total	−10.29	1.44	−9.84	1.3	7.73	1.01	7.68	1.51	15
t-test (females-males)		**$t = -4.05, p = 0.002$**				**$t = -4.88, p = 0.0003$**				
Xiyasi	F	−13.82	1.8	−14.2	1.1	7.77	0.99	7.73	0.7	11
Xiyasi	M	−10.78	1.63	−10.23	1.75	8.33	0.85	8.4	1.07	19
Xiyasi	Total	−11.89	2.23	−11.45	2.92	8.12	0.93	8.18	0.93	30
t-test (females-males)		***$t = -4.62, p = 0.0002$***				$t = -1.56, p = 0.13$				
Thermal Plant	F	−11.21	1.35	−11.05	1.48	8.19	0.76	8.25	0.82	8
Thermal Plant	M	−10.97	0.67	−11.3	0.15	8.83	0.81	9.2	0.3	3
Thermal Plant	Total	−11.15	1.18	−11.3	1.48	8.36	0.79	8.4	1.04	11
t-test (females-males)		$t = -0.40, p = 0.69$				$t = -1.19, p = 0.31$				
Xinghong	F	−11.17	1.43	−10.95	1.33	8.62	0.66	8.55	0.52	36
Xinghong	M	−10.46	1.81	−10	1.04	9.22	0.86	9.4	0.89	20
Xinghong	U	−11.75	2.3	−11.65	0.44	8.95	0.52	8.85	0.15	6
Xinghong	Total	−11	1.67	−10.8	1.41	8.85	0.76	8.8	0.82	62
t-test (females-males)		$t = -1.52, p = 0.12$				**$t = -2.71, p = 0.010$**				
Nanyang City, Xichuan County, Henan Province:										
Shenmingpu	Total	−12.69	0.79	−12.75	0.89	8.74	1.25	9.2	0.74	14
Wenxian county, Henan Province:										
Chenjiagou	F	−10.32	1.2	−10.25	1.41	8.9	1.02	9	0.96	4
Chenjiagou	M	−9.22	0.78	−8.9	0.59	9.55	0.66	9.7	0.74	17
Chenjiagou	U	−9.97	1.89	−9.5	0.74	8.9	0.68	8.9	0.74	18
Chenjiagou	Total	−9.68	1.47	−9.4	0.74	9.18	0.76	9.1	0.89	39
t-test (females-males)		$t = -1.75, p = 0.16$				$t = -1.20, p = 0.30$				

[1] Sources: Xiyasi and Changxinyuan (Dong et al. 2017), Xinhong, Thermal Power Plant, and Chenjiagou (Zhou et al. 2017), Shenmingpu (Hou et al. 2012).

Statistically significant p values are in bold.

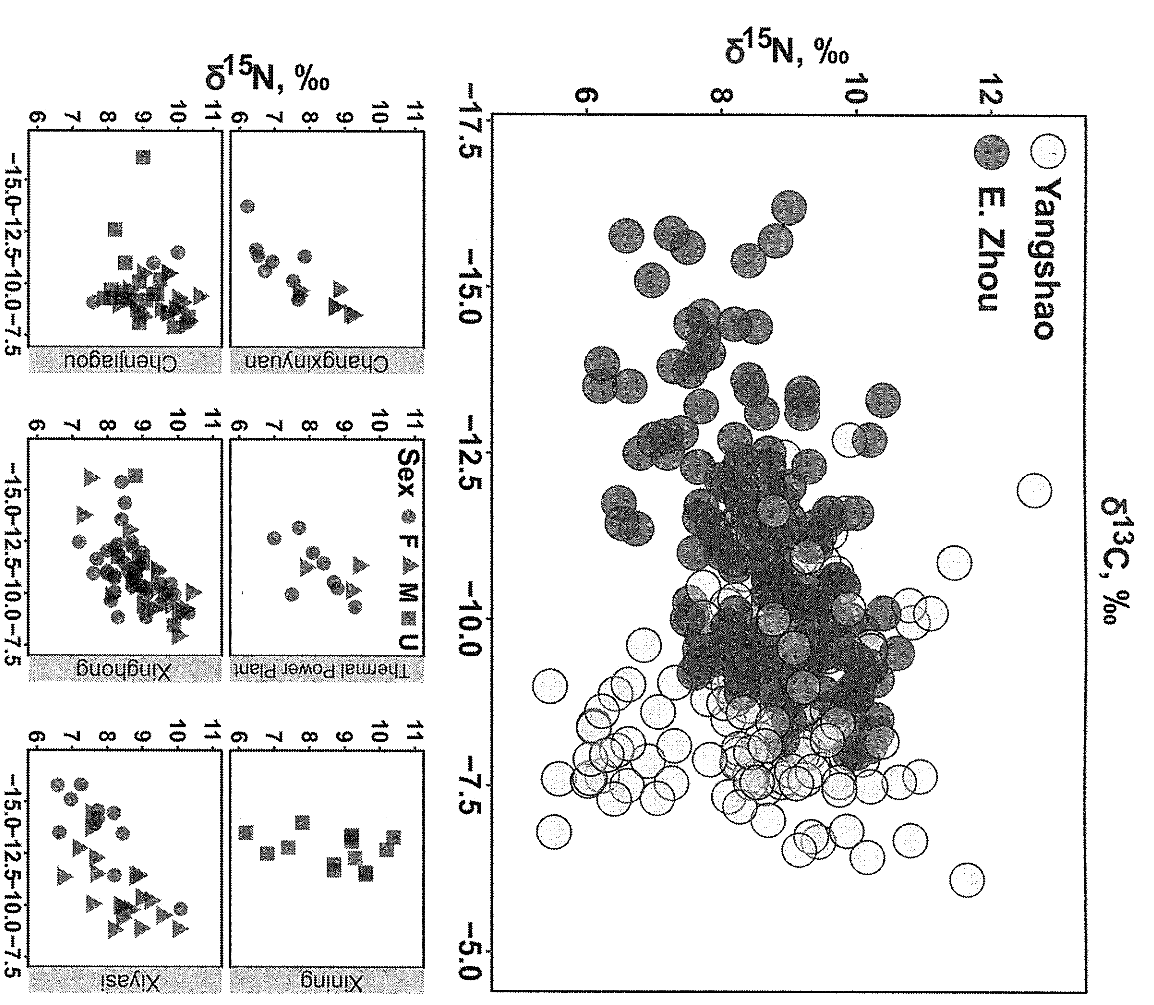

Figure 2.4 δ¹³C and δ¹⁵N values of human bone collagen samples from Eastern Zhou sites. Top: Eastern Zhou vs. Yangshao. Because rice consumption has likely affected Gouwan isotopic values, data from that site were not shown on this chart. Bottom: sex differences within each Eastern Zhou site.

of the cereals themselves. However, the latter explanation doesn't seem to be supported by the high variation of δ¹⁵N values in human bone samples from early dynastic sites (Figure 2.3). Field fertilization should lead to greater uniformity of δ¹⁵N values, especially for sites that display a narrow range of δ¹³C variation.

Table 2.6 Animal stable isotope data from Neolithic and Bronze Age archaeological contexts of the Chinese Central Plain

site	*province*	*period*	*species*	*δ¹³C, ‰*					*δ¹⁵N, ‰*					*N*
				mean	*SD*	*med*	*min*	*max*	*mean*	*SD*	*med*	*min*	*max*	
Xipo	Henan	Middle Yangshao 4000–3500 BC	pig	−7.5	0.2	−7.5	−7.7	−7.4	7.7	0.3	7.7	7.5	8	2
			dog	−8.1	NA	NA	NA	NA	6.9	NA	NA	NA	NA	1
Xipo	Henan	Middle Yangshao 4000–3500 BC	pig	−7.0	0.4	−7.1	−7.5	−6.5	NA	NA	NA	NA	NA	4
Kangjia	Shaanxi	Longshan 3000–1900 BC	pig	−10.3	2.4	−11.5	−11.8	−7.5	8.7	0.9	8.7	7.8	9.6	3
			dog	−11.8	3.9	−11.8	−14.3	−9.0	9.7	0.3	9.7	9.5	9.8	2
			bovine	−14.7	0.6	−14.7	−15.1	−14.2	7.0	0.6	7.0	6.6	7.4	2
			sheep	−18.8	NA	NA	NA	NA	6.6	NA	NA	NA	NA	1
			deer	−17.2	NA	NA	NA	NA	8.0	NA	NA	NA	NA	1
Taosi	Shanxi	Late Longshan 2600–1900 BC	pig	−7.1	1.6	−6.6	−11.8	−6.2	7.2	0.4	7.3	6.6	7.9	11
			dog	−6.8	0.4	−6.7	−7.5	−6.4	8.8	1.1	8.5	7.5	10	5
			bovine	−11.3	2.2	−11.8	−13.5	−7.3	6.6	1.2	6.3	5.3	8.7	6
			sheep	−17.2	0.4	−17.2	−17.7	−16.6	6.8	1	7.4	5.5	7.8	5
Xinzhai	Henan	Late Longshan	pig	−9.2	3.6	−9.2	−20.2	−8.1	6.2	1.8	6.1	4.5	10	10
			pig	−8.5	1	−8.1	−10.7	−7.1	6.2	0.9	6.1	4.4	7.6	11
			dog	−10.4	2.1	−10.4	−12.8	−7.9	6.8	1.2	6.6	5.8	8.4	4
			bovine	−9.8	1.7	−9.9	−12.5	−7	6.3	0.9	6.1	4.9	7.6	11
			sheep	−14.4	1.6	−14.8	−16.2	−11.5	5.6	0.5	5.8	4.8	6.2	8
			deer	−16.2	3.3	−16.4	−12.3	−19.8	5.3	0.8	5.2	4.4	6.4	4
Wadian	Henan	Late Longshan 2600–1900 BC	pig	−11.4	2.4	−11.6	−16.1	−8.1	6.9	1	7	5.5	8.7	10
			dog	−10.1	1	−10.5	−11	−8.5	7.2	1.1	7.2	5.9	8.5	7
			bovine	−12.7	2	−13.2	−16	−9.4	7.6	0.8	7.8	6	9.1	9
			sheep	−16.6	0.9	−16.6	−17.3	−16	7.6	0.1	7.6	7.5	7.7	2
			deer	−20.8	0.9	−21.1	−21.6	−18.8	5	1.2	5.2	2.8	6.9	10
Erlitou	Henan	Erlitou 1900–1500 BC	pig	−10.5	3	−12	−12.5	−7.1	8.4	0.6	8.7	7.7	8.8	3
Zhangdeng	Henan	Proto–Shang ca. 2000–1600 BC	pig	−7.7	1.3	−7.3	−11.2	−6.4	7.7	0.5	7.7	6.6	8.4	18
			dog	−7.6	0.9	−7.5	−8.8	−6.7	7.3	0.4	7.4	6.7	7.7	4
			bovine	−9	3.4	−9.6	−18.9	−6.2	6.8	1.4	6.2	4	8.7	12
			sheep	−15.4	2.7	−15.1	−21.4	−10.7	7.7	1.2	8	5.2	10.8	13
Baicun	Hebei	Proto–Shang ca. 2000–1600 BC	pig	−7	0.4	−7.2	−7.2	−6.5	7.8	0.5	7.7	7.4	8.3	3
			dog	−8	1.6	−8.0	−9.1	−6.9	7.2	0.5	7.2	6.9	7.6	2
			bovine	−8.3	1.8	−8.3	−10.9	−5.8	7.3	1.0	7.3	5.9	8.3	5
			sheep	−12.1	2.6	−11.9	−16.5	−6.4	6.2	1.1	5.8	5.1	8.3	13
			deer	−20.8	0.5	−21	−21.3	−20.2	3.4	0.5	3.3	2.8	3.9	5
Tianli and Changxinyuan	Henan	Eastern Zhou	bovine	−10.1	1.9	−10.4	−11.7	−6.8	6.4	2.2	7.2	2.4	7.7	5
			dog	− 12.9	2.9	− 13.2	− 15.7	− 9.4	6.2	1.1	6.3	4.9	7.3	4
			pig	− 11.7	2.7	− 13.1	− 14.4	− 7.9	6.1	1.1	6.1	5.1	7.7	7
			sheep	− 15.7	2.1	− 15.8	− 18.6	− 13.1	9.0	1.6	9.3	6.6	10.7	6

Xipo (Pechenkina et al. 2005; Zhang et al. 2011), Kangjia (Pechenkina et al. 2005), Taosi (Chen et al. 2012), Xinzhai (Wu et al. 2007; Dai et al. 2016), Wadian (Chen et al. 2016), Erlitou (Zhang et al. 2007), Zhangdeng (Hou et al. 2013), Baicun (Ma et al. 2016), Tianli and Changxinyuan (Dong et al. 2017; Zhou et al. 2017), and present chapter.

Eastern Zhou pig bone samples display a much larger range of $\delta^{13}C$ variation than pig bones from earlier sites. Because domesticated pigs tend to have a short lifespan, this range in $\delta^{13}C$ values from Eastern Zhou may reflect the variation in wheat harvests and wheat availability from year to year. Provisioned by typical household refuse, pig isotopic values may also mirror status differences among Eastern Zhou households.

Finally, sheep and goats show highly negative $\delta^{13}C$ values, similar to those of wild animals in the area and indicative of an overwhelmingly C3 pattern of wild vegetation in the pastures. A marked separation between human and sheep/goat isotopic values seems to suggest that these animals were raised for wool and/or ritual purposes, contributing to human diet only infrequently (Dong et al. 2017).

Conclusions

A comparative analysis of stable isotope values among multiple Yangshao sites indicates that human diets varied considerably from site to site in terms of the proportion of millets and animal products in the diet. These dietary differences are reflected in the variation in oral health, as Yangshao skeletal assemblages with higher $\delta^{13}C$ values also display a higher rate of caries. There is also a trend toward a greater frequency of cranial lesions suggestive of childhood anemia in human remains from Middle/Late Yangshao sites with higher $\delta^{13}C$, although these differences do not attain statistical significance. Despite considerable diet variation during Yangshao, the composition of male and female diets appears to have been very similar, suggesting that access to food resources was not gender biased at the time.

An increased proportion of C3 cereals in the human diet, i.e. wheat and barley, as well as beans, is evident isotopically only after 2700 BP. At the time of the Eastern Zhou, human isotopic values and hence human diets became more variable within each site yet overlapped considerably among different sites. The composition of male diets as reflected by stable isotopes is often significantly different from that of females. A greater proportion of C3 plants and lesser proportion of animal products became characteristic of female diets during the Eastern Zhou. These differences suggest gender-biased access to food resources and likely gender segregated meal consumption. The presence of C3 cereals in pig feed is also seen during the Eastern Zhou, indicating that C3 cereals had become a common part of the household refuse, which was used to provision pigs.

Works cited

Ambrose, S.H. (1991) 'Effects of diet, climate and physiology on nitrogen isotope abundances in terrestrial foodwebs', *Journal of Archaeological Science*, 18: 293–317.

Ambrose, S.H. (1993) 'Isotopic analysis of palaeodiets: methodological and interpretive considerations', in: M. K. Sandford (ed.) *Investigations of Ancient Human Tissue*, Langhorne: Gordon and Breach Science Publishers.

Atahan, P., Dodson, J., Li, X.Q., Zhou, X.Y., Chen, L., Barry, L., and Bertuch, F. (2014) 'Temporal trends in millet consumption in northern China', *Journal of Archaeological Science*, 50: 171–7.

Atahan, P., Dodson, J., Li, X., Zhou, X.Y., Hu, S., Chen, L., Bertuch, F., and Grice, K. (2011) 'Early Neolithic diets at Baijia, Wei river valley, China: stable carbon and nitrogen isotope analysis of human and faunal remains', *Journal of Archaeological Science*, 38: 2811–7.

Barton, L., Newsome, S.D., Chen, F.H., Wang, H., Guilderson, T.P., Bettinger, R.L., and Hole, F. (2009) 'Agricultural origins and the isotopic identity of domestication in northern China', *Proceedings of the National Academy of Sciences of the United States of America*, 106: 5523–8.

Bocherens, H., and Drucker, D. (2003) 'Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: Case studies from recent and ancient terrestrial ecosystems', *International Journal of Osteoarchaeology*, 13: 46–53.

Bray, F. (1984) *Biology and Biological Technology: Agriculture*, Cambridge: Cambridge University Press.

Cai, L., and Qiu, S. (1984) 'Carbon-13 evidence for ancient diets in China (碳十三测定和古代食谱研究)', *Kaogu (考古)*, 10: 949–54.

Chen, Q. (2006) 'A study of the faunal remains from the Xishan site in Zhengzhou (郑州西山遗址出土动物遗存研究)', *Acta Archaeologica Sinica (考古学报)*, 3: 385–418.

Chen, S.X. (2014) 'The creation of female origin myth: a critical analysis of gender in the archaeology of Neolithic China', *Totem: The University of Western Ontario Journal of Anthropology*, 22: 24–30.

Chen, X., Fang, Y., Hu, Y., Hou, Y., Lü, P., Yuan, J., Song, G., Fuller, B.T., and Richards, M.P. (2016) 'Isotopic reconstruction of the late Longshan period (ca. 4200–3900 bp) dietary complexity before the onset of state-level societies at the Wadian site in the Ying river valley, Central Plains, China', *International Journal of Osteoarchaeology*, 26: 808–17.

Chen, X., Yuan, J., Hu, Y., He, N., and Wang, C. (2012) 'A preliminary exploration to the domestic animal raising strategy: the evidences from carbon and nitrogen isotope analyses (陶寺遗址家畜饲养策略初探:来自碳、氮稳定同位素的证据)', *Archaeology and Technology(考古与科技)*, 9: 843–50.

Cohen, M. N. and Armelagos, G. J. Editors. (1984) *Paleopathology at the Origins of Agriculture*. Orlando, FL: Academic Press.

Crawford, G., Underhill, A., Zhao, Z., Lee, G-A., Feinman, G., Nicholas, L., Luan, F., Yu, H., Fang, H., and Cai, F. (2005) 'Late Neolithic plant remains from northern China: preliminary results from Liangchengzhen, Shandong', *Current Anthropology*, 46: 309–17.

Dai, L., Li, Z., Hu, Y., Zhao, Q., and Wang, C. (2014) 'The age profile of sheep and the strategy of animal resources utilization at Xinzhai site [新砦遗址出土羊的死亡年龄及畜产品开发策略]', *Kaogu (考古)*, 1: 94–103.

Dai, L.L., Li, Z.P., Zhao, C., Yuan, J., Hou, L., Wang, C., Fuller, B.T., and Hu, Y. (2016) 'An isotopic perspective on animal husbandry at the Xinzhai site during the initial stage of the legendary Xia dynasty (2070–1600 BC)', *International Journal of Osteoarchaeology*, 26: 885–96.

Deniro, M.J., and Epstein, S. (1981) 'Influence of diet on the distribution of nitrogen isotopes in animals', *Geochimica et Cosmochimica Acta*, 45: 341–51.

Dodson, J.R., Li, X., Zhou, X., Zhao, K., Sun, N., and Atahan, P. (2013) 'Origin and spread of wheat in China', *Quaternary Science Reviews*, 72: 108–11.

Dong, Y. (2013) 'Eating identity: food, gender, and social organization in Late Neolithic Northern China', unpublished Ph.D. thesis, University of Illinois at Urbana-Champaign.

Dong, Y., Morgan, C., Chinenov, Y., Zhou, L., Fan, W., Ma, X., and Pechenkina, K. (2017) 'Shifting diets and the rise of male-biased inequality on the Central Plans of China during Eastern Zhou', *Proceedings of the National Academy of Sciences of the United States of America*, 114: 932–7.

Engels, F. (1891 [2004]) *The Origin of the Family, Private Property and the State*, Chippendale, NSW: Resistance Books.

Fan, W. (2000) 'Results of excavations at guanjia (关家遗址发掘获重要成果)', *Zhongguo Wenwu Bao (中国文物报)*: 1.

FAO, Food Policy and Nutrition Division. 1972. Food composition table for use in East Asia. Rome: Food Policy and Nutrition Division, Food and Agriculture Organization of the United Nations. Rome: FAO.

Farquhar, G.D., O'Leary, M.H., and Berr, J.A. (1984) 'On the relationship between carbon isotope discrimination and the intercellular carbon dioxide concentration in leaves', *Australian Journal of Plant Physiology*, 9: 121–37.

Flad, R., Li, S., Wu, X., and Zhao, Z. (2010) 'Early wheat in China: results from new studies at Donghuishan in the Hexi corridor', *The Holocene*, 20: 955–65.

Fu, Q., Jin, S., Hu, Y., Ma, Z., Pan, J., and Wang, C. (2010) 'Agricultural development and palaeodietary study of Gouwan site, Xichuan, Henan [河南淅川沟湾遗址农业发展方式和先民食物结构变化]', *Zhongguo Kexue Zazhishe* (中国科学杂志社), 55: 589–95.

Fuller, D.Q., Denham, T., Arroyo-Kalin, M., Lucas, L., Stevens, C.J., Qin, L., Allaby, R.G., and Purugganan, M.D. (2014) 'Convergent evolution and parallelism in plant domestication revealed by an expanding archaeological record', *Proceedings of the National Academy of Sciences of the U S A*, 111: 6147–52.

Fuller, D.Q., and Zhang, H. (2007) 'A preliminary report of the survey archaeobotany of the upper Ying valley (Henan province) (颍河中上游谷地植物考古调查的初步报告)', in: School of Archaeology and Museology, Peking University and Henan Provincial Institute of Cultural Relics and Archaeology (ed.) *Archaeological Discovery and Research at the Wangchenggang Site in Dengfeng (2002–2005) (登封王城岗考古发现与研究 [2002～2005])*, Zhengzhou: Great Elephant Publisher.

Gao, Q., and Lee, K.Y. (1993) 'A biological perspective on Yangshao kinship', *Journal of the Anthropological Archaeology*, 12: 266–98.

Gong JZ (2007) 'Inequalities in diet and health during the intensification of agriculture in Neolithic China'. Unpublished BA Thesis (Harvard University).

Guo, Y., Hu, Y., Gao, Q., Wang, C., and Richards, M.P. (2011) 'Stable carbon and nitrogen isotope evidence in human diets based on evidence from the Jiangzhai site, China', *Acta Anthropologica Sinica (人类学学报)*, 30: 149–57.

Hou, L., Li, S., Hu, Y., Hou, Y., Lu, P., Cao, L., Hu, B., Song, G., and Wang, C. (2013) 'A preliminary study of the mode of domestic animal husbandry in the pre-Shang culture period. (先商文化时期家畜饲养方式初探)', *Huaxia Kaogu (华夏考古)*, 2: 130–9.

Hou, L., Wang, N., Lu, P., Hu, Y., Song, G., and Wang, C. (2012) 'Transition of human diets and agricultural economy in Shenmingpu site, Henan, from the Warring States to Han dynasties', *Zhongguo Kexue: Diqiu Kexue* (中国科学: 地球科学), 42: 1018–25.

Hu, Y., Ambrose, S.H., and Wang, C. (2006) 'Stable isotopic analysis of human bones from Jiahu site, Henan, China: implications for the transition to agriculture', *Journal of Archaeological Science*, 33: 1319–30.

Hu, Y., Wang, S., Luan, F., Wang, C., and Richards, M.P. (2008) 'Stable isotope analysis of humans from Xiaojingshan site: implications for understanding the origin of millet agriculture in China', *Journal of Archaeological Science*, 35: 2960–5.

Institute of Archaeology, Academia Sinica. (1991) *Radiocarbon Dates 1965–1991*, Beijing: Cultural Relics Publishing House.

Institute of Archaeology, Academia Sinica, Xi'an Banpo Museum. (1963) *The Neolithic Village at Banpo, Xian (西安半坡)*, Beijing: Wenwu.

Jiao, T. (2001) 'Gender studies in Chinese Neolithic archaeology', in: B. Arnold and N. L. Wicker (eds.) *Gender and the Archaeology of Death*, Walnut Creek, CA: AltaMira Press.

Lan, W., and Chen, C. (2014) 'Plant macroremains from Guanzhuang site in Xingyang, Henan (荥阳官庄遗址浮选样品植物大遗存分析)', *Dongfang Kaogu (东方考古)*: 78–89.

Lee, G-A., and Bestel, S. (2007) 'Contextual analysis of plant remains at the Erlitou period Huizui site, Henan, China', *Bulletin of the Indo-Pacific Prehistory Association*, 27: 49–60.

Lee, G.A., Crawford, G.W., Liu, L., and Chen, X. (2007) 'Plants and people from the Early Neolithic to Shang periods in north China', *Proceedings of the National Academy of Sciences of the U S A*, 104: 1087–92.

Lee, Y.K. (2007) 'Centripetal settlement and segmentary social formation of the Banpo tradition', *Journal of Anthropological Archaeology*, 26: 630–75.

Li, F. (2013) *Early China: A Social and Cultural History (New Approaches to Asian History)*, Cambridge: Cambridge University Press.

Li, X., Dodson, J., Zhou, X., Zhang, H., and Masutomoto, R. (2007) 'Early cultivated wheat and broadening of agriculture in Neolithic China', *The Holocene*, 17: 555–60.

Li, Z., Brunson, K., and Dai, L. (2014) 'The zooarchaeological study of wool exploration from the Neolithic age to the early Bronze age in the Central Plains (中原地区新石器时代到青铜时代早期羊毛开发的动物考古学研究)', *Quaternary Sciences (第四纪研究)*, 34: 149–57.

Liu, D. (1986) 'Survey of the Neolithic village of Xishan in Zhengzhou city (郑州市西山村新石器时代遗址调查简报)', *Cultural Relics of Central China (中原文物）*, 2: 23–6.

Liu, L., Yang, D., and Chen, X. (2006) 'On the origin of the *Bubalus bubalis* in China (中国家养水牛起源初探)', *Acta Archaeologica Sinica (考古学报)*, 2: 141–78.

Liu, X., Fuller, D.Q., and Jones, M. (2012) 'Early agriculture in China', in: G. Barker and C. Goucher (eds.) *The Cambridge World History*, Cambridge: Cambridge University Press.

Lu, H., Yang, X., Ye, M., Liu, K.B., Xia, Z., Ren, X., Cai, L., Wu, N., and Liu, T.S. (2005) 'Culinary archaeology: Millet noodles in late Neolithic China', *Nature*, 437: 967–8.

Lu, H., Zhang, J., Liu, K.B., Wu, N., Li, Y., Zhou, K., Ye, M., Zhang, T., Zhang, H., Yang, X., Shen, L., Xu, D., and Li, Q. (2009) 'Earliest domestication of common millet (*Panicum miliaceum*) in East Asia extended to 10,000 years ago', *Proceedings of the National Academy of Sciences of the U S A*, 106: 7367–72.

Lukacs, J., and Largaespada, L. (2006) 'Explaining sex differences in dental caries prevalence: saliva, hormones, and "life-history" etiologies', *American Journal of Human Biology*, 18: 540–55.

Lü, P. (2010) 'On the origin of Chinese domestic cattle', in: *Zooarchaeology (动物考古)*. Beijing: Cultural Relic Publishing House.

Ma, X. (2003) 'Emergent social complexity in the Yangshao culture: Analyses of settlement patterns and faunal remains from Lingbao, western Henan, China', unpublished Ph.D. thesis, La Trobe University, Australia.

Ma, X., Li, X., and Yang, H. (2005) *A Great Breakthrough in the Fifth Excavation at Xipo in Lingbao, Henan. 26. Zhengzhou: Henan Provincial Institute of Cultural Relics and Archaeology.*, Zhengzhou: Henan Provincial Institute of Cultural Relics and Archaeology.

Ma, X., Li, X., and Yang, H. (2006) 'A study of jade articles from the Yangshao cultural cemetery at Xipo in Lingbao. (灵宝西坡仰韶文化墓地出土玉器初步研究)', *Cultural Relics of Central China (中原文物)*, 3: 72–6.

Ma, Y., Fuller, B.T., Wei, D., Shi, L., Zhang, X., Hu, Y., and Richards, M.P. (2016) 'Isotopic perspectives (δ 13C, δ 15N, δ 34 S) of diet, social complexity, and animal husbandry during the proto-Shang period (ca. 2000–1600 bc) of China', *American Journal of Physical Anthropology*, 160: 433–45.

McGovern, P.E., Zhang, J., Tang, J., Zhang, Z., Hall, G.R., Moreau, R.A., Nunez, A., Butrym, E.D., Richards, M.P., Wang, C.-S., Cheng, G., Zhao, Z., and Wang, C. (2004) 'Fermented beverages of pre- and protohistoric China', *Proceedings of the National Academy of Sciences of the United States of America*, 101: 17593–8.

Minagawa, M., and Wada, E. (1984) 'Stepwise enrichment of δ^{15}N along food chains: Further evidence and the relation between δ^{15}N and animal age', *Geochim Cosmochim Ac*, 48: 1135–40.

O'Leary, M. H. (1988) Carbon isotopes in photosynthesis: fractionation techniques may reveal new aspects of carbon dynamics in plants. *Bioscience*. 38:328–36.

Pechenkina, E., Ambrose, S., Ma, X., and Benfer, R.J. (2005) 'Reconstructing northern Chinese Neolithic subsistence practices by isotopic analysis', *Journal of Archaeological Science*, 32: 1176–89.

Pechenkina, E., Benfer, R., and Ma, X. (2007) 'Diet and health in the Neolithic of the Wei and middle Yellow river basins, Northern China', in: M. Cohen and G. Crane-Kramer (eds.) *Ancient Health: Skeletal Indicators of Agricultural and Economic Intensification*, Gainesville: University Press of Florida.

Pechenkina, E.A., Benfer, R.A., Jr., and Wang, Z.J. (2002) 'Diet and health changes at the end of the Chinese Neolithic: the Yangshao/Longshan transition in Shaanxi province', *American Journal of Physical Anthropology*, 117: 15–36.

Pechenkina, K., Ma, X., and Fan, W. (2013) 'Trajectories of health in early farming communities of East Asia', in: K. Pechenkina and M. Oxenham (eds.) *Bioarchaeology of East Asia: Movement, Contact, Health*, Gainesville: University Press of Florida.

Peng, Y., Xiao, J., Nakamura, T., Toshio, Liu, Baolin, and Inouchi, Y. (2005) 'Holocene East Asian monsoonal precipitation pattern revealed by grain-size distribution of core sediments of Daihai lake in Inner Mongolia of north-central China', *Earth and Planetary Science Letters*, 233: 467–79.

Ren S, Wu Y. 1999. Fifty years of Neolithic archaeology in China. *Kaogu* (考古) 9:11–22.

Schoeninger, M.J., and Deniro, M.J. (1984) 'Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals', *Geochim Cosmochim Ac*, 48: 625–39.

Schoeninger, M.J., and Moore, K.M. (1992) 'Bone stable isotope studies in archaeology', *Journal of World Prehistory*, 6: 247–96.

Shelach, G. (2004) 'Marxist and post-Marxist paradigm for the Neolithic', in: K. M. Linduff and Y. Sun (eds.) *Gender and Chinese Archaeology*, Walnut Creek, CA: AltaMira Press.

Shelach, G. (2006) 'Economic adaptation, community structure, and sharing strategies of households at early sedentary communities in northeast China', *Journal of Anthropological Archaeology*, 25: 318–45.

Tayles, N., Domett. K., and Nelsen K. (2000) 'Agriculture and dental Caries? The case of rice in prehistoric Southeast Asia', *World Archaeology*, 32: 68–83.

van der Merwe, N.J. (1982) 'Carbon isotopes, photosynthesis, and archaeology: different pathways of photosynthesis cause characteristic changes in carbon isotope ratios that make possible the study of prehistoric human diets', *American Scientist*, 70: 596–606.

Walker, P.L., Bathurst, R.R., Richman, R., Gjerdrum, T., and Andrushko, V.A. (2009) 'The causes of porotic hyperostosis and cribra orbitalia: a reappraisal of the iron-deficiency-anemia hypothesis', *American Journal of Physical Anthropology*, 139: 109–25.

Wang, X. (1993) 'On the Shijia type of Yangshao culture (论仰韶文化史家类型)', *Acta Archaeologica Sinica (考古学报)*, 4: 415–34.

Wang, Y., Nan, P., Wei, D., Hu, Y., Wang, X., and Wang, C. (2014) 'Dietary differences in humans with similar social hierarchies: example from the Niedian site, Shanxi (相近社会等级先民的食物结构差异--以山西聂店遗址为例)', *Acta Anthropologica Sinica (人类学学报)*, 33: 82–9.

Wei, X. (2014) 'The discoveries and preliminary research of plant remains in the region of the western Henan and the southwestern Shaanxi in the Neolithic age', Dongfang Kaogu (东方考古), 11: 343–64.

Wu, X., Xiao, H., Wei, C., Pan, Y., Huang, Y., Zhao, C., Xu, X., and Ogrinc, N. (2007) 'The stable isotopic evidences of paleodiet of human and pigs, agriculture practices, and pig domestication at Xinzhai site, Henan (河南新砦遗址人、猪食物结构与农业形态和家猪驯养的稳定同位素证据)', *Science for Archaeology (科技考古)*, 2: 49–58.

Xi'an Banpo Museum. (1975) *The Matrilineal Clan Commune from the Cultural Remains of Banpo Type Yangshao Culture (从仰韶文化半坡类型文化遗存看母系氏族公社)*. *Wenwu* (文物) 12: 12:72–78.

Xi'an Banpo Museum. (1978) 'A Neolithic site at Shijia in Weinan county, Shaanxi province (陕西渭南史家新石器时代遗址)', *Kaogu (考古)*, 1: 41–53.

Xi'an Banpo Museum, Shaanxi Institute of Archaeology, and Lintong County Museum. (1988) *Jiang Zhai: Report on the Excavation of the Neolithic at Jiangzhai by the Excavation Group Site (姜寨: 新石器时代遗址发掘报告)*, Beijing: Cultural Relics Publishing House.

Xiang, H., Gao, J., Yu, B., Zhou, H., Cai, D., Zhang, Y., Chen, X., Wang, X., Hofreiter, M., and Zhao, X. (2014) 'Early Holocene chicken domestication in northern China', *Proceedings of the National Academy of Sciences of the U S A*, 111: 17564–9.

Xiao, J., Xu, Q., Nakamura, T., Yang, X., Liang, W., and Inouchi, Y. (2004) 'Holocene vegetation variation in the Daihai lake region of north-central China: a direct indication of the Asian monsoon climatic history', *Quaternary Science Reviews*, 23: 1669–79.

Yan W. 1992. Origins of agriculture and animal husbandry in China. In: Aikens CM, Rhee SN, editors. *Pacific Northeast Asia in prehistory*. Pullman: Washington State University Press. pp. 113–123.

Yang, X., Wan, Z., Perry, L., Lu, H., Wang, Q., Zhao, C., Li, J., Xie, F., Yu, J., Cui, T., Wang, T., Li, M., and Ge, Q. (2012) 'Early millet use in northern China', *Proceedings of the National Academy of Sciences of the U S A*, 109: 3726–30.

Yu, Y. (1977) 'Han', in: K. C. Chang (ed.) *Food in Chinese Culture: Anthropological and Historic Perspectives*, New Haven: Yale University Press.

Yuan, J. (2001) 'The most recent studies of early Chinese domestication (中国新时期时代家畜起源的问题)', *Wenwu (文物)*, 5: 51–8.

Yuan, J., and An, J. (1997) 'Two questions of Chinese zooarchaeology (中国动 物考古学研究的两个问题)', Zhongguo Wenwu Bao (中国文物报), 4.27: 3.

Zhang, G., and Lu, L. (2004) 'Archaeological study on civilization forming process in Haidai district: the chronology, character and social property of Neolithic culture in Lubei district', *Guanzi Xuekan*, 1: 70–80.

Zhang, X., and Guo, Y. (2003) 'New discoveries of archaeological sites near Xi'an [西安再次发现大型史前环壕聚落遗址] ', *Zhongguo Wenwu Bao (中国文物报)* 8.29: 1.).

Zhang, X., Qiu, S., Bo, G., Wang, J., and Zhong, J. (2007) 'Carbon 13 and nitrogen 15 analysis of human remains from Erlitou and Taosi sites (二里头遗址、陶寺遗址部分人骨碳十三、氮十五分析)', *Science for Archaeology (科技考古)*, 2: 41–8.

Zhang, X., Zhao, X., and Cheng, L. (2011) 'Human diets of Yangshao culture in the Central Plains', *Chinese Archaeology*, 11: 188–96.

Zhang, Z-P. (1985) 'The social structure reflected in the Yuanjunmiao cemetery', *Journal of Anthropological Archaeology*, 4: 19–33.

Zhao, Z. (2011) 'New archaeobotanic data for the study of the origins of agriculture in China', *Current Anthropology*, 52: S295–S306.

Zhao, Z., and He, N. (2006) 'Results and analysis of 2002 soil sample flotation from Taosi (陶寺城址2002年度浮选结果及分析)', *Kaogu (考古)*, 5: 77–90.

Zhou, L. (2016) "From state to empire: human dietary change on the central plains of China from 770BC to 220 AD", unpublished Ph.D. thesis, University of Alberta.

Zhou, L., Garvie-Lok, S., Fan, W., and Chu, X. (2017) 'Human diets during the social transition from territorial states to empire: stable isotope analysis of human and animal remains from 770 BCE to 220 CE on the Central Plains of China', *Journal of Archaeological Science: Reports*, 11: 211–23.

3

THE BRONZE AGE BEFORE THE ZHOU DYNASTY

Robert Bagley

Preliminaries: scope, aims, and sources

In East Asia the earliest state-level societies that we know much about are those of the Yellow and Yangtze river valleys in the second millennium BC. In calling them states, we are diagnosing social organization from material remains: we take city walls, imposing building foundations, large-scale metal production, elite burials, and widely distributed artifact types to be material residues of highly stratified societies. Some of these features, city walls for example, have an earlier history, and a case for earlier states could be made. The third millennium Liangzhu culture of the Yangtze delta region is an obvious candidate. Toward the middle of the second millennium, however, the rise of a distinctive metal industry, and with it the characteristic artifacts of the Chinese Bronze Age, cast bronze bells and ritual vessels, was a new and consequential development. Writing may have been invented at about the same time, though we have no trace of first stages. The civilized societies to which metallurgy and writing direct our attention arose in the middle Yellow River valley, but by 1200 BC they had flourishing offspring throughout the Yangtze valley as well. These societies, whose achievements were inherited by the first millennium Zhou civilization, are our subject.

The period of concern to us, roughly 1800–1000 BC, will for convenience be called the Early Bronze Age (EBA). For the earlier part of the period the dating of archaeological sites depends on radiocarbon measurements, which give absolute dates – calendar dates – but have uncertainties on the order of one or two centuries. Toward the end of the period we begin to rely on information taken from later texts. We try to fix the date of the Zhou conquest of Shang, an event that figures prominently in the texts, and then count generations backward from it. The conquest date endorsed by the state-sponsored Xia Shang Zhou Chronology Project is 1046 BC.[1] "*Ca.* eleventh century BC" might be more realistic, but whichever we prefer, a date for the Zhou conquest is, in the material record, a date for an event at one city. It is a date for the supposedly punctual end of the Anyang settlement and hence for the end of the pottery sequence that archaeologists have constructed there. Other sites can be connected with the conquest date and the pottery sequence it terminates only by correlating their material culture with the material culture of Anyang. For an important tomb discovered a few decades ago at Xingan in Jiangxi, for example, neither radiocarbon nor written evidence is available. A date for the Xingan tomb can only be estimated by comparing its contents with the contents of Anyang tombs. As the best-dated and