# A Posthumanist Approach to the Origins of Rice Agriculture in Southern China

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Explaining the origins of agriculture is a topic of ongoing debate in anthropology. Traditional explanations have often been categorized as either push or pull models. The former considers the transition as an adaptive response to environmental change, and the latter views farming as a result of cultural innovations. The theoretical debates reflect the traditional dichotomy between materialism and idealism in archaeological research. Yet underlying both approaches is an anthropocentric ontology that privileges humans over nonhumans as the principal agents of historical change. This paper seeks to transcend the limitation through a close examination of the role of nonhumans in the origins of rice agriculture in southern China. Challenging traditional approaches that attribute the rise of agriculture to human interventions on the environment, this paper explores how the active agencies exercised by nonhumans, such as plants and material tools, entrapped humans into a long-term dependence and later into a sedentary lifestyle, eventually leading up to fully agricultural societies.

Archaeology has roughly been theoretically divided between processual and postprocessual approaches. In general, processual archaeology adopts a (neo)Darwinian perspective, considering cultural change as an adaptation to the natural environment; postprocessual archaeology takes an agency-oriented perspective, stressing the importance of cultural innovations, social values, and beliefs in bringing about change (Binford 1962; Hodder 1986; Trigger 1989). These two approaches occupy the materialist and idealist ends of a theoretical spectrum, reflecting a deeply rooted dichotomy between Enlightenment rationalism and its countermovement Romanticism in the eighteenth century (Trigger 2004). The bifurcated tradition has cast a long shadow over one of the discipline's most enduring debates: the origins of agriculture.

The transition from hunting and gathering to agriculture marked a major change in human history. Beginning around 10,000 years ago, formerly mobile hunter-gatherers began to domesticate a wide range of plants and animals, eventually establishing food production economies in dispersed parts of the world (Price and Gebauer 1995). The reasons for this transition have been the subject of a large body of research. Early theoretical framings revolved around an opposition between idealist and materialist approaches. Lewis H. Morgan (1877), for example, claimed that the transition to agriculture was a stage of an upward movement that originated from "germs of thoughts" (33). While this idealist narrative was widely held by Morgan's predecessors and contemporaries (e.g., Ferguson 1768; Turgot 1895; Westropp 1872), it was soon rebutted by V. Gordon Childe (1928) and others (e.g., Huntington and Cushing 1934; Newberry 1923; Pumpelly 1908; Toynbee 1934). Influenced by Darwinism evolutionism, Childe proposed an "oasis theory," portraying agriculture as a cultural response adaptive to a resource-depressed environment.

The theoretical division remained in the subsequent research on the transition to agriculture. Since then, diverse models have been proposed, but little consensus has been achieved. These various explanations embrace the full spectrum from materialist to idealist. Materialist explanations stress climatic, demographic, and geographical conditions as determining factors bringing about subsistence change. Idealist explanations assume the importance of cultural innovations, emphasizing social values, beliefs, and ideologies. In what follows, I briefly outline the two approaches and illustrate how an anthropocentric ontology restricts their interpretive scope. I conclude by presenting a case study that seeks to transcend the limitation through a close examination of the role of nonhuman agents in the origins of rice agriculture in southern China.

## Limitations of Traditional Approaches

The materialist approach takes a (neo)Darwinian perspective that treats the agricultural transition as the outcome of environmental adaptation. When the glacial retreat altered the worldwide distribution and abundance of ecological resources at the end of the Pleistocene, some communities began domesticating plants and animals as a more efficient subsistence strategy for surviving in their transformed environments. Classic explanations have proposed specific "push" factors such as deteriorating climate (Bar-Yosef 2011; Childe 1936; Richerson, Boyd, and Bettinger 2001) and population pressure (Binford 1968; Cohen 1977; Flannery 1968). According to this approach, plants and animals are primarily economic resources. Material tools are utilitarian and functional. Human culture adapts to environmental conditions (Binford 1964).

The idealist approach, conversely, follows an agency-oriented perspective that attributes the agricultural transition to the

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endogenous changes in human culture. Scholars in this camp have proposed various types of "pull" factors, including improved technologies and skills (Braidwood 1960, 1963), increased social competition (Asouti and Fuller 2013; Bender 1978; Hayden 1990; Kuijt 1996; Smalley and Blake 2003; Wright 2014), and changing human cognition and symbolic capacities (Boyd 2006; Cauvin 1994; Hodder 1990; Watkins 2004; Wilson 2007). The agricultural revolution was therefore understood as an epiphenomenon of deeper cultural processes. Within this perspective, plants and animals are culturally meaningful. Material objects are not simply utilitarian but rather symbolic representations of human thought. Instead of simply adapting to their environmental conditions, humans are driven by a cultural impetus for change.

Lewis Binford's (1968) and Barbara Bender's (1978) classic discussions of the agricultural revolution in Southwest Asia demonstrate the differences between the two approaches I have sketched here. According to Binford, increased sea level in the early Holocene provided humans with unprecedented resources in the coastal areas, leading to sedentism and population increase. As a result, some groups had to migrate into marginal zones with fewer food resources. In these areas, the equilibrium between population and food was disrupted, and farming emerged as the best solution to resource precarity. This stimulus-response reasoning was considered overly simplistic by Bender, who instead attributed the economic transition to the changes in the social structure. Bender argued that before farming emerged, foraging groups in the Near East had already developed certain levels of social hierarchization involving alliance formation, trade, and positions of authority. Leaders in these societies would require food control and wealth accumulation, making increasing demands for surplus production and, in some cases, an incentive for a shift to food production.

While the two theories proposed different prime movers for the initial transition to agriculture, they share the same problem: a goal-oriented narrative. Binford and Bender were among a large company of scholars who assumed that the ultimate benefits of agriculture would have been self-evident in its early stage. In Binford's scenario, people opted for farming as an optimal choice to solve the problem of food shortage. In Bender's theory, leaders in early complex societies consciously took farming as a wealth accumulation strategy for social competition. Both theories envision humans—the primary agents of historical change—to be capable of making decisions that lead to predictable consequences. The danger of such intentionalist approaches, as David Rindos (1980, 1984) has long pointed out, is that they may "attribute powers to people or to culture that they do not have" (1984:6). Following Charles Darwin's (1859) concept of unconscious selection, Rindos proposed that agriculture was the outgrowth of mutualistic interaction between humans and plants coevolving into a symbiotic relationship.

The coevolutionary model had a clear impact on the subsequent research. Recent debates between human behavioral ecology (HBE) and niche construction theory (NCT) have moved beyond the simple push or pull models toward a focus on the coevolutionary relationship between humans and the environment. HBE proponents follow the assumption that hunter-gatherers are optimal foragers who make their subsistence decisions based on a cost-benefit rationale (Bettinger 2006; Piperno and Pearsall 1998; Winterhalder and Douglas 2006; Winterhalder and Goland 1997; Winterhalder and Smith 2000). If the availability of higher-ranked foraging resources declines, the expected energetic return for foraging becomes smaller than a particular farming activity and foragers become farmers. However, niche construction theorists argue that humans are not simply adaptive "optimal foragers" but "ecological engineers" who constantly modify their environment and thus codirect their evolution (Jablonka 2011; Laland and O'Brien 2012; O'Brien 2012; Odling-Smee, Laland, and Feldman 2003; Rowley-Conwy and Layton 2011). Following this principle, Bruce Smith (2007, 2012, 2015) and Melinda Zeder (2012*a*, 2016) proposed a cultural niche construction (CNC) model, suggesting that initial domestication was the result of deliberate human enhancement of ecosystems, where a wide range of species "auditioned" as potential domesticates and some eventually became domesticated (for other NCT/CNC explanations, see O'Brien and Laland 2012; Rowley-Conwy and Layton 2011).

The HBE and NCT/CNC models either emphasize the "adaptive" or "innovative" aspects of human-environment interaction. Nevertheless, both approaches rely on certain kinds of goal-oriented human behavior to initiate domestication. For HBE, it is about maximizing reproductive success through optimal resource use (Gremillion and Piperno 2009; Winterhalder and Douglas 2006); for NCT/CNC, it is the "deliberate environmental enhancement" (Smith 2015:230). While such intentional practices certainly played a role in human-environment interaction, it is debatable whether they can be considered causative in the development of agriculture. First, it has been known that in many regions, agriculture did not result in an overall improvement of nutritional or living conditions (Flannery 1969; Sahlins 1972). Indeed, increasing archaeological evidence shows that the first farmers were less healthy and no more productive than the early Holocene foragers (Cohen and Armelagos 2013; Cohen and Crane-Kramer 2012; Pearce-Duvet 2006). If agriculture was less "optimal" than foraging, why was the route from foraging to agriculture (with few exceptions) generally unidirectional? Second, there is no consensus about why some niche-construction communities adopted agriculture—such as the Natufians—and some not at all—such as the Jomon people (Bleed and Matsui 2010; Rowley-Conwy and Layton 2011). If niche construction—a universal practice among human societies—is to be understood as accountable for the agricultural transition, one should expect NCT/CNC models to explain how the same process has led to different consequences (see a summary by Wallach 2016).

These goal-oriented narratives are fundamentally anthropocentric, and their origin can be traced to the modernist foundation of archaeology (Lucas 2004; Thomas 2004). Characterized by epistemic breaks with the Aristotelian teleology that considers all matter as active and progressive toward their

ideal forms (telos), modernist thinking dismisses the agency of nonhuman entities, instead regarding humans as the principal agents of historical change (Schnapp, Shanks, and Tiews 2004; Shapin 1996; Thomas 2004:8–11). As a result, most archaeological theories on the origins of agriculture consider nonhuman entities as nutritional resources, utilitarian tools, or symbolic representations subject to human exploitation or meaning making. For example, HBE theorists rank plants and animals according to their energetic return (Bird and O'Connell 2012; Gremillion and Piperno 2009; Winterhalder and Douglas 2006). Smith (2012) assesses different plants based on their "economic values to humans" (266). Bender (1978) considers artifacts such as obsidian and polished stone dishes to be "elite goods" that reflect human "socioeconomic inequalities" (215). Hayden (1990) sees the first domesticates as prestige goods for social events like feasting. Cauvin (1994) and Hodder (1990) suggest that certain art objects and architectural elements are the symbolic presentations of psychocultural change within the human mind. All these narratives make humans the active protagonists of history. Nonhuman animals, plants, and material things are portrayed as having no agential capacities of their own since they are passive entities utilized or symbolized by humans.

This anthropocentric ontology is a peculiarly Western construct. Numerous ethnographic studies have shown that the agential distinction between humans and nonhumans does not exist in many indigenous ontologies (Descola 1992; Ingold 2000; Kohn 2005; Strathern 1980; Viveiros de Castro 1998; Watts 2013). Philippe Descola (1994), for instance, through his ethnography on the Achuar Indians of the Upper Amazon, shows that the Achuar classify most plants and animals as persons with souls, whose main attributes are in every way identical with those of humans. Marilyn Strathern (1980) argues that the idea of culture-nature is completely absent among the Hagen of Papua New Guinea, a society that applies the concept of cultivation uniformly across activities such as raising children, gardening and planting, and breeding pigs.

More importantly, recent research has produced mounting data indicating a protracted process of domestication, supporting Rindos's hypothesis of unconscious domestication. Archaeobotanical evidence shows that there is a long lag time—perhaps a millennium—between the initial cultivation of cereals and the emergence of recognizable domestication traits (Allaby et al. 2017; Fuller, Asouti, and Purugganan 2012; Purugganan and Fuller 2009; Tanno and Willcox 2006; for a different opinion, see Abbo and Gopher 2017, 2020). Several scholars (Heiser 1988; Jones et al. 2021; Zohary, Tchernov, and Horwitz 1998) have identified a range of morphological changes in seed plant domestication that could have resulted from unconscious selection, rather than deliberate human manipulation. Even after the initial domestication appeared, there was a long temporal span leading up to fully agricultural societies, around 5,500 years in Mesoamerica, 4,000 years in eastern North America, and perhaps 3,000 years in the Near East (Smith 2001). The transition was so gradual that the earliest plant cultivators and animal herders most likely embarked on the process unconsciously, without a sufficient understanding of the mechanisms involved to be able to foresee an end product that would come thousands of years later (Leach 2007). If the incipient farmers were not conscious of the long-term implications of their actions, it is not necessary to center humans as the primary agents of the agricultural transition.

This paper decenters humans. By provincializing human actions, it frames humans as simply one of many actors in the long march of time. Recent anthropological literature on posthumanism shows the analytical fruits of making a radical break with the anthropocentric ontology. Terms such as "multispecies ethnography" (Kirksey and Helmreich 2010; Smart and Smart 2017), "biosociality" (Ingold and Palsson 2013), "multinaturalism" (Viveiros de Castro 1998), "companion species" (Haraway 2003), and "more-than-human sociality" (Tsing 2013) have begun to dissolve the boundaries between human and nonhuman entities, conflating the immutable dualities of modernist ontologies. At the same time, archaeological applications of new materialist thought such as "symmetrical archaeology" (Normark 2010; Olsen 2012; Webmoor 2007; Witmore 2014), "actor network theory" (Callon 1984; Callon and Law 1997; Knappett 2005; Latour 1993, 2005), "assemblage theory" (Deleuze and Guattari 1987; Jervis 2019), and "entanglement" (Barad 2007; Hodder 2012) have moved beyond an economic/representational binary perspective of materiality by exploring how material things are capable of making demands on humans and influencing human actions. Hence, material objects may also act as essential participants in historical processes generally attributed to human action. These new approaches give us reasons to reconsider the roles of nonhuman participants in the processes constituting agricultural transition.

## A Posthumanist Approach to the Origins of Agriculture

A posthumanist approach to the origins of agriculture begins with abandonment of "the long dictatorship of human beings" (Harman 2002:2). The advent of farming, as Bjørnar Olsen (2007:586) has noted, was made possible by humans entering into intimate relations with nonhumans during a relatively brief period. These nonhuman actors, including plants, animals, and material things, all have varied intrinsic qualities that made an immense impact on humans, thus codirecting the pathways of agricultural transition.

Plants and nonhuman animals have particular life rhythms and behavioral traits that shape our cohabitation with them. When humans domesticated plants, plants also "domesticated" humans (Leach 2003; Tsing 2012). The evolution of nonshattering spikelet and erect growth makes cereals more productive but also dependent on humans for their seed dispersal, drawing humans into additional labor commitment, including threshing, winnowing, and maintaining soil nutrients (Fuller, Allaby, and Stevens 2010). The lives of farmers are consequently regulated by the life cycles and the needs of the plants they grow (van der Veen 2014). Similarly, nonhuman animals

actively engage in their relationships with humans. Instead of humans selecting smaller animals for domestication, it may have been the smaller ones that sought a closer relationship with humans (O'Connor 1997). For example, dogs may have evolved from wolves by scavenging on human refuse (Coppinger and Coppinger 2001; Zeder 2012*b*), while cats were likely self-domesticated by inviting themselves to human settlements because of the high concentration of food found there (Driscoll, Macdonald, and O'Brien 2009). Domestication, therefore, was not simply about human domination but processes in which nonhuman species figured out how to live with and used humans for their own purposes (Rindos 1984; Tsing 2018). During domestication, plants chose humans to protect and disseminate them; animals recruited humans as a companion species (Cassidy and Mullin 2007; Haraway 2003; Swanson, Lien, and Ween 2018).

In addition to living organisms, the material world itself has long gone unrecognized as an agent of change. Material things can make a vital difference to human life by providing a sense of permanence (Boivin 2004). Soil- and stone-based materials, such as pottery, stone tools, and houses, are not easily transportable and require an extended period for manufacture. Their weight and stability may have circumscribed human mobility, encouraging a more sedentary lifestyle. At the same time, material things possess an immanent potential to change. By not working properly and causing disturbance, things stimulate improvement or transformation (Harman 2002; Heidegger 1962; Olsen 2010:139–141). For example, pottery vessels that tend to break easily may encourage human attempts to improve, making changes to clay recipes, firing temperature, and construction techniques. This dialectical process, which is initiated by material object malfunction and spurred by human response to breakdown, would generate what we consider to be changes in the archeological record. Thus, material things are not simply utilitarian objects or symbolic representations—they are also actors capable of channeling and guiding human action.

Several recent archaeological studies have applied non-anthropocentric approaches to explaining the agricultural revolution. Ian Hodder's (2018*a*) entanglement theory explores how nonhuman things such as grinding stones, sickles, and hearths afforded humans certain opportunities but also constraints and dependency, eventually drawing humans into sedentism and farming in the Middle East. John Robb's (2013) model of Neolithic transition in Europe demonstrates how the unintended consequences of human-material interactions "locked"hunter-gatherers into an irreversible commitment to farming. Dorian Fuller's (Fuller, Allaby, and Stevens 2010; Fuller et al. 2016) studies draw attention to plants' ecological and physiological characteristics, which trapped humans into a series of labor investment. Inspired by these works, the following case study aims to show how nonhuman actors mediated and directed human action, together leading to an unintended consequence more generally known as the agricultural revolution in southern China.

## The Origins of Rice Agriculture in Southern China

### *Setting the Scene*

In 11,000 BP, the Yangtze River of southern China was a marshland of foragers. By 5000 BP, the area was a cultivated landscape populated by rice farmers. The shift from foraging to rice farming was an extended process that lasted for several millennia (fig. 1*A*). Hunter-gatherers in this region began harvesting rice in the terminal Pleistocene, but they remained mobile, occupying seasonal cave camps for thousands of years (Crawford 2006; Lu 2006; MacNeish 1995; Peking University and JPICRA 2014; Zhao 2010). Around 10,000 BP, rice domestication began in the Shangshan culture, when people established sedentary communities in the lower river valleys (see earlier debates in Fuller and Qin 2010; Jiang and Liu 2006; Liu et al. 2007; see updated evidence in Huan et al. 2015; Ma et al. 2016; Wu et al. 2014; Zheng et al. 2016; Zuo et al. 2016). The domestication process was not complete until the late Liangzhu culture (5300–4400 BP), when large-scale farming systems were established (Ma et al. 2016).

Traditional explanations fall into the two aforementioned approaches. Following the materialist approach, Lu et al. (2002) and Yoshinori Yasuda (2008) suggest that climatic fluctuations during the Holocene may have pushed foragers to adopt rice cultivation to solve the problem of seasonal food shortage. Rice would have been a favorable food for storage, offering an ideal risk-buffering source of subsistence when primary resources declined. This explanation, however, has not been supported by archaeobotanical and paleoenvironmental data. For millennia, rice cultivation was carried out in conjunction with hunting and gathering (Crawford 2011*a*), without bringing any instant transformations to the subsistence economy. At Kuahuqiao (8000–7000 BP), after at least 2,000 years of rice cultivation, the plant assemblage contained more than 40 wild species, and rice constituted only a small component of the human diet (Pan 2011). The Lower Yangtze River was a resource-rich environment with a wide range of wild plants and animals (Li et al. 2018). There is therefore no plausible motivation for the early Holocene foragers to start domesticating rice for survival, as they could easily turn to alternative resources.

Conversely, scholars using the idealist approach argue that rice was domesticated as a prestige food for social purposes. Brian Hayden (2009, 2011), for example, suggests that initial rice domestication emerged from complex societies with competitive social relations. In these societies, self-interested aggrandizers attempted to gain social status by serving rice—a crop of high prestige value—to impress guests at social events such as feasts and ritual ceremonies. Such social motivations led to intensified rice cultivation and eventually domestication. While rice may have been used for social purposes during its long process of domestication, as evidenced by the finding of possible rice alcohol from Jiahu (ca. 9000 BP; McGovern et al. 2004), current archaeological evidence, however, indicates that initial rice domestication began before, not after, the emergence of complex social relations (Liu and Chen 2012:76–82).

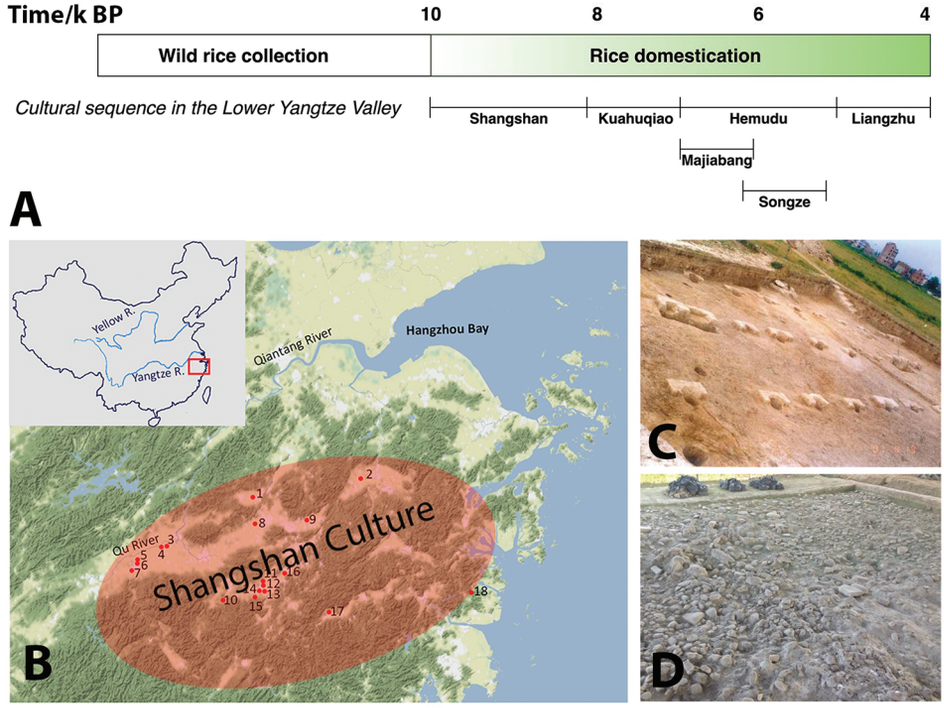


Figure 1. *A*, Cultural history and rice domestication in the Lower Yangtze River region (for macrobotanical evidence, see Fuller et al. 2009; Zheng et al. 2016; for phytolith evidence, see Huan et al. 2015; Ma et al. 2016; Wu et al. 2014; Zuo et al. 2017). *B*, Distribution of Shangshan culture sites. *C*, House F1 at the Shangshan site, representing a pile-dwelling house. *D*, Stone tool piles at Hehuashan, a Shangshan culture settlement.

What has been largely ignored in the previous research on the matter is the agency of material culture. If we compare the lifeways of hunter-gatherers 30,000 years ago and the incipient rice farmers 10,000 years ago in southern China, one striking difference is that the latter involved an explosion of material things—stone tools, pottery, houses, storage facilities, burial places, and so on. Some of these material elements first appeared in the terminal Pleistocene and were produced in very small quantities during a long-lived nascent phase. From the beginning of the Holocene, however, these elements began to be produced at a substantially greater scale. The transformed material surroundings might have channeled humans into new patterns of living, long before the advent of agriculture. Therefore, tracing the deep history of material culture may provide key clues to developing a new understanding of the agricultural transition in southern China.

### *Terminal Pleistocene: The Emergence of a New Material World*

In China, significant transformations took place in the terminal Pleistocene. Figure 2 charts the time line of the appearance of six elements central to the agricultural transition in China: (1) grinding stones, which include slabs, handstones, mortars, and pestles for processing a variety of food and nonfood substances; (2) pottery, the first major human technique of artifact production in which the material itself is chemically transformed, possibly related to boiling food; (3) plant-harvesting implements, which include flake and microliths, that assisted humans in collecting a variety of plants; (4) polished stone tools, especially adzes and axes that would provide a resistant edge for carpentry and other activities; (5) plant and animal domestication, which includes millets and dogs in northern China and rice in southern China; and (6) sedentary structures, such as architecture and storage facilities indicative of long-term habitation. The diagram includes only data from well-dated sites with clear stratigraphy (see citations in the figure legend).

While this is an oversimplified schematic rendering of the terminal Pleistocene to early Holocene record in China, the diagram shows two clear patterns in the history of regional material culture. First, around the Last Glacial Maximum (LGM), several new material tools—grinding stones, pottery, polished stone tools, and microliths—appeared in China. Once these new technologies emerged, they stayed in human communities and later coalesced into farming societies. Second, although people began to harvest the progenitors of domesticated plants as early as 25,000 years ago, morphologically altered crops did not arrive on the scene until the Holocene.

One may consider the process to be a good example of environmental adaption: the LGM brought pronounced cold/dry intervals on the East Asian continent (Clark et al. 2009; Xu et al. 2013), and the stress from resource deterioration likely encouraged hunter-gatherers to explore a wider range of resources by expanding their repertoire of material technologies. To improve chances of survival, some invented grinding stones to

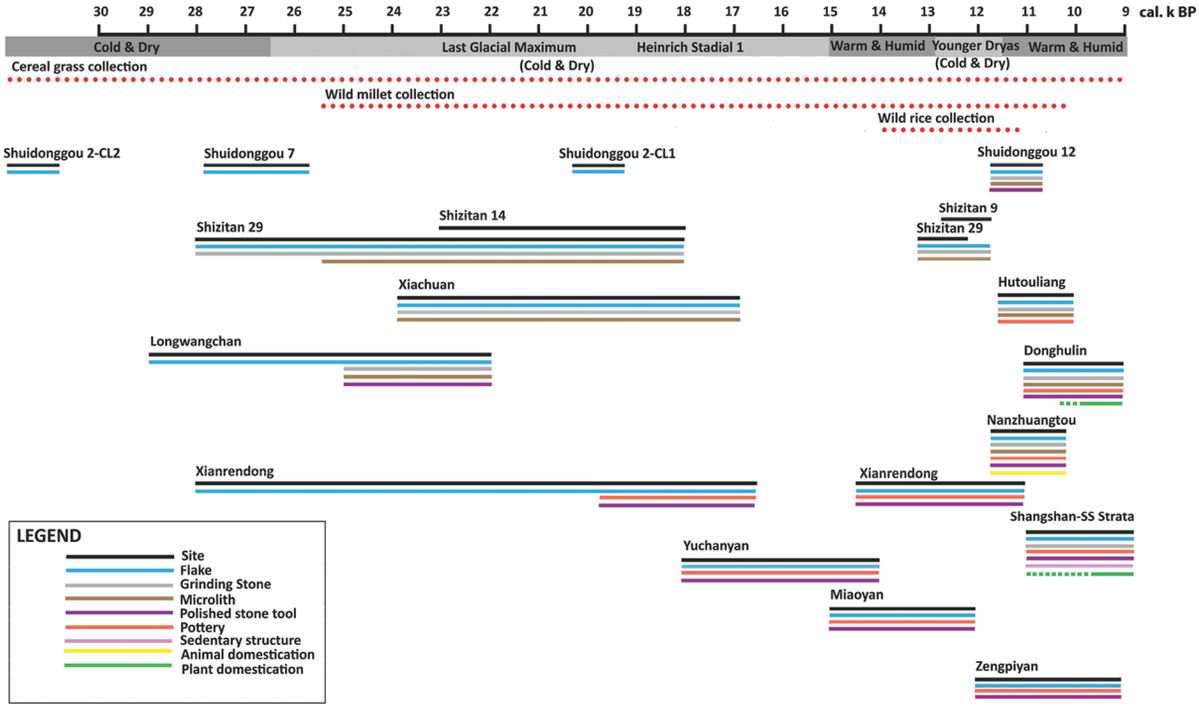


Figure 2. Time line of the appearance of key technological innovations and other cultural developments in China. Archaeology site references: Shuidonggou 2-CL2 (Chen et al. 2012), Shuidonggou 7 (Pei et al. 2014), Shuidonggou 2-CL1 (Chen et al. 2012), Shuidonggou 12 (Gao et al. 2014), Shizitan 29 (Song et al. 2017), Shizitan 14 (Shizitan Archaeology Team 2002), Shizitan 9 (Shizitan Archaeology Team 2010), Xiachuan (Lu 2006; Liu and Chen 2012; Wang, Wang, and Chen 1978), Hutouliang (Liu and Chen 2012; Zhang et al. 2010), Longwangchan (Zhang et al. 2011), Xianrendong (MacNeish 1995; Peking University and JPICRA 2014), Yuchanyan (Yuan 2002), Miaoyan (Chen 1999; Liu and Chen 2012), Zengpiyan (Zhongguo Shehui Kexueyuan 2003), Donghulin (Zhao 2006), Nanzhuangtou (Yuan and Chen 1992), and Shangshan-Shangshan Strata (ZPICRA 2016*a*). Data for climatic change: Clark et al. (2009), Dykoski et al. (2005), Song et al. (2017), Wang et al. (2001), Xu et al. (2013). Evidence of Paleolithic cereal harvesting: Guan et al. (2014), Liu et al. (2018), Peking University and JPICRA (2014), Zhao (2010).

process hard-to-digest plant foods such as small grass seeds and fibrous tubers (Liu et al. 2013), and some began to produce pottery, possibly for prolonged cooking (Wu et al. 2012; Zhang 2002). These technological innovations are material evidence of human adaptation to the severe environmental conditions of the LGM (Barton, Brantingham, and Ji 2007; Bettinger et al. 2007).

But environmental adaptation does not explain the whole picture. A closer examination of the terminal Pleistocene record shows that the time period between 30,000 and 9000 BP witnessed several distinct climatic swings—the climate oscillated between "cold and dry" and "warm and humid"—but there was no corresponding "fluctuation" in technological production over this period. An obvious question presents itself: when the climate became warm and humid around 15,000 BP, why did people not return to their lighter and simpler pre-LGM life, with no pottery, polished stones, or grinding stones? Manufacturing these tools might involve arduous labor and circumscribe hunter-gatherers' mobility. In other words, the post-LGM hunter-gatherers could have lived without the aid of these tools, like their pre-LGM predecessors, who survived in an even colder and drier environment (Song et al. 2017; Wang et al. 2001). Why did people continue using these tools after the LGM?

The short answer is that the material cultural environment had transformed after the LGM. When the last glaciation receded around 15,000 BP, humans no longer dwelled in the same environment—they had crafted a new material world. Once new technologies emerged, humans tended to develop a dependence. To explain this trend, I focus on two sources of human dependence: human bodies and the materiality of tools.

One source of dependence comes from human bodies. Tools allow a more thorough artificial processing of food, but at the same time they may induce anatomical changes that "parasitize" humans. While more comprehensive data are yet to be collected, Brace and his colleagues' (Brace and Nagai 1982; Brace, Shao, and Zhang 1984) preliminary analyses show a marked reduction in tooth size in East Asian populations since the beginning of the Late Pleistocene, possibly caused by the adoption of new food preparation technologies. The invention of pottery and grinding stones may have enabled humans to process foods in such a manner that the retention of teeth is no longer of crucial importance for survival. Holt and Formicola's (2008) study on European skeleton samples indicates a similar trend in human bodies, including declined craniodental robusticity, reduced stature, and smaller tooth size, correlating with the appearance of new technologies

following the LGM. In other words, humans were able to reduce their digestion load by outsourcing part of their body's functions to tools (Hodder 2018*a*). Tools functioned as a kind of extended human body.

The other source of dependence comes from the materiality of tools. Tools are active agents with the capacity to entrap humans into long-term reliance by at least two means. First, once a tool is invented, it tends to become multifunctional, drawing humans into greater reliance (Hodder 2012). Grinding stones, for example, were probably invented for a specific task, but once such investment has been made, people extended it to other purposes. The grinding stones from Shizitan offer a strong case in demonstrating such a process (Liu et al. 2011, 2013, 2018). At Shizitan, the earliest grinding stones (~28,000–26,000 cal BP) were used to process small cereal grasses and tubers, but later on they became involved in an extended array of tasks, including crushing hematite (ca. 26,000–24,000 cal BP, 12,700–11,600 cal BP), processing beans (23,000–19,500 cal BP), and grinding acorns (12,700–11,600 cal BP). This multitasking of tools created dependence traps for the humans that employed them.

Second, tools have deficiencies. When tools create problems, humans tend to fix them by putting in more investment rather than giving up entirely, thus activating the potential for improvement and change (Hodder 2012; Olsen 2010). The pottery production history exemplifies this tendency. The earliest pottery from the lower levels of Xianrendong in southern China was simple, made of coarse tempers, and fired at low temperatures (MacNeish 1995). These earliest pots were likely used for cooking (Wu et al. 2012), but they were also very fragile and tended to break easily. The fragility of these pots therefore posed a problem. However, instead of going back to life without pottery, the Xianrendong people decided to fix the problem because going back would mean giving up all the investment already made. They were drawn into investing even more time and energy in making more durable pots. As a result, the later pottery from the upper levels was made of finer tempers and fired at higher temperatures (MacNeish 1995; Peking University and JPICRA 2014:260–261). Making a greater investment therefore made it more difficult to give up. In other words, the "perfectibility" of tools drew humans into accumulative labor investment, making it difficult to revert to a way of life without these tools.

From the LGM onwards, hunter-gatherers in China appear to have developed an increasing reliance on material things. The occupation history of the Xianrendong cave offers a specific example of human dependence on tools. Figure 3 illustrates the time line of the technological innovations at the cave (data from Peking University and JPICRA 2014). The cave has a long history of repeated human occupation (28,000–12,000 cal BP). During the earliest phase (28,000–20,000 cal BP) the cave was a seasonal camp periodically occupied by foraging groups. The occupants produced small, portable stone tools that were made expediently. Bone tools were also small in size, consisting of mostly hunting tools such as arrowheads and awls. Starting around 20,000 cal BP, however, there was a gradual transformation in tool production and site occupation. The cave's occupants began to invest more effort into making stone tools like adzes, anvils, and whetstone. These tools were relatively larger in size, involved more labor, and were probably used for more diversified tasks such as grinding, tool polishing, and carpentry. The appearance of these new technologies also coincided with the beginning of pottery production, possibly related to the motivations such as more effective cooking (MacNeish 1995; Wu et al. 2012). The invention of these specialized tools occurred during the LGM when vegetation cover in the mountainous regions became sparser (Yue et al. 2012).

There was a hiatus in the cave's occupation from 17,000 to 14,000 cal BP, possibly related to a cave top collapse that made it unsuitable for dwelling (Peking University and JPICRA 2014). Around 14,000 cal BP, the cave was occupied again. At this time the climatic condition became warmer, leading to rapid restoration of dense forest with high taxonomic richness (Yue et al. 2012). But it would have been difficult for the new dwellers to adopt a lifestyle similar to that experienced at the lower levels, when only small tools were made for hunting and

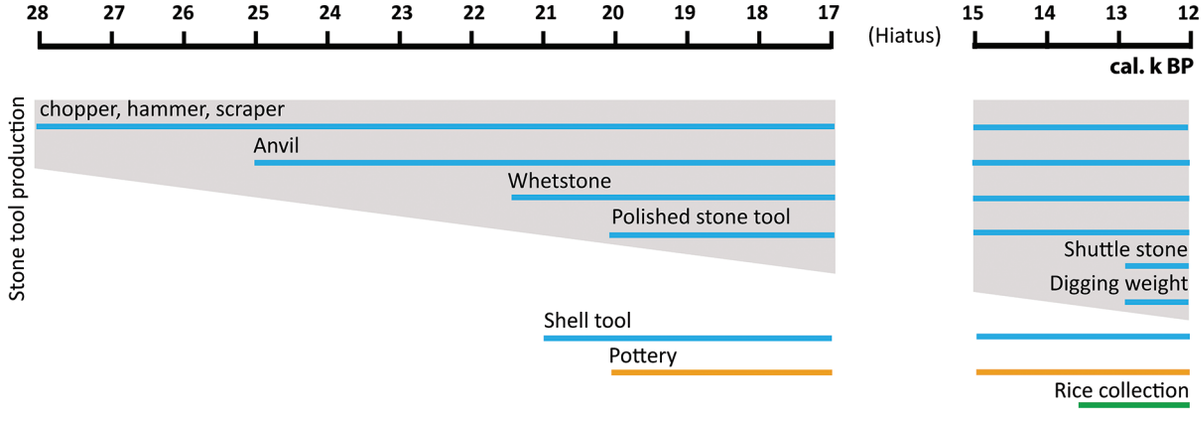


Figure 3. Time line of major technological innovations at Xianrendong (data from Peking University and JPICRA 2014).

gathering. By this time, they would have become dependent on many tools for daily tasks, such as pottery for cooking, adzes for carpentry, and whetstones for tool polishing.

Thus, around 14,000 cal BP, the new Xianrendong occupants continued to make pottery and other tools like their predecessors had. In general, cultural deposits became thicker, indicating prolonged occupation. Botanical and faunal data also suggest three-season occupation (Lu 2013; Peking University and JPICRA 2014). Increased sedentism motivated more investment in tool making, and thus, people were continuously expanding their material tool kit. Perforated digging weights appeared for the first time, likely in relation to more intensive digging activities for getting clay and/or tubers. Another innovation was the stone shuttle, which could have been used for weaving textiles. By this time people were already entrenched in a lifestyle that heavily relied on material tools, and it became difficult to turn back.

In summary, by the end of the Pleistocene, some foraging communities in China had become dependent on an expanding repertoire of material tools for daily activities. This new material world set up the stage for the transition that later arrived on the scene—the emergence of settled life and food production in the Lower Yangtze River.

### *Early Holocene: The Origins of Rice Farming in the Lower Yangtze River*

At the first glance, the emergence of the Shangshan culture (10,000–8600 cal BP) in the early Holocene appears to be a major departure from the preceding foraging lifeways. Unlike the terminal Pleistocene hunter-gatherers who were mostly mobile and relied on wild species, the Shangshan people settled down in open-air communities and began to domesticate rice, predating any signs of rice cultivation elsewhere in Asia (Zheng et al. 2016; Zuo et al. 2017). However, if we focus on Shangshan's material culture, there was nothing revolutionary. All the major material components—pottery, grinding stones, harvesting implements, and polished stones—had already been invented by the hunter-gatherers of the terminal Pleistocene.

What the Shangshan people did do, however, was initiate the "mass production" of these Pleistocene innovations (fig. 1*D*). A simple numerical comparison of grinding stone is suggestive of the scale of this transformation: at Shizitan Locality 29, the hunter-gatherers who repeatedly occupied the site over 11,000 years (29,000–18,000 cal BP) left only nine grinding stones (CHCSU and SPIA 2017). By comparison, at Shangshan, the early Holocene occupants produced 324 grinding stones over 1,400 years (1000–8600 cal BP; ZPICRA 2016*a*). Factoring in the excavation area and occupational length, the results suggest that for every single grinding stone produced at Shizitan Locality 29, there were 110 grinding stones produced at Shangshan over the same period. In short, what were considered luxuries during the Pleistocene were now everyday necessities. The observed phenomenon leads us to ask: why did the Shangshan people produce so many more tools than their predecessors?

It has hitherto been assumed that the scalar increase of material production was a consequence of cereal domestication (Chen 2002; Song 1997). However, recent research from botanical residue and ceramic petrographic analyses (Kwan et al. 2018; Liu et al. 2010*b*; Wang and Jiang 2022) provides the grounds for an explanation that reverses this causal order. Rather than being the driver of material production, rice domestication was instead the unintended consequence of increased material production and sedentism. More specifically, humans did not initially settle down for rice cultivation but were trapped into a sedentary life by the active agencies of material tools and another wild plant: acorns.

A comprehensive starch residue analysis based on a total of 93 Shangshan grinding stones and pottery indicates that they were primarily used for processing acorns (and tubers and cereals to a lesser extent; fig. 4*A*–4*C*; Wang and Jiang 2022). The grinding stones, which are large in size and relatively immovable, were used for pounding acorns. The flat-bottom basins, which are the most dominant pottery type and accounting for 80% of the pottery assemblage, were used as acorn leaching containers. The flat- or round-bottomed jars, which constitute about 15% of the pottery assemblage, were used for cooking acorn porridge. In China, acorns did not become part of food resources until the early Holocene (Liu et al. 2011, 2010*a*; Shelach-Lavi and Tu 2017; Wang et al. 2016; Yang et al. 2014; Zhao 2010), when the warming climate spurred an expansion of oak forests in many mountainous regions, including the Lower Yangtze River (Cao et al. 2015; Ren and Beug 2002). Taken together, the evidence suggests that acorn processing was central to Shangshan foodways. The nut acted as a powerful magnet that drew foragers to settle in particular locales and expand the scale of their tool production.

For the Shangshan people, acorns presented both new opportunities and new problems. Acorns were attractive plant foods because they were highly productive, rich in nutrients such as starch and fat, and naturally packed in shells and thus good for storage (Barlow and Heck 2003; Bohrer 1972). However, these nuts contained a bitter-tasting tannic acid, which had to be removed before human consumption. One solution was to dig a large leaching pit in a mound of sand that would allow the water to drain through, a percolation method used by many indigenous groups in North America (Driver 1952; Mayer 1976; Ortiz 1991:95–107). Alternative methods include placing acorns in a running stream, in a net bag or basket, and letting them sit for several days (Mason 1992; Mason and Nesbitt 2009). Another method is active water leaching, which involves mixing acorn flour and water in a large waterproof container, leaving the mixture to settle, and then pouring off the water, a process to be repeated several times. This method would require that the container be sufficiently large to hold the full amount of water needed to leach a given amount of acorns. The Shangshan people opted for this strategy and created a bulky, basin-shaped vessel type for this task (fig. 4*B*).

If we compare the Shangshan acorn-processing method with those adopted in other world regions, the Shangshan tool kit

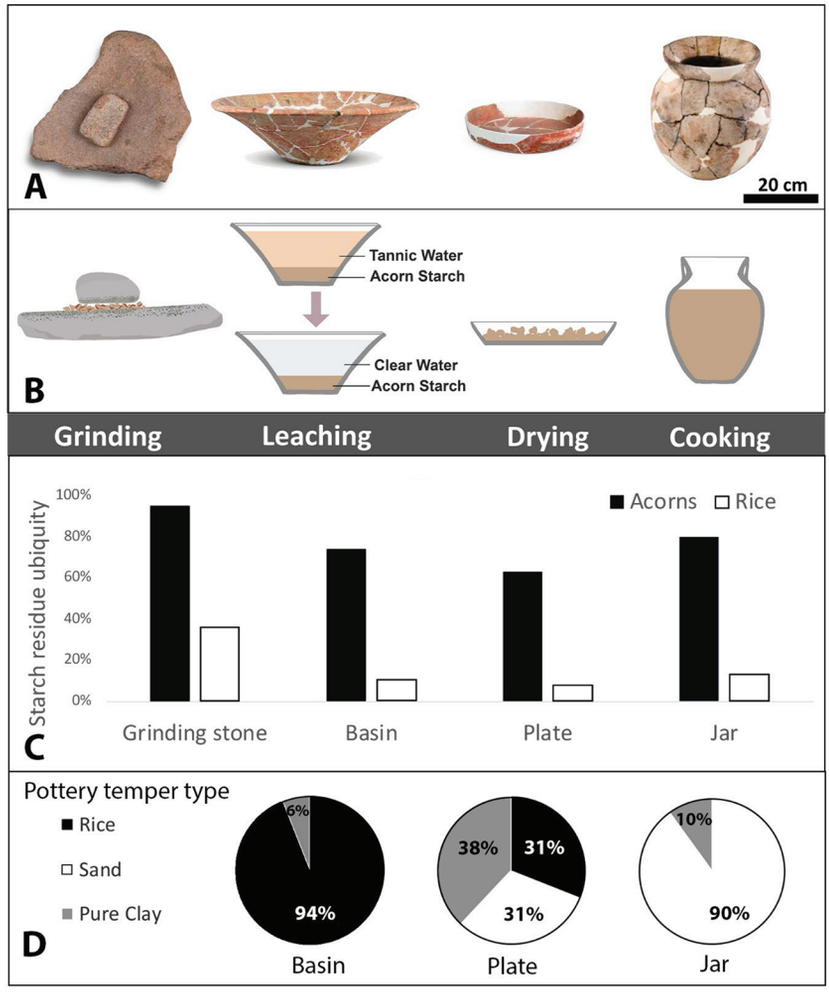


Figure 4. *A*, Major elements of Shangshan material culture. *Left to right*, grinding stone, basin, plate, jar. *B*, Reconstruction of Shangshan acorn-processing technology. *C*, Comparison of starch residue ubiquities of acorns and rice from the Shangshan site (data from Wang 2019; Wang and Jiang 2022). *D*, Proportions of Shangshan pottery tempers in three vessel types (data from Kwan et al. 2018).

involves significantly more material. The method relied on both grinding stones and pottery, which were not always used together in many other acorn-processing cultures. Grinding stones are heavy and almost impossible for transportation; constructing the bulky leaching basins would not have been a simple task. The acorn-processing method does not seem to be an "optimal" strategy from the HBE perspective. Why did the Shangshan people not just dig a sand basin or use a basket, like indigenous Americans? How did they fall into this "thing-heavy" processing method?

The reasons were likely related to the preexisting material cultural traditions. As noted above, as early as the LGM, hunter-gatherers in China began to use grinding stones and pottery for a variety of daily tasks, gradually developing a dependence on these tools. By the time of the Shangshan, these tools might have become a habitual component of everyday life. Thus, when the problem of acorn processing emerged, the Shangshan people simply applied the existing technologies to new functions. In other words, the processing technique was already geared up in the terminal Pleistocene—when grinding tools and pottery first emerged—long before acorns arrived on the scene.

A key development during this period was an innovative use of rice chaff as a pottery temper (fig. 4*D*). Thin-section petrographic analysis of Shangshan ceramics shows predominant use of rice as a temper for pottery making (61% of total), especially acorn-leaching basins (94% of total; Kwan et al. 2018). All earlier pottery in China is mineral or clay tempered (Wu et al. 2012; Zhang 2002). The invention of rice-tempered pottery might be related to several reasons. First, the typical clay of the Lower Yangtze was excessively wet, plastic, and thus unworkable. By using organic inclusions such as rice chaff, potters could make the clay immediately serviceable (Kwan et al. 2018; Skibo, Schiffer, and Reid 1989; Stimmell and Stromberg 1985:242). Second, rice chaff creates lighter vessels. As a general rule, plant materials as a temper almost entirely oxidize during the firing process. The resulting porosity creates

ceramic body up to 34% lighter than those tempered inorganic materials such as minerals (Skibo, Schiffer, and Reid 1989), making them suitable for large pots, especially those used for acorn leaching. By making pots lighter and expediting the manufacturing process, rice attracted humans into a close relationship with one another.

While rice was a "necessity" for pottery making during the Shangshan culture, as a food source the crop was of minor importance. Rice residues were rarely found on culinary tools, unlike acorns, which had a ubiquitous presence (fig. 3*C*). These results suggest that, for the Shangshan people, the demand for rice temper was stronger than the appetite for rice grains.

I suggest that pottery making drew the Shangshan people into initial rice cultivation and perhaps kicked off the initial domestication process. As mentioned above, the key characteristic of rice temper is its ability to produce expedient and lightweight pottery. These two advantages can achieve their best performance if the temper particles are big and dry. In general, larger and drier temper particles displace the clay—increasing the surface area of the paste that is exposed to air for evaporation—and brings unprocessed clay paste to a workable state quickly (Rye 1981; Shepard 1965). Therefore, the Shanghan potters would have preferred to harvest dry (i.e., nonshattering seeds that stay on the plant after maturity) and large rice seeds to green and small-seeded ones. If people saved some of the harvested seeds and sowed again in the next season, such cultivation practices would have produced selection pressure favoring nonshattering mutants.

As people set off the domestication process and expanded their material production, the physicality of tools and plants further tied them to specific locales and thus created a tendency toward sedentism. Tool production would have required knowledge of local resources for obtaining raw materials, encouraging a sense of place and history compounded by occupation at the same localities for an extended period. As people accumulated their material production to a certain degree, it became impossible to carry them from place to place, making settling down the only choice. The development of Shangshan culture witnessed a clear trend toward increasing settlement size and complexity. In the early phase around 10,000 BP, settlements were small villages of up to 3 ha composed of relatively simple houses and pits. By 9000 BP, a number of 10-ha "megavillages" such as Xiaohuangshan and Huxi appeared (Zhang and Wang 2005). These megavillages were characterized by ditch enclosures, deep storage pits, burials, and multiunit houses (ZPICRA 2016*b*).

As humans began to domesticate rice, the crop also became dependent on people for its reproduction, entrapping them into a set of complex labor-demanding activities such as sowing and soil management (Fuller et al. 2016). Once humans had embarked on the pathway of domestication, they gave up being mobile, arguably losing the skills required to carry on a fully foraging lifestyle until they reached a point of no return.

Archaeological data indeed show a steady trend toward intensified rice cultivation. Beginning around 9000 BP, people began to modify their landscape by weeding and possible water management. Archaeobotanical assemblages from the Huxi (9000–8400 cal BP) and Kuahuqiao (ca. 8000–7000 cal BP) show evidence of disturbed, well lit, and dry through wetlands relatively free of common reed (Crawford 2011*a*; Pan 2011; Zheng et al. 2016). Around 7000 BP, people of the Hemudu culture developed irrigated rice paddy fields, an innovation that required more labor commitment and thus tied people further to their land (Fuller et al. 2009; Zheng et al. 2009). As the scale of rice production expanded, more effort was directed toward cultivation, leaving less time for gathering and hunting wild species (Pan 2011). Around 5800 BP at Caoxieshan, acorns and many other nuts were absent, and rice dominated the plant food economy (Fuller and Weisskopf 2011). By this time, there was no returning to the previous foraging lifestyle, because people had already invested so much in cultivation and material production. They had unwittingly become trapped in a labor-demanding life of farming.

## Conclusion

This paper aims to reorient archaeological investigation of the agriculture transition. The current research agenda has been restricted by an unfruitful debate between push and pull models, a dichotomy between materialist and idealist approaches, and an anthropocentric ontology that privileges humans as the locus of action in historical processes. The core of the theoretical argument here is to decenter humans as autonomous, independent beings in the formation of agricultural societies, recognizing that nonhuman actors—through their intrinsic qualities—are vital, constituent parts of the process. This posthumanist approach to agricultural transitions challenges dominant ideas of ourselves as fundamentally different from other forms of life (Smart and Smart 2017:44). By demonstrating the transition to agriculture as an unintended consequence of iterative, dialectical interactions between humans and nonhumans, this approach renders the search for push or pull models unnecessary.

While the posthumanist approach echoes Rindos's coevolutionary model, it is more holistic by including a variety of nonhumans actors—both biotic and abiotic—as agents of historical change. Most of the previous studies treat the environment from a biophysical perspective, perceiving it as an ecological setting that provides "natural" resources for human survival. Not only do human societies dwell in a world of ecological elements; they also construct a material cultural environment on which they depend for a livelihood. These materials, produced in various forms such as utilitarian tools, architectural structures, and artistic objects, are active components of human engagement with the world.

My case study exemplifies how a posthumanist approach operationalizes in the research on the transition to agriculture in southern China. Beginning in the late Pleistocene, humans in China invented a diversified array of technologies such as grinding stones and pottery. While these new material tools

enabled humans to interact with a wider range of nonhuman species, they also structured human lives by creating a long-term, almost irreversible dependence on these tools. In the early Holocene, humans in turn began mass producing their Pleistocene innovations in order to process newly abundant plant resources. In the Lower Yangtze River, acorns acted as a transformative agent in this transition by inviting hunter-gatherers to settle in particular locales and expand their material production. Rice attracted humans into initial cultivation by its ability to make pottery. The evolution of the crop's domestic traits subsequently drew humans into cultivation, further trapping humans into the pathway of domestication. In short, the emergence of sedentism and initial rice domestication was a result of a problem-solving sequence caused by bitter-tasting acorns, heavy tools, versatile rice grains, and tool-dependent humans.

There is no intention to dismiss the importance of environmental change in the agricultural transition but rather an introduction of a nonanthropocentric perspective that permits symmetrical relationships between humans and nonhumans. In fact, how environmental change works out "on the ground" is to reconfigure the quantity and diversity of actors within a community. In the case of southern China, the LGM effectively shuffled the active members within a community: many subtropical forest species disappeared, some grassland species arrived, and new material implements such as pottery entered the scene (Li et al. 2013; Wu et al. 2012; Xiao et al. 2018). As pottery and other new food-processing tools enrolled within a community, humans were able to establish new relationships with other actors, such as clay and hard-to-digest food species. These new relationships afforded humans with new opportunities but also constraints, channeling human actions and leading to increased sedentism. Similarly, rice domestication can be regarded as a process of changing human-plant engagement. Instead of leaving some *Oryza rufipogon* to germinate on their own, humans established the conditions to help the growth of *Oryza sativa* along the way to maturation (Ingold 2000:77–88; Witmore 2007:555).

Taken together, these conclusions depart from the anthropocentric approaches that attribute the rise of agriculture to human interventions on the environment. Instead, this paper explores how the active agencies exercised by plants and tools entrapped humans into a long-term dependence and later into a sedentary lifestyle, eventually leading up to fully agricultural societies in southern China.

## Acknowledgments

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# Comments

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Over the past three decades, Chinese archaeology's engagement with world archaeology and its multidisciplinary research strategies drawing on the natural sciences has given rise to greater considerations of cultural processes, particularly concerning technological development or human interactions with the environment and the socioeconomic changes these may bring about: nowhere is this more apparent than in studies related to the origins of agriculture. While Jiajing Wang labels such studies as "traditional," in China, they are not: they are a second wave. The traditional approach involves implicit material culture typology oriented toward the construction of essentialist culture-history structured by progressivist notions of culture change, and discussions of theory and epistemology are limited. Wang's article represents a welcome move toward explicit theoretical considerations and, in particular, the questioning of underlying assumptions concerning the primacy of human agency in cultural change. However, while Wang calls for a posthumanist breaking away from anthropocentric ontologies through the recognition of the "active agencies" of "material tools," her interpretations involving these tools and the sites from which they derive remain rooted in the traditional approach and suffer from its pitfalls.

Although Wang highlights the drawbacks of the push/pull (materialist/idealist) and other debilitating dichotomies of theoretical stances, many discussions today recognize the interexistence of multiple sides. Dismissing Bar-Yosef (2011) as an advocate of monolithic climate push models is to miss key underlying themes evolving in his work by that time: climate correlation is not causation, and Bar-Yosef was actually pushing us to search for the still-unknown impetuses for the beginnings of cultivation across the social and cultural realms, including intergroup dynamics as balances of power and access to resources shifted between more mobile versus more sedentary groups and perceived notions of territorial access, all of which he encapsulated in the ideas of "relative demographic pressure" (originally proposed with Belfer-Cohen and Belfer-Cohen [2001] concerning hominid migration) and of resilience—not just success but also the divergent paths, and failures, that stories of progress, such as of the origins of agriculture told here, often choose to overlook. Demography, although ignored by Wang, and especially sedentism, do matter in this story, as they force us to shift our vantage and scales of analysis from the

narrow view of the singular site to the regional level and beyond, because the networks of interactions between groups were extensive.

Related to this problem of narrow vantage, Wang's argument taken as a general theory for rice agriculture origins in South China faces a problem: Shangshan is not the only pot on the fire. While sedentism, increasing use of pottery, and the beginnings of rice cultivation were occurring in the Shangshan Culture, they were also co-occurring in the Middle Yangtze region, but with different sets of material culture and subsistence activities—so far, with grinding slabs and acorns absent—as village sites of the Pengtoushan culture attest (Cohen 2014). Not once is the Pengtoushan culture mentioned in Wang's article. Pengtoushan vessel forms are quite different from Shangshan's, but they, like Shangshan's, are tempered with rice stems and chaff. Pengtoushan lithics maintain the Late Paleolithic cobble tool assemblages but with the addition of polished axes and adzes, not grinding slabs. Pengtoushan should force us to reevaluate the primacy and/or nature of the agency of acorns and grinding slabs in the origins of rice agriculture. Or did Shangshan's pot come to the boil first? Or something else? No matter which, Wang's model fails to withstand this broader perspective.

One way to shore this up might be consideration of the social realm: how do objects and their agencies relate to the vast social changes likely underlying the origins of agriculture, across multiple regions? Wang is perhaps prematurely throwing social relationships onto her midden heap of outmoded idealist approaches: why not instead consider how "material tools" could be agents in the transformation of these social relationships? To do so, archeologists need to turn to new, empirically grounded approaches to material culture, such as Preucel (2016, 2022) and Colwell (2022) point out in their discussions of Peircean semiotic mediation.

I would also suggest that how site function interacts with the (dynamic) agencies of objects needs to be incorporated better (or should I dare suggest that if the tools have agency, why not the site itself?). Wang's discussions of site function—based in traditional approaches—have some problems. For example, stating that the thickening of cultural deposits at Xianrendong is an indicator of "prolonged occupation" is a false and ironically anthropocentric assumption, because anthropogenesis (human agency!) is only a minor input in the formation of the site, as our micromorphological research shows (Patania et al. 2019). In the two sampled areas of the cave, the deposits mostly built up through flooding, and cultural materials ended up in the cave through dumping and not from people living in the cave! Wang's calculus involving intensity of site occupation and tool production to derive humans' "increasing reliance on material things" needs to consider site function.

It also needs to consider how the traditional approach can skew views of technological change and their connections. The Shizitan site is 1,400+ km away from Shangshan in a completely different cultural and environmental sphere (Song et al. 2017)—is the comparison being validated by a teleological historical paradigm of a unilineal path to modern political China (Clark 2018)? Also, to argue that Neolithic people at Shangshan are more bound by the agency of material culture than Shizitan 29 because of grinding slab numbers (324:9) is to ignore the 74,726 other lithics at Shizitan 29 and the incredible evolution of microblade technology observable at the site from a technofunctional rather than a traditional morphological typological approach (Song et al. 2019): in many ways, the mobile hunter-gatherers surviving the harsh environments of North China during the Last Glacial Maximum may have been much more bound by the agency of their lithics! While Wang's calls for new, posthumanist views of agency are novel for China and intriguing, more fitting ways to study material culture and broader scales of analysis are needed to realize the potential of this approach.

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Wang sets out the case for less anthropocentric understanding of agricultural origins and the particular case of the rice domestication process in eastern China (the Lower Yangtze region). Empirically, this builds on recent work that has shown domestication to be much longer and more drawn out than previous models focused on human agencies of social competition or adaptationist approaches. The limitations of traditional explanatory positions are nicely summarized. Many fail by creating "a goal-oriented narrative." Wang notes that this is at odds with a protracted process of "perhaps a millennium," but a millennium is actually too short to encompass any of our better-documented cases of original cereal domestication or agricultural origins. Two thousand years (100 human generations) should be regarded as a bare minimum for the domestication of emmer, einkorn, and barley in Southwest Asia (Fuller et al. 2018), or African pearl millet (Fuller et al. 2021), and even longer for Chinese rice. However, as demonstrated in Allaby et al. (2017), this only accounts for the final and faster end of the domestication process, when we can reasonably infer persistent traditions of systematic cultivation. Instead, the appearance and slow increase of rare mutations, like nonshattering cereals, must date many millennia earlier. Estimates for wheats and barley suggest that the slow increase in what would become domestication traits in the Holocene began around 10,000 years earlier, around the Last Glacial Maximum, implying that something about the environment in which those wild cereals were growing, alongside Epipaleolithic hunter-gatherer traditions, had already dislodged the cereals from a purely wild equilibrium. A similar approach to Lower Yangtze rice projected the appearance of nonshattering as a rare but increasing variant since ca. 13,000 BP (Allaby et al. 2017). The implications of this are that we need to conceive of a slow coevolution of rice with

anthropogenic environments, in a broad sense, as taking place for millennia before being racheted up by cultivation that culminated in domestication (fixation of traits) in the middle Holocene societies that archaeologists usually recognize as early farming cultures. This implies the need to decenter human agency from domestication, which calls for a landscape-scale perspective (Allaby et al. 2022), a process philosophy perspective (Bogaard et al. 2021), or posthumanism (Wang).

Starting from various theoretical assumptions about decentering human agency, Wang outlines a longer-term material culture framework in which to place rice domestication. Rice domestication, she argues, was an unintended outcome of technological developments for other reasons. She argues that the accumulation of diverse artifacts involved with food processing and environmental manipulation create their own inertia. Cultural traditions that make grinding stones, cooking pots, and microliths tend to expand the range of uses of these things included in food gathering and processing, and they are more likely to invest in improving these technologies than abandoning them. Thus, acorns, which had clearly become an important carbohydrate staple across large parts of north and central China, were processed by a combination of these methods, including the production of larger ceramic basins by the Early Holocene Shangshan culture in Zhejiang. Wang notes that other methods, without ceramics, for example, could equally have removed tannins from acorns. I suspect, however, that the combined methods used at Shangshan would have been more efficient (faster, for larger quantities of acorns) than methods known ethnohistorically from California or elsewhere.

In this context, she argues that rice husk as a temper for large ceramics was needed, perhaps more so than use of rice for food. It is misleading, however, to argue that this favors domestication per se (nonshattering, larger grains), as mature spikelets (wild or domesticated) provide dry husks, and even if they "preferred to harvest dry" spikelets, this will not cause genetic changes in rice populations. Genetic data make it clear that domestication results from the accumulation of several mutations, some affecting panicle structure and seed shedding, which must be maintained by environments, such as cultivation or weeded wetlands, that favor reduced wild-type reproduction. One of the first changes was likely a gene that causes closed panicle architecture in which shattering spikelets get caught, making them easier to harvest (Ishikawa, Castillo, and Fuller 2020). But many of these will still fall through the harvesting process, thus reproducing this trait in wild harvested stands, even if not routinely cultivated. Nonshattering is likely to have appeared and increased under cultivation in these closed panicle populations. Once nonshattering became prominent, new labor traps and drives for technological innovations to improve harvesting and storage are to be expected. In other words there was a long-term fluctuation of labor efficiency driven by evolution of the rice plant and technological innovation, or what Wang has dubbed the drive for "perfectibility of tools." What I found missing from Wang's account, however, was a more nuanced appreciation of the stepped changes implied by rice genetics and how these coevolve with different aspects of human practices, technologies, and the wider landscape of vegetation. Also, rice was not domesticated only in the Lower Yangtze, so we must ask whether similar or divergent processes took place in the Middle Yangtze, the Huai, or the Ganges regions of early rice.

Niche construction theory (NCT) was rejected as human centric, but I would object that this misses the wider relevance of the NCT perspective. As noted by Bogaard et al. (2021:2) many examples of "one-sided niche construction" that are human centred persist, but a posthumanist or process perspective on NCT should give more weight to unintended coevolutionary processes—species like grain weevils or cereal weeds have evolved dependence on the environments of settlements (which concentrate nutrients in the landscape) or arable fields (which reduce species diversity but increase competition; Fuller and Stevens 2017). Meanwhile, human technological innovations are frequently "improved" to fight such "pests" (but never win). Plants construct soil (affecting microbiome; Pieterse et al. 2016) and are impacted by herbivores that are impacted by hunting. Technological inertia, usefully considered by Wang, is just one strand in an entangled landscape.

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Wang's paper offers a compelling critique of anthropocentric ontology in archaeological research on the origin of agriculture. She argues that both the materialist approach treating the transition as an adaptive response to environmental change and the idealist approach treating it as an expanding realm of social competition are fundamentally flawed for their assumption of domestication as a goal-oriented endeavor aimed at maximizing reproductive success of plants. Those stated benefits, however, actually took millennia to develop, which represents a very different rhythm of time from that of human intentionality.

Instead of focusing on human-centered endgame goals, Wang's intriguing case study on the origin of rice domestication in the Lower Yangzi invites us to explore how the active agency of nonhuman actors, such as their distinctive life cycles, physical properties, technological configurations, and behavioral traits, entrapped humans into a long-term dependence and later into a sedentary lifestyle through sustained interactions from the Terminal Pleistocene to the Early Holocene. Wang traces this transition to the Early Holocene adaption of a Last Glacial Maximum (LGM) tool kit, including pottery and grinding stones, that was initially developed by mobile hunter-gatherers to cope with food shortage. By using this tool kit for

the consumption of acorn as part of an expanding Early Holocene diet, the prehistoric communities associated with the Shangshan material culture (10,000–8200 cal BP) put in motion a new set of technological elaborations and material entanglements that eventually led to the development of agriculture as an unintended consequence.

The key physical attributes contributing to this transformation are the toxicity of acorn as an Early Holocene food source and the fragility of pottery as a processing and cooking vessel for acorn consumption. Acorns were leached in pottery vessels for detoxification before they were cooked for consumption. Early Holocene potters of the Lower Yangzi chose rice chaff as an ideal temper to improve fracture resistance, heat conductivity, and weight reduction. Early rice plantation, Wang argues, was aimed at producing rice chaff as plant temper for pottery production. The eventual consumption of rice grain as a food source was an unintended by-product of this initial domestication. This chain of transformations increasingly channeled Neolithic communities of the Lower Yangzi toward sedentary life through the next five millennia.

Departing from the sweeping generalizations in previous research on the transition to agriculture, Wang's case study highlights the critical importance of understanding the configuration of knowledge, technologies, and things within a society. Within such a dynamic theater of interactions, the life cycles, vulnerabilities, physical attributes, and even sheer weight of nonhuman actors all have potential to alter humans' relationship with them and the trajectory of technological development. This is a significant contribution of Wang's posthumanist approach, whereas nonhuman actors were no longer regarded simply as "nutritional resources, utilitarian tools, or symbolic representations subject to human exploitation or meaning making."

Returning to the dichotomy between materialist and idealist approaches discussed at the onset of this paper, my question is about the place of human agency in the posthumanist approach. As communities adapt to problems emerging from climate-induced environmental change and from the materiality of their tools and technology, how do we reposition human agency into this interaction between human and nonhuman actors that account for both human and nonhuman agencies? Wang's argument for the development of a tool kit to adapt to LGM and the exploitation of new food sources resulting from the climatic change in the Early Holocene is consistent with a materialist approach. The problem-solving orientation of ceramic production for the purpose of acorn consumption is based on utility and functionality, thus an extension of a materialist approach and practical reason. The technological choices made to cope with nonhuman agency therefore represented an expansion in the range of material circumstances that the prehistoric communities adapted.

A focus on nonhuman agency appears to replace instead of complement human agency. I am not yet ready to give up on the symbolic significance of rice grain altogether based on the lack of evidence for ubiquitous rice consumption and on the absence of social inequality in Early Holocene society. My reasoning is twofold. First, if wild rice were highly prized among the communities for its culinary or ritual significance, then the lack of representation in acorn-dominated Early Holocene subsistence is expected. Residue analysis by Wang, Jiang, and Sun (2021) on elaborately constructed pottery vessels from the Qiaotou (9000–8700 cal BP) site in Lower Yangzi revealed that these painted vessels once held rice beer made with mold saccharification-fermentation starter. Nearly contemporaneous in chronology, the Shangshan site and the Qiaotou site are separated by 30 km in distance. It is unlikely that rice was desirable primarily for chaff as a plant temper for pottery production by one community and was valued as a key ingredient for alcohol production by another within the same region. The remarkable improvement in the quality of pottery vessels from Qiaotou suggests that alcohol consumption might have helped accelerate the refinement of ceramic industries and rice plantation in the Lower Yangzi during the Early Holocene. The use of rice chaff for pottery production could be a by-product of rice consumption rather than the impetus for it.

Second, the absence of marked social inequality should not be used as evidence against the desirability and ritual significance of rice consumption. In previous research, there is a tendency to reduce the idealist approach to early food production to the works of self-interested aggrandizers (usually alpha male figures) and their alternative "leadership strategies." Like the anthropocentric ontology critiqued in this paper, such a reduction does not do justice to indigenous ontologies that defy modern classification of humans and nonhumans. Could prehistoric communities have a meaningful engagement with rice as a ritually significant food item without making any association with the political goals of the aggrandizers to attract followers and elevate their own status? Can we identify an idealist component within the posthumanist approach, where social values, beliefs, and ideologies actually mattered?

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Wang's article makes a substantial contribution to the literature on agricultural beginning in China and its theoretical inferences, using the process of rice cultivation as a case. The paper embodies a great deal of recent studies, set within a thoughtful theoretical framework. It is encouraging to see this presentation in a high-profile anthropological journal broadening the horizon of foraging-farming transitions in China, not just in terms of the new evidence documented but also in its attempts to think through agricultural ontology, an approach that in my view is new to Chinese archaeology. While the East Asian domestication pathways have been a subject of major debate in the past two decades, I doubt Donna Haraway and the

"biosociality" theory have featured much in Chinese archaeological bibliographies before.

The paper benefits from the wealth of recent investigations of the regions, and I appreciate the author's effort in pulling together a rich body of theoretical literature. My starting point is a broad agreement with the author. This comment will, however, focus on considering the communicative aspects (rather than technical aspects) of companionship, including nonhuman entities as a central theme set by the author. The author could move even further to explore the material and biological practices embedded in the logic of "science of the concrete," a rubric coined by Lévi-Strauss (1969). This is not necessarily a quibble, as the theme is beyond the current scope of the paper but can inspire future conversations if fully unpacked. In a sense, the main issue may or may not be identified within the realm of materialist/idealist dichotomy as positioned or the Durkheimian schema of mundane and profane for the same matter. Rather, the issue is embedded in the later anthropological debate concerning structure and structuralism. The nature of the Pleistocene roots of the Chinese Neolithic and not the Bronze Age is an inspiring question. By which I do not mean an evolutionary process as advocated by Morgan, but more in Lévi-Strauss's thesis of the Neolithic as a category of practices embedded in a "logic of the concrete," which can be seen as a continuity of the Paleolithic discourses, as the paper rightly suggested, but a departure (though not a clear cut) from the subsequent Bronze Age approach partially proven by the invention of the logographic writing system.

Then the question is whether rice cultivation (or food production in general) was a part of the Paleolithic-Neolithic science of the concrete—to follow the argument structure of this article seeing rice cultivation as an unintended consequence of material-physiological dependency of older traditions—and, if so, why agriculture is seen as a single category cross-culturally. To some, the latter point may seem to be irrelevant, but it is an essential problem in my view that is too often seen as granted rather than taken as an issue. The problem is what common patterning underlies the unambiguous differences in agricultural origins in different parts of the world. For example, is the origin of agriculture in the southwestern Asian hilly flanks the same entity as the Chinese *Nongye* (农业), or are the structural differences masked by the translations or archaeological descriptions?

This is one of the areas where cross-cultural comparison can be productive, and discourses within China alone are not enough. One of the best examples is embedded in the case brought up by the author, the chronological mismatch between food preparation tools and the significant later biological domestication. There has been considerable momentum in establishing tensions between the development of foodways and symbolic elaborations of food (Fuller and Rowlands 2011; Haaland 2007). In Asia, such a theme is grounded in contrast between a cooking pot (steaming and boiling) tradition in East Asia and a grinding and baking tradition in southwest Asia, a distinction manifested by striking differences in the archaeological record: in the Near East, domestication of cereals appeared thousands of years earlier than ceramics, whereas in China, pottery predated cultivated cereals by millennia. Such deep-seated culinary differences were like the basis, rather than the consequence, of the taxonomic and biological differences between the eastern and western agricultural systems.

During the subsequent mid-Holocene agricultural dispersals, recent research drew attention to the geographical decoupling of the cultigens and cooking technologies, such as the eastern movements of wheat and barley into ancient China, from the western grinding-and-baking cuisines and adaptation into the eastern small-grained boiling contexts (Ritchey et al. 2022). Such tensions between foodways and food elaborations constitute a good example of the independency of entities forming a complex web of value to which humans contribute but are not necessarily at the center of, a vital point made by the author.

The example further highlights the necessity in understanding regional variations of such interdependent structures that are often more conservative than participating actants and the transcendent value of cross-cultural analysis, allowing cultural-specific discussions of what can be viewed as regional dialects of the science of the concrete, not necessarily in the way to imagine being stuck in the Neolithic, as Jack Goody (2010) alluded to, but to encourage conversations of the past with more presence of the global south (and east in this case). There is plenty of work to be done. That does not take away from the substantial contribution made by the author and the important issues discussed in the paper. If we move our lens forward to more contemporary conditions, it may well be the basis for understanding realities with less anthropocentric ontology and the opportunities, if nothing else, for thinking about alternative futures.

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## Cultural Inheritance and Agricultural Innovation

In this article, Jiajing Wang introduces a potent new player into discussions of agricultural origins in southern China: pottery. Through a detailed study of the development, construction, and varied uses of pottery vessels in the Late Pleistocene and earliest Holocene, Wang makes the convincing argument that technological demands for durable pottery production drew humans into closer relationships with the wild ancestor of domesticated rice, *Oryza rufipogon*. By focusing on the materiality of the pottery and the demands imposed by its physical structure on human makers and users, Wang highlights the agentive role of pottery in the initial domestication of rice.

The strength of this approach is based on a robust understanding of the continuities in technological tool kits for food

production between the Late Pleistocene and the Early Holocene, including the widespread use of microliths, grinding stones, and pottery, technologies also argued to play a key role in predomestication plant use in Southwest Asia (Bar-Yosef 1998; Piperno et al. 2004). In Southwest Asia, these tools led to extended interactions between people and cereals that eventually came under cultivation and domestication, supporting arguments for diverse forms of "low-level food production" (Smith 2001) over a period of millennia (Fuller, Asouti, and Purugganan 2012). Wang argues that the course of events was different in southern China, with technologies developed to process other food resources, primarily acorns, that only eventually became applied to the processing of rice. This distinct agricultural trajectory, well documented here through starch analysis of grinding stones and pottery vessels from Shanghan, represents an important contribution to comparative understandings of agricultural origins.

Wang also rightly focuses on the role of inherited cultural knowledge in the construction and multiple uses of both grinding stones and pottery vessels that led to their increasing production for acorn processing in the Early Holocene. Cumulative cultural knowledge is especially important in the maintenance, propagation, and diversification of complex technologies, with both population size and connectivity important in maintaining technologies, including agriculture (Henrich 2004; Morales, Rodriguez, and Marrero 2016). The body of literature often termed dual-inheritance theory (Boyd and Richerson 1985) explains the evolutionary underpinnings of the generation of cumulative cultural knowledge by modeling how individuals interacting with others through cultural learning mechanisms can produce and sustain knowledge and technologies. In this strictly evolutionary epistemology, the development and adaptation of ceramic technologies for the use of rice can be explained as the result of long periods of cultural knowledge accumulation about pottery, lithic technologies, local ecologies, and food preparation, set in an environment of cultural learning and effective transmission of that knowledge among individuals and across generations. As Wang argues, the adaptation of existing ceramic technologies for acorn leaching (rather than, e.g., leaching pits) reflects a preexisting system of cumulative cultural knowledge that led to a particular adaptive choice for processing a novel food item. In this sense, the pathway to rice domestication through the medium of pottery can be framed as an evolutionary process.

To make this point is not to argue, however, that the entanglements between people, rice, pottery, and acorns described by Wang are either invalid or useless. In fact, considering entanglements, especially those based on the physical materiality of objects and organisms, is particularly instructive in the case presented here. By identifying the technological demands of ceramics that advantaged people using plant temper in their construction, while at the same time recognizing the bulkiness, weight, and fragility of large, open pottery vessels, Wang makes the important insight that sedentism, intensive acorn use, and repeated harvesting of wild rice became mutually reinforcing activities. The "dependence trap" (Hodder 2012) of these large, relatively immobile objects directed humans toward increased sedentism to minimize the costs of movement. Simultaneously, their deficiencies, argues Wang, brought humans along a trajectory toward improvement, rather than abandonment, of these technologies, leading to greater use of wild rice temper and eventual cultivation (and, later, domestication) of rice. This sequence of events is supported by the archaeological evidence presented here.

I would argue, however, that just because this sequence can be explained as a set of entanglements and the archaeological evidence supports this sequential chronology does not mean that this sequence actually *explains* the domestication of rice. I present this argument in two ways. The first is based on particular exigencies of rice cultivation, while the second extends this notion using the approach of "plausible alternative histories" (Morehart 2012).

Wang argues that selective sowing of mature, dry, nonshattering rice took place as a consequence of selection for best temper characteristics. This helps to explain the evolutionary mechanism by which *O. rufipogon* was selected for characters associated with the resulting domesticate, *Oryza sativa*. This argument is then extended toward increased intensification in rice cultivation, with increased labor required to weed and irrigate rice. What is not explained here, however, is why intensification occurred. Did the demand for rice temper outstrip its natural availability? Did rice already become an important food source, leading to intensification as a food item? These questions remain unanswered.

Consider, instead, a "plausible alternative history" of rice cultivation that did not lead to intensive agriculture. At this very point, when rice became important for temper and developed nonshattering rachises, it could instead have remained a "low-level" cultigen (Smith 2001), farmed using low-risk, extensive strategies that maximized diversified subsistence avenues within a forager-farmer (or even forager-farmer-herder, with domesticated pigs in the region before 8000 cal BP; Price and Hongo 2020) subsistence strategy. Such strategies are evident in societies worldwide as evolutionarily stable, long-term adaptations (Zeder 2015). As Morehart (2012:277) argues, considerable insights come from explaining why one historical trajectory, but not another, occurred. I suggest that considering this plausible alternative will help us understand not only the domestication of rice but also the origins of an intensive rice-based agricultural economy.

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I congratulate Wang on this thought-provoking paper. Wang demonstrates in this paper that adopting a multispecies and posthumanist, rather than ethnocentric, approach is useful in

generating interesting insights into processes of animal and plant domestication. I particularly appreciate the nuanced unpacking of the long-term interplay between humans, technologies, and tools in the creation of the Neolithic lifeways. My quandary with this paper is twofold, at both the concrete (how the domestication of plants is explained) and the epistemological (the implications of adopting a posthumanist paradigm) levels. I hope that thinking through those issues will be useful for the paper's author and readers alike.

Similar to the case study discussed here—rice domestication in southern China—our research in northeast China demonstrated that the process of domestication (in this case, of millet) was a very long one (Stevens et al. 2021). Moreover, long after millet had been cultivated and was in the process of domestication, the diet of the Neolithic villages' population was predominantly based on the collecting and hunting of wild resources (Teng et al. 2019). However, Wang's stereotypical and rather schematic presentation does not do justice to existing explanations of this long-term trajectory. In her discussion, Wang contrasts a materialist approach, according to which climatic-induced stress "pushed foragers to adopt rice cultivation to solve the problem of seasonal food shortage," with an idealist approach, according to which "rice was domesticated as a prestige food for social purposes." She fails to acknowledge the fact that the most recent reconstructions of this trajectory in South and North China attribute the process to a complex interplay of factors such as the transition to sedentary lifeways, the social processes that accompany such transition, the use of existing and novel technologies, experimentations with food cultivation, and the intentional planting of food near the emerging villages, as well as intracommunity and longer-range interactions and exchanges (Allaby et al. 2021; Fuller 2020; Shelach-Lavi et al. 2019). Although they are not employing a posthumanist vocabulary, such models are not very different from the one presented by Wang. Thus, I would urge her to address (or at least acknowledge) the complex human-related processes—which combine economic, social, and cultural motivations—before she arbitrarily discards them in favor of a posthumanist paradigm. For example, I agree and have written extensively how "tracing the deep history of material culture may provide key clues to developing a new understanding of the agricultural transition" (e.g., Shelach-Lavi 2015:51–66; Friesem et al. 2019 present a similar case study from the Levant). But is such a long-term trajectory proof of the agency of artifacts, or is it just another way of saying that human actions, be it through the development of new technologies, the exploitation of new resources, or the intervention with the natural environment, have consequences that humans were unable to predict and that could manifest long after the people who initiated those processes are gone? Although I recognize specific insights gained from adopting a posthuman approach, I am not convinced that by adopting this framework Wang is able to significantly challenge current understandings of the development of agricultural lifeways in ancient China. I guess that, on this practical level, I concur with other skeptical voices that question the overall usefulness of applying the "ontological turn" to archaeological research (e.g., Gardner 2021).

At the epistemological level, one should be more conscious of the implications of phrases such as "agency of material culture." What does it mean? Do we really think that animals, plants, and even inanimate objects are actors in the same way that humans are? Or is it a metaphor that helps us think about human entanglement with the natural environment? It is common knowledge by now that some animals, such as pigs and dogs, "domesticated themselves." The idea that plants "domesticated" humans is an even more far-reaching metaphor, and so is the idea that not only animals and plants but also even minerals and artifacts have agency and that through their unique intrinsic qualities, they "force" people to use them in certain ways. Can we really equate human agency with such nonhuman agencies? My answer is an empathetic no. Human agency is not only complex, intensive, and multidimensional but also continuous and protracted. The comparison, at the beginning of the paper, between materialist and idealist models explaining the transition to agriculture is, in fact, a formulaic dichotomy between complementary aspects of the same process. Clearly, as much as the transition to agriculture was a product of material human needs (to facilitate the acquisition of food) and of technologies invented by humans, it was also a product of human culture. Cultural values, such as taboos on the consumption of certain foods or prestige associated with other types of food, affected the evolution of humans' interactions with their environment. These processes did not end with the beginning of agriculture. Intensification of food production through, for example, the feeding of animals with domesticated grains and the fertilizing of the agricultural fields with animals' manure created a positive feedback loop of intensification and the expansion of agricultural niches (Yang et al. 2022). Social processes, such as the development of elite control over the work of nonelites, often results in the intensification of agricultural production. Can we attribute such extensive range and long-term effects to the "agency" of animals, plants, and minerals? My problem is not with the use of agency as a metaphor to help us recognize that humans are not the rational creatures we once imagined them to be and that our actions often have consequences that we cannot foresee and are unable to undo. But the fact that human actions cause unintended and sometimes long-delayed consequences (something that most researchers would agree on) is not the same as claiming that humans have less agency or that nonhuman actors have agency.

This blurring of the differences between human and nonhuman has significant consequences. By creating an illusion of equivalence between the actions of humans and nonhumans, we risk misunderstanding the processes of human history, including the transition to agriculture, agricultural intensification and diversification, and their effects. Ascribing a humanlike agency to animals, plants, and artifacts inevitably lifts some of the responsibility from our (human) shoulders (Preucel 2021:464). The transition to sedentism and agriculture

had long-term consequences, such as environmental degradation and the loss of biodiversity (Elvin 2008; Huan et al. 2022). If all beings and things have agency, are humans—especially since we were unaware of the future consequences of plant domestication—somehow less responsible for them? Do pigs, because they "domesticated themselves" and "forced" humans to economically rely on them, share their responsibility?

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Wang provides a thought-provoking alternative perspective on the origins of agriculture and encourages scholars to contemplate novel mechanisms. Her argument states that "pottery making drew [foragers] into initial rice cultivation and perhaps kicked off the initial domestication process." While providing a new perspective, what she presents is still a basic pull argument, with the word "drew" simply replacing "pulled." Given that there is no real explanation for why an "entanglement" with grinding stones would force humans to invent pottery, and why the "entanglement" with pottery would cause crops to evolve domestication traits and people to invent farming, it appears that Wang's overall thesis is teleological. As she does not see culture as adaptive (following Hodder 2012, 2018*b*), then all that is left to explain the trajectory toward increasing complexity that she describes is an innate drive in humanity for progress or to accrue things (vaguely reminiscent of the sociobiologists; e.g., Morgan 1877). In fact, entanglement theory could be rebranded as greed theory, as it assumes that humans are driven by a biological urge to own more "things" even at the expense of diminished quality of life. Additionally, Wang's overall claim that grinding stones and ceramics caused domestication fits very well into her "anthropocentric ontology" category of ideas, as she considers only the perspective of humans and their cultural trappings, ignoring the role of rice in the mutualism. Rice enters the equation with its own ecological limitations, ranges of developmental plasticity, evolutionary legacy, and phenotypic diversity.

Wang claims that "the agential distinction between humans and nonhumans does not exist in many indigenous ontologies," specifically noting that "this anthropocentric ontology is a peculiarly Western construct." Her sweeping generalization buries any meaningful discussion under a Euro-American prejudice (e.g., transubstantiation, veneration of public depictions of political leaders, empowerment of relics or books, the Beast's Castle, or My Little Toaster). What she actually seems to mean is that biological science has yet to identify a consciousness within any inanimate object (i.e., rejecting animism or totemism). Therefore, a scientific approach cannot defend the claim that grindstones forced humans to invent agriculture. It is equally erroneous to claim that approaches utilizing ecology, evolutionary biology, or what Wang disparagingly refers to as "a (neo)Darwinian perspective" neglect to consider the role of plants and animals. Ecologists, by definition, study the interaction between organisms and the biotic and abiotic world around them. When Wang claims that she "seeks to transcend the limitation [of the anthropocentric ontology] through a close examination of the role of nonhuman agents," it appears that she is calling for an ecological perspective for domestication studies. Indeed, many archaeologists overlook the important ecological role of plants and animals in the domestication process. Ultimately, what Wang calls an "anthropocentric ontology" is simply an anthropological approach divorced from evolutionary biology or ecology, although to claim that all such anthropologists are "anthropocentric" (or, worse, that their ontology centers on anthropocentrism) seems extremely unjust. Wang struggles to fit the dichotomy that she sees in archaeological theory into existing terminology: processual/postprocessual, modern/postmodern, materialist/idealist, and humanist/posthumanist. But, in the end, she constructs a dichotomy placing modern science (ecology and evolutionary biology) in opposition to antiscientific approaches. This dichotomy fixes positivist, rationalist (and empiricist), and modern scientific (including the full spectrum from Popperian to Kuhnian) thought in opposition to antipositivist (maybe interpretivist), mysticism, and traditional knowledge systems (what Wang calls "indigenous ontologies"). As a side note, I find it worrisome that a sharp line is so often drawn between "ontologies," as traditional ecological knowledge is often constructed through observation and experimentation and is therefore scientific.

As Wang aptly illustrates, postmodern thought has manifested in the sciences in varied ways. Historians of science have traced intellectual lineages from the Counter-Enlightenment thinkers, through the various schools of romanticists, idealists, historicists, transcendentalists, and nihilists. While it would be disingenuous to claim that all of these guilds are similar, there is a shared rejection of scientific inquiry, especially of positivism, and retaliation against rationalism. In his great polemic, Popper (1945) compellingly argued for an intellectual linkage between the German Romanticist movement (and the Counter-Enlightenment more broadly) and its embrace of mysticism and antiscientific concepts, stretching from Hegel to Marx and Engels, to the rise of early twentieth-century European nationalism. Given the current global resurrection of nationalism, anti-intellectualism, and increased prominence of popularist ideals, science is clearly still as relevant as Sagan's proverbial "candle in the dark" (Sagan and Druyan 1995).

Wang uses the terms "entangled" and "entrapped" as proxies for mutualism, as she seems to have an aversion to the use of established terminology or ideas that come from the biological sciences (again following Hodder 2018*b*). Wang recognizes the growing trend among scholars to resurrect the Rindosian approach and correctly links human behavioral ecology (HBE) and niche construction theory (NCT) to these ideas (see Abbo

and Gopher 2020). Wang describes the NCT approach to domestication as organisms "codirect their evolution"; I have argued elsewhere that the Zeder application of NCT largely replicates Rindos (1984) and that Laland's application draws from HBE (Spengler 2021). Rindos (1984) heavily cited a foundation of ecological theory and Darwinian thought. The greatest limitation to Wang's thesis, and the entanglement theory that she pulls from, is its insularity—only citing scholarship from within the intellectual guild, ignoring mainstream discussions. Echo chamber discourse is a worrisome trend, as seen among some NCT proponents who avoid engaging with ecological or evolutionary biological literature from outside their community.

In 1984, Rindos recognized that the processes that ecologists clump under mutualism are the same as those that led to the development of cultivation behaviors and evolution of domestication traits. It has taken archaeologists four decades to fully embrace his perspective, but there is currently an astonishing explosion of intellectual inquiry within domestication debates (Spengler 2020). Many of these scholars are engaging in fascinating ethnoarchaeological studies, testing concepts in the field, and exploring new methods in the lab. They are devoting their time to studying ecological thought and Darwinian ideas. It is essential for the future prosperity of archaeological theory that scholars avoid echo chambers and engage in conversations with ecologists and evolutionary biologists—domestication is evolution and cannot be discussed without evolutionary theory, and culture is adaptive (and compounding; see Richerson and Boyd 2005) and tied into ecological and social parameters, making it impossible to discuss the origins of cultivation outside an ecological framework.

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As the first attempt to employ posthumanism to interpret the origin of rice agriculture, Wang's article introduces a welcome change in perspective. By emphasizing the agency of nonhumans, including plants and technologies, in the process of agricultural transition, Wang challenges the dominant anthropocentric narratives of domestication and agriculture in East Asia. While the interactions and coevolution of humans, plants, and animals have been investigated extensively by niche construction theory (NCT), technology's agency in agricultural transitions has not received the attention it deserves, even though technology's affordances and constraints have been considered major factors in the development of domestication and agriculture (e.g., Hillman and Davies 1999; Xie et al. 2017). Wang's article brings the understanding of technology's agency to a more sophisticated theoretical level and examines it in the context of a dedicated case study from the Lower Yangzi basin. However, Wang's posthumanist approach is not without problems.

Wang suggests that archaeologists should consider human-object relations in a symmetrically dialectical fashion for understanding agricultural origins. Regrettably, her case study asymmetrically emphasizes the agency of plants and technology over that of humans. She argues that (1) acorns "entrapped" hunter-gatherers in particular locales and forced them to expand their material production; (2) rice attracted humans to cultivate it as pottery temper; and (3) rice production and tools (particularly pottery and grinding stones) entrapped humans into increasing investments on them, leading them to become technology dependent and sedentary and eventually leading to agriculture. This narrative reverses the anthropocentric perspective: materials are active, while humans are passive, dependent, and submissive. This object-oriented approach lends support to recent critiques of posthumanism (Van Dyke 2021).

Moreover, Wang's narrative oversimplifies the rather dynamic and complex processes of human-plant-material coevolution that the archaeological and ecological data present. Paleoethnobotanical studies have revealed that acorns and rice were two of more than a hundred plant species used by humans in the Lower Yangzi region during the early and middle Holocene, many of which were cultivated, including peaches, apricots, foxnuts, and water chestnuts (Crawford 2012; Pan 2017; Pan, Zheng, and Chen 2018). Such an actively managed landscape involving wetlands and forest edges over millennia before rice-based agriculture invites complex, situated explanations rather than a deterministic, single-cause argument (Crawford 2012). While the reasons for which Shangshan people chose rice chaff over available alternatives (e.g., Job's tears, barnyard grass, reeds, and sedges, as Wang pointed out) for pottery temper remain unknown, it is unlikely that rice was initially used mainly for temper. Although rice phytoliths are rarely found in Shangshan culinary pots, the fact that rice grains are absent in the Shangshan pottery temper (Zheng and Jiang 2007) and that rice was processed using grinding tools (Wang and Jiang 2022; Yang et al. 2015; Yin et al. 2018) suggests that dehusked rice was cooked in organic containers that did not survive postdepositional processes, a possibility consistent with ethnographic observations in Asia (Wang and Jiang 2022). Proportions of cultivated and domesticated rice in people's overall plant diets fluctuated significantly throughout the Shangshan, Kuahuqiao, and Hemudu periods, at times significantly falling behind the consumption of barnyard grasses, fruits, and nuts (Pan 2017; Yang et al. 2015; Zheng, Sun, and Chen 2012). A steadier increase of rice consumption likely started around 6100–6000 BP, but rice did not become a staple food until the Liangzhu period, 5300–4300 BP (Pan 2017). Therefore, the major question to ask about agricultural development in the Lower Yangzi basin is how and why certain human-object connections (surrounding rice farming in this case) eventually became the primary strand in the web of connections in the ecosystem. Isolating two plant species and two technologies (viz., pottery and grinding stones) from the complex web of

human-plant-material interactions and the landscape in which these interactions occurred is not the most appropriate approach to tackle the question.

Societies who shared materials and technologies central to Wang's argument did not necessarily develop conventionally defined agriculture or become reliant on domesticated plants as staple food. For example, sedentary communities south of the Yangzi River used pottery (among many other elaborated goods), polished and grinding tools, and plants (including acorns) but did not develop agriculture until direct impacts from the middle and lower Yangzi farmers (Hung 2019). Likewise, the Jomon people in the Japanese archipelago occupied large villages and used pottery and grinding stones to process diverse materials, including a substantial proportion of acorns for over 10,000 years without becoming entrapped by a particular domesticated plant. Instead, Jomon people actively managed the landscape and had broad-spectrum diets and nonfood plant resources (including multiple domesticated plants) varying across time and place (Crawford 2011*b*; Habu 2014; Mizoguchi 2019; Yasui 2021). I suspect that future archaeological findings in the Lower Yangzi region will reveal similar local diversity of dietary patterns among contemporary communities during the Shangshan, Kuahuqiao, and Hemudu eras.

The divergence of foodways, despite humans engaging with seemingly similar resources and material things, requires researchers to examine agricultural transitions as a continual process of becoming that involved a full range of active agents, including humans, plants, animals, technological traditions, and the ecological and sociocultural settings in which these interactions occurred (e.g., DeLanda 2016; Harris 2021; Ingold 2000). Only with thorough, fine-scale, diachronic, and relational analysis can we reveal the long-term ecological and cultural inheritance that shaped a human community's perceptions of problems, needs, options, and risks that ultimately guided their interactions with the environment in ways that may or may not have led to agriculture. NCT conceptualizes these issues more broadly than Wang's posthumanist approach and provides a more inclusive tool to describe and explain these processes, thereby allowing archaeologists to introduce technology's agency into the dialogue without falling into the object-oriented trap.

# Reply

## Reconstructing Human History in a More-Than-Human World

My article was originally submitted prior to the outbreak of COVID-19. After more than three years, nonhuman actors have made a profound impact on people worldwide. Our global experience with viruses demonstrates how these nonhuman actors have shaped our actions and perceptions in intense, unexpected, and disruptive ways. Despite the diverse and sometimes conflicting opinions that this article has garnered, the importance of adopting a less anthropocentric perspective that acknowledges the tremendous roles nonhumans have played in historical trajectories should hardly be a controversial claim.

Here I identify and respond to four major theoretical and empirical threads that emerged from the lively discussion my article provoked. They are posthumanist ethics, archaeological interpretation, nonhuman agency, and niche construction theory (NCT).

One major critique of posthumanism is that it risks foreclosing important questions of ethics and social inequalities by shifting responsibility from humans to nonhumans (see, e.g., Shelach-Lavi's commentary; Preucel 2021; Van Dyke 2021). I share these concerns and emphasize that my call for a posthumanist approach is not to relieve humans of responsibility. But granting humans responsibility where it does not fully correspond is not a viable ethnical position either. My research suggests that the capacity of humans in directing historical events has been overstated in the archaeological literature (e.g., Bender 1978; Binford 1968; Morgan 1877). Challenging the notion of human exceptionalism, I demonstrate how nonhumans, such as plants and human-made tools, can be regarded as active participants in history making, an idea well documented by posthumanist scholars (e.g., Haraway 1985; Latour 2005; Tsing 2015, 2018). Moreover, studying nonhuman agency may enhance, rather than excuse, human responsibility. As Latour documented in France, the pasteurization movement was not solely a human effort but rather a complex interplay between microbes, laboratory equipment, government agencies, scientists, and policymakers (Latour 1988). In this instance, recognizing the agency of microbes transformed French society's perception of health and disease, leading to the acceptance and eventual widespread implementation of pasteurization as an effective strategy for disease prevention and control.

Decentering humans in archaeological narratives not only is an ethical responsibility but also provides more accurate interpretations of the past. As my case study of Shangshan demonstrates, the development of the "basin"-type pottery for leaching was not solely a product of human ideas but also partially motivated by the chemical composition of tannin-rich acorns, which required specific processing methods for human consumption. This indicates that an inherent property of the acorn itself, like its tannin content, shaped the development of ceramic technology. By considering nonhuman agency—the capacity of nonhumans to make differences in the world—we move beyond imposing anthropocentric ideological assumptions on the past and gain a more holistic perspective that centers interactions between humans and nonhumans (also see Barrett 2012; Harris and Cipolla 2017:35–51; Robb 2010).

The challenge archaeologists face in interpreting archaeological records is perpetual, as Xinyi Liu's reference to Lévi-Strauss's (1966) concept of "science of the concrete" reminds

us. Because archaeologists can never fully know the thoughts of those they study, our work is fragmentary, deductive, and subjective. In *The Savage Mind*, Lévi-Strauss distinguishes between two idealized ways of doing things: bricolage and engineering. Bricoleurs work with limited existing resources and improvise, whereas engineers adopt a more planned approach and complete projects in a direct line from conception to realization. Given the at least 5,000-year gap between initial plant domestication and the establishment of farming communities, the Neolithic people in the Lower Yangtze were likely bricoleurs who started cultivating rice without modern scientific knowledge or a preconceived idea of agriculture. The shift to agriculture was the outcome of numerous improvised bricolage projects, developed without a predesigned plan. Archaeologists, conversely, start with the end result of agriculture and then work backward to understand its origin, acting as "engineers" with a preconceived model and exploring its internal mechanics. In other words, archaeologists and historical actors look at history from opposing points of view, with the latter lacking foresight on long-term consequences and the former benefiting from hindsight. The mismatch between short-term human foresight and long-term historical trends makes it basically impossible to reliably answer "why" questions—"Why domesticate rice?" or "Why rice farming?"—that speak to historic actors' intentions. These questions are influenced by our present-day understanding of the social and environmental impacts of farming on later societies, which was not available to early Neolithic individuals.

To overcome the "bricoleur versus engineer" dilemma, we can adopt the "plausible alternative histories" approach as proposed by John M. Marston (also see Morehart 2012; Schmidt and Patterson 1995). This approach helps archaeologists steer clear of the "prophet trap" by asking more open-ended questions like "how intensified rice cultivation occurred." Building upon Marston's insights, future research in the Lower Yangtze might start by exploring the plausive alternative pathways that could have been taken after the initial stage of rice cultivation. These might include (1) rice cultivation communities remaining in low-level food production without fully transitioning to agriculture (Smith 2001); (2) the replacement of rice cultivation with other plants such as roots and nuts, which were also available in the region (Wang and Jiang 2022); or (3) a return to hunting and gathering. While this list of possibilities is not exhaustive, it encourages archaeologists to adopt a bricoleur's viewpoint of history, exploring all plausible alternatives rather than following a predetermined path. The approach thus broadens the scope of archaeological interpretations by increasing the range of hypotheses to be tested.

Recognizing the limitations of human foresight does not imply that humans are passive and submissive, nor does it suggest that the actions of humans and nonhumans are equivalent in weight and outcome (see Xie, Shelach-Lavi). Instead, both humans and nonhumans possess unique and diverse agencies that interact and influence each other, collectively shaping historical processes. As my analysis of pottery history in China demonstrates, people were innovative bricoleurs who used the materials available to them to create diverse forms of pottery since the Paleolithic period. At the same time, the development of pottery technology was possibly the result of trial and error with various clay sources, tempering materials, and firing methods, an experimental process that was partially triggered by problems with pot malfunctions. This highlights that historical trajectories are constituted by the interactions between human and nonhuman agencies.

NCT is a cornerstone for explaining coevolutionary processes related to the emergence of agriculture, as Dorian Fuller and Liye Xie highlight in their comments. A posthumanist perspective like my own does not deny the broader relevance of NCT but instead questions its effectiveness as a stand-alone explanatory framework for specific historical phenomena (also see Wallach 2016). NCT defines niche construction as a process by which organisms modify their environment, thereby shaping their own and other species' revolutionary pathways (Odling-Smee, Laland, and Feldman 2003). Humans are considered niche constructors, as our activities inevitably modify our environment, including those of agriculturalists, foragers, pastoralists, horticulturalists, and others. However, current NCT literature has not provided a clear explanation for why this universal human phenomenon has led to such diverse subsistence strategies worldwide. A comparison between the Neolithic Lower Yangtze and the Jomon Japan highlights this gap. Both regions experienced niche construction through a variety of human activities, such as plant and animal management, forest manipulation, and residential building (Bleed and Matsui 2010; Crawford 2012). The Lower Yangtze eventually developed rice agriculture, while the Jomons did not. When the same explanation (niche construction) can lead to different outcomes (farming vs. no farming), it is important to question whether the explanation fully accounts for the phenomenon in question.

Fuller and Xie also raise valid concerns about the limitations of my case study, as it focuses on a select number of nonhuman actors, including pottery, grinding stones, acorns, and rice. This does not encompass all of the nonhuman actors that need to be considered, and my analysis is exploratory rather than definitive. More research is needed to better understand the role of other nonhuman actors in the Neolithic Lower Yangtze region and surrounding areas. I also hope to further explore the effects of social changes during the transition to rice agriculture, as Min Li and David J. Cohen emphasize in their comments. In the Lower Yangtze region, early Neolithic sites show several changes from preceding Paleolithic communities, such as increased sedentism, sophisticated craft production, and interregional interaction. This trend continued throughout the Kuahuqiao and Hemudu culture. Further research is necessary to understand how these social changes reflect human social relations, values, ideologies, and their connections to the emergence of agriculture. A posthumanist perspective aligns with the emphasis on social change, recognizing that nonhumans, including objects, plants, animals, and others

were a part of a larger tapestry of social relations that included humans.

As Min Li correctly points out, rice was an ingredient for fermented beverages related to burial rituals at the site of Qiaotou (Wang, Jiang, and Sun 2021). This finding supports the idea that rice was valued for its ritual and culinary significance, but its connection to rice domestication remains uncertain. Other plants including Job's tears and tubers were also used as brewing ingredients at Qiaotou, suggesting that various plants, not just rice, were part of early Neolithic rituals. Additionally, not all ritually valued plants are domesticated; ethnographic records in North America show that while plants like acorns, wild rice, and berries hold significant social and ritual values in indigenous communities, they have not been domesticated (Crown et al. 2012; Jenks 1901; McCarthy 1993). The current evidence seems to suggest that rice has served multiple purposes, including as a pottery temper, a brewing ingredient, and food, among others. Its social and cultural values likely changed as it underwent domestication.

Finally, I would like to clarify some misunderstandings in Robert N. Spengler III's comments. First, Spengler misrepresents my argument by suggesting that I use the terms "entangled" and "entrapped" as proxies for "mutualism." Mutualism typically refers to the reciprocal relationships between two organisms, such as the symbiotic interaction between flowers and bees (Bronstein 2015). The term is not applicable to the relationships between humans and tools. As I state in the article, grinding stones "entrapped" people into long-term reliance by providing more finely processed foods. But this is not a "mutualistic" relationship, as the grinding stones do not benefit from the interaction. Second, my article does not propose "an innate drive in humanity for progress or to accrue things," as Spengler claims in his response. My sole assumption is that humans are essentially tool makers (*Homo faber*) and dependent on material things for daily life. However, Spengler is correct in pointing out that my research is underpinned by a "Euro-American prejudice" in explaining cultivation. This observation is accurate in the sense that my case study is of Neolithic China and not any site in Euro-America. It would therefore be inappropriate to blindly impose a Euro-American framework on such a study without first evaluating its relevance. Western epistemologies have long guided archaeological studies in China, and their uncritical use is precisely one of the things that this article pushes back against. While constructive criticism helps drive intellectual debates forward, mansplaining other scholars' work undermines that collective project.

While we may each have different approaches to studying the past, I am grateful to those commentators who have offered insightful critiques on the interpretive approach and results I presented in the article. This dialogue has produced new and challenging questions that are fundamental to our practices as archaeologists. Ultimately, archaeology is about studying humans in relationships with nonhumans in the past. Performing this work means an archaeological sensibility toward other forms of beings, including plants, animals, and materials, all of which form a key part of human history.

—Jiajing Wang

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