When Did Humans Learn to Boil?

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ABSTRACT

The control of fire and the beginning of cooking were important developments in the evolution of human foodways. The cooking techniques available to our ancestors for much of the Pleistocene would have been limited to simple heating and roasting. The next significant change in culinary technology came much later, when humans learned to wet-cook (i.e., "boil," *sensu lato*), a suite of techniques that greatly increased the digestibility and nutritional worth of foods. Most archaeologists assume that boiling in perishable containers cannot pre-date the appearance of fire-cracked rock (FCR), thus placing its origin within the Upper Paleolithic (UP) and linking it to a long list of innovations thought to have been introduced by behaviorally modern humans. This paper has two principal goals. The first is to alert archaeologists and others to the fact that one can easily and effectively boil in perishable containers made of bark, hide, leaves, even paper and plastic, placed directly on the fire and without using heated stones. Thus, wet-cooking very likely pre-dates the advent of stone-boiling, the latter probably representing the intensification of an already existing technology. The second goal is to suggest that foragers might have begun stone-boiling if they had to increase the volume of foods cooked each day, for example, in response to larger average commensal-unit sizes. Enlarged hide and bark containers are inherently flimsy, and at some point it would have become necessary to support them in a pit. Moreover, since hides shrink when filled with water and heated, stone-boiling, by removing the container from direct contact with flames, may have extended its use-life, thereby freeing up valuable hides for other purposes such as clothing and shelter. To date, the evidence that is available for wet-cooking prior to the UP remains limited and largely circumstantial. Birch tar mastic found on several Middle Paleolithic (MP) stone tools shows that Neanderthals already by the late Middle Pleistocene were using birch bark, an ideal material for making cooking vessels. And they had ample access to hides and paunches, both of which also make serviceable containers. The best evidence at present for pre-UP wet-cooking are starch grains extracted from dental calculus of a Shanidar Neanderthal. These grains are distorted in a manner that is suggestive of cooking in the presence of moisture. Obviously, this evidence does not prove that Neanderthals, or earlier hominins, were in fact wet-cooking but, given the simplicity of the technology and the wide availability of suitable container materials, it seems highly likely. Scholars interested in the evolution of human diet and culinary technology need to be aware of this likelihood, and begin to focus their collective efforts on finding innovative ways to "see" wet-cooking in the Paleolithic record.

INTRODUCTION

> "In an animal hide, hung from a thong-lashed frame set over a fire, a savory broth bubbled. Careful watch was kept to make sure the liquid didn't boil down too far. As long as the level of boiling broth was above the level reached by the flames, it kept the temperature of the skin pot too low to burn."
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> Jean Auel, *The Clan of the Cave Bear* (1980: 81)

Some readers will undoubtedly find the core conclusion of this paper—that humans began wet-cooking (henceforth simply "boiling," *sensu lato*) prior to the Upper Paleolithic (UP)—to be somewhat disquieting because of its rather speculative nature, though, as I will try to show in what follows, I believe it is quite likely, and definitely an issue in need of further pursuit. While we all prefer solid evidence over conjecture, the latter is sometimes necessary when the majority of scholars in a field are firmly convinced from the outset that they already know the answer, and hence see no reason to explore the issue further. Such is the case with the antiquity of wet-cooking. Archaeologists "know" that perishable containers made from hides, gut, bark, leaves, and other inherently flammable materials cannot be placed directly on or in the fire or they will be quickly consumed by the intense heat and flame. Thus, boiling would not have been possible until humans learned to cook indirectly, i.e., by transferring hot stones from a separate fire to the perishable container containing the liquid; and heated stones—objects that are quite easily recognized and which preserve well in the archaeological record—do not appear in any noticeable quantity until the UP. But the basic premise is wrong. One can readily boil water in perishable containers directly over open flames—in fact, even in a paper cup with

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a blow torch—no hot rocks or boiling pits needed! The container will not burn so long as it remains filled with liquid. So humans may well have been wet-cooking before the onset of the UP, perhaps long before. But we will never know until archaeologists recognize just how easy it is to cook this way, and start looking for innovative ways to detect the practice in the absence of heated stones—archaeology's traditional "smoking gun."

COOKING

There is still considerable uncertainty and debate about when humans first began to use and then control fire. Some authors favor a date as early as 1.5–2.0 mya, although the majority push the first systematic use of fire upward into the Middle Pleistocene, with many converging on a date of around 300–400 kya, and a few even later (Alperson-Afil 2008; Berna et al. 2012; de Lumley 2006; Fernández Peris et al. 2012; Goren-Inbar 2004; Gowlett 2006; James 1989; Roebroeks and Villa 2011; Rolland 2004; Sandgathe et al. 2011; Shimelmitz et al. 2014; Straus 1989; Wrangham 2009). Although concrete evidence for human use if not actual control of fire early in the Pleistocene remains scant and controversial, Richard Wrangham and colleagues have detailed a number of anatomical features that appear in early *Homo*, perhaps as much as 2.0 mya, that in their view may well reflect an early emergence of cooking as a distinctly human adaptation (Aiello and Wheeler 1995; Boback et al. 2007; Carmody et al. 2011; Groopman et al. 2015; Perry et al. 2015; Wrangham 2009; Wrangham and Conklin-Brittain 2003; Wrangham et al. 1999). Among the many features that may point to early reliance on cooking are decreases in molar and jaw size, thinner tooth enamel, reduced masticatory muscle mass, and decrease in overall gut volume, as well as changes in gut proportions (reduced colon, enlarged small intestine). Moreover, recent observations of both monkeys and apes in the wild have greatly reduced the seemingly insurmountable cognitive gap with regard to fire that we once envisioned between us and our primate relatives. It appears that the ability to conceptualize the behavior of fire—that is, to deliberately monitor its spread rather than flee from it, to observe its impact on landscapes and resources, and then to make use of recently burned areas—may not be a uniquely human propensity, but may instead be a behavior whose roots lie deep in our primate ancestry (Herzog et al. 2014; Pruetz and LaDuke 2010). In any case, regardless of when humans first began to make regular use of fire, once they did, they could cook, a momentous step in human biocultural evolution (Darwin 1871: 132), as it greatly increased not only the range of foods our ancestors could safely eat, but also their net worth in terms of both calories and nutrients (Katz 1987, 1990; Wrangham 2009).

If we take the archaeological record at face value, cooking throughout most of the vast span of the Pleistocene must have been limited to simple heating or roasting (Johns 1996: 73), either by positioning foods directly over open flames or by placing them within, beneath, or adjacent to a bed of hot coals. The basis for this assertion seems straightforward enough. Fireproof containers such as ceramics are a late development. In a few areas such as China, the Russian Far East, and Japan, pottery containers appear in very small numbers following the Last Glacial Maximum, but in most parts of the world they are an invention of the Holocene (Barnett and Hoopes 1995; Craig et al. 2013; Jordan and Zvelebil 2009; Kuzmin 2006; Rice 1999; Wu et al. 2012; Zhushchikhovskaya 1997). To most of the archaeological community that means that in contexts predating the introduction of pottery any sort of wet-cooking (boiling, simmering, steeping, blanching, steaming) must of necessity have been done in perishable containers, and that in turn would have required the use of heated stones.

As stones are heated their color and often their texture become altered in recognizable ways, the specifics depending on such things as the nature and composition of the rocks (e.g., granite, quartzite, sandstone, limestone), their porosity and permeability, the length of time they are heated, the temperature to which they are subjected, the number of times they are reused, and so forth. In addition to color and texture changes, the rocks often crack or shatter, forming distinctively irregular fracture surfaces and considerable quantities of tiny debris or grit. There have been many experimental studies documenting what happens to rocks when heated in a fire, and a smaller number to see what happens when hot rocks are quenched in cold water, as would happen in stone-boiling (Batchelor 1979; Brink and Dawe 2003; Dumarçay et al. 2008; Ellwood et al. 2013; Gao et al. 2014; Gose 2000; Holstad 2010; Homsey 2009; House and Smith 1975; Jackson 1998; Lucquin and March 2003; Oestmo 2013; Pagoulatos 1992; Perry and Quigg 2011; Petraglia 2002; Soler Mayor 2003; Tennis et al. 1997; Thoms 2008a; Wilson and DeLyria 1999). Unfortunately, few of these studies are comparative in nature, looking for reliable criteria that would allow archaeologists to distinguish rocks discolored and fractured in the absence of moisture (e.g., those used for warmth-banking around the perimeter of hearths) from those broken in the presence of steam (e.g., heated in an earth oven), and those that have been used in stone-boiling. Thus, in the absence of other sorts of data, such as the configuration of the hearth or pit feature from which the rocks were recovered, we often cannot tell with any confidence whether we are dealing with some form of earth-oven cookery or stone-boiling.

In any case, when does thermally-altered rock, whether from stone-boiling or pit-baking, become commonplace in the archaeological record? C. Loring Brace in a string of influential papers published from the 1970s through the 1990s documented a noticeable reduction in Neanderthal molar size beginning perhaps as much as 100 kya, and attributed the trend to developments in human food-processing technologies, most especially to the advent of "earth oven" cooking (e.g., Brace 1979, 1980, 1997; Brace et al. 1987). According to Brace, "for years, archaeological site reports *dealing with the Mousterian* and the Upper Palaeolithic have recorded what they call 'hearths' with quantities of associated fire-cracked and blackened cobbles or 'river pebbles' of about the size of a human fist or a little larger" (Brace 1997: 545; emphasis mine). Curiously, however, he provides very few citations directly relevant to the Middle Paleolithic (MP) to back up this assertion other than Movius's (1966) classic study of the hearths at Abri Pataud, which of course are UP, not MP, in age. In fact, while there is well-documented evidence in the MP of shallow basin-shaped hearths, less-well-defined surficial "fireplaces" and "burned areas," and, in some sites, substantial deposits of ash (e.g., Kebara Cave in Israel, Grotte XVI and Pech de l'Azé IV in France, Abric Romaní in Spain [Allué et al. 2012; Dibble et al. 2009; Karkanas et al. 2002; Meignen et al. 2007]), there is strikingly little evidence of fire-cracked rock (FCR) anywhere within the Eurasian MP record, a point underscored by Paul Mellars (1996: 296–301) and reinforced by many others (e.g., Sandgathe et al. 2011: 218; Stiner 2006: 226). FCR is simply not a prominent part of the MP record. In fact, FCR does not appear in more-than-negligible quantities until the Aurignacian, some 30–35 kya, and then gradually increases in frequency during the subsequent Gravettian and Magdalenian periods (Bosinski 1995; Dumarçay and Caron 2010:91; Movius 1966; Nakazawa et al. 2009; Nigst and Antl-Weiser 2011; Straus 2005: 153).

Pits that would have been suitable for stone-boiling are equally scarce until the UP (Mellars 1996: 305–307, 364; Speth et al. 2012), although the evidence for subsurface features of this sort may have been obscured or erased by post-depositional taphonomic processes. Not surprisingly, therefore, because of the late appearance of heated stones (and potential boiling-pits), archaeologists almost without exception have come to the (logical) conclusion that wet-cooking is a late addition to human culinary practices, another of a long list of technological achievements which we owe to the enhanced cognitive powers of fully modern humans (Hayden 1981: 520, 525, 529; Manne 2012; Manne et al. 2005; Movius 1966; Nakazawa et al. 2009; Petraglia 2002: 242; Washburn and Lancaster 1968: 295).

WET-COOKING WITHOUT HEATED STONES

Wet-cooking today in its many variants is an integral and vital part of human culinary practices across the globe, and its importance is evident, not just among farming peoples, but also among foraging populations from the tropics to the arctic (Johns 1996; Linton 1944; Nelson 2010). Obviously, most ethnographically-documented foragers do (or did) much of their wet-cooking in ceramic (or metal) pots, which has led many archaeologists to assume these containers to be historic introductions or borrowings from neighboring farming or pastoralist societies. However, the widespread occurrence of pottery among late prehistoric hunter-gatherers both in the Old and New World indicates that boiling was part of the culinary practices of many foragers throughout the mid- to late-Holocene and in some areas much earlier (e.g., Barnett and Hoopes 1995; Craig et al. 2013; Harry and Frink 2009; Jordan and Zvelebil 2009; Kuzmin 2006; Rice 1999; Speth 2012; Wu et al. 2012; Zhushchikhovskaya 1997).

And one can extrapolate the presence of both boiling and earth-oven cooking further back in time by the widespread occurrence of thermally-altered rocks, bearing in mind of course that the two cooking methods are not always readily distinguishable solely on the basis of the stones. In the New World, FCR is nearly ubiquitous throughout the "Archaic," though interestingly not so during the preceding Paleoindian period (Bousman and Oksanen 2012: 216; Chatters et al. 2012: 41; Ferring 2001: 124; Gramly 2008: not paginated; Hill 2007: 299; Jodry and Stanford 1992: 154; Miller and Kenmotsu 2004: 221; Thoms 2008b: 121). The absence of FCR in the northeastern part of the continent, where Clovis-age foragers are thought to have been heavily dependent on caribou, is particularly curious given that ethnohistorically documented caribou hunters commonly rely, at least seasonally, on bone-grease (Binford 1978; Chapdelaine 2012; Gramly 1982, 2010; Meltzer 1988; O'Shea et al. 2013; Pasda 2013; Pelletier and Robinson 2005). In the Old World, FCR appears early in the UP but becomes far more common toward the close of the period and especially during the subsequent Mesolithic (Benison 1999: 310; Chatters et al. 2012: 41; Ferring 2001: 124; Nakazawa et al. 2009). But that is where the record stops. The noteworthy scarcity of thermally-altered rock in the MP, and earlier, has convinced archaeologists that Neanderthals and their "archaic" contemporaries and predecessors lacked the ability to boil foods.

But did they? Can one boil foods directly over flames or hot coals in perishable containers without using heated stones? If one were to judge by the near-total silence on the topic in the mainstream archaeological literature, I suspect the answer would be a resounding "no." I have combed the archaeological literature looking for articles that explicitly talk about the feasibility of direct boiling in perishable containers and have come up with only four (the possibility is also noted, though only in passing, by two others—Brown 1989: 207 and Ikawa-Smith 1976: 514). Two of the articles, both by Michael Ryder (1966, 1969), are brief reports on experiments to test the feasibility of boiling in skins and paunches (an animal's rumen or stomach). They were published nearly half a century ago and together—according to *Google Scholar*—have only been cited 12 times over the intervening five decades (excluding citations of my own). The third article, nearly three decades old, is by Margaret Holman and Kathryn Egan (1985). This interesting paper, which attempts to replicate traditional Native American methods for boiling maple sap into syrup using birch bark trays placed directly on hot coals, is cited only nine times (again not including my own). Unfortunately, these authors do not consider the important implications of their boiling experiments for understanding the evolution of human culinary technology, and the other papers that cite this one are all concerned in one way or another with issues related either to maple syrup or to forestry. In other words, although the Holman-Egan paper would be of considerable interest to Paleolithic scholars concerned with the evolution of human foodways, they did not pursue this avenue of thinking. Unlike the others, the fourth article, by Kit Nelson (2010), is quite new and its citation rate, not surprisingly, is still small (11). Using ethnographic and ethnohistoric data, Nelson's primary goal was to determine whether the divergent geographic distributions of stone-boiling and direct boiling can be predicted by major environmental parameters. Again, like the Holman-Egan paper, Nelson does not explore the evolutionary implications of her findings.

Interestingly, among my archaeological colleagues, on a number of occasions I have encountered what seems to be a curious "disconnect" when it comes to their ideas about boiling in the Paleolithic. A number of them clearly endorsed the idea that wet-cooking did not originate until the UP, in large part because of the near-total absence of thermally-altered stones in preceding periods. However, when I showed them a *YouTube* video clip of someone boiling water in a paper cup on the kitchen stove, they remembered that they too had done the same thing when they were kids, most often as Boy Scouts. Yet none of them seem to have made the connection between what they had done as kids and contemporary archaeological issues related to the evolution of human cooking.

A search of *YouTube* videos, episodes from the popular *Survivorman* TV show, innumerable wilderness survival and "how to" camping manuals, and even novels such as Jean Auel's *Clan of the Cave Bear* (1980) and *The Land of Painted Caves* (2011), shows that direct boiling in perishable containers without heated stones is widely known among the public, almost to the point of being "common knowledge." In fact, one wonderful book entitled *50 Dangerous Things (You Should Let Your Children Do)* by Gever Tulley and Julie Spiegler (2011: 26) provides kids with step-by-step instructions on how to boil water safely on the kitchen stove using only a paper cup. From these and many other sources, many widely accessible on the Internet, it is obvious that one can easily and effectively boil water directly over a campfire, on a backyard grill, on the kitchen stove, over a Bunsen burner, or even with a blowtorch, using as one's container a remarkable array of flammable or heat-sensitive materials, including: paper cups; plastic bags and water bottles; waterproofed baskets; bark, reed, or bamboo trays; bamboo tubes; wooden bowls; coconut shells; tortoise shells; skull caps; animal guts or paunches; even large leaves. And in the more traditional scholarly literature, especially in the fields of ethnography, ethnohistory, and history, there are innumerable explicit descriptions of cooking in perishable containers without using heated stones (e.g., Driver and Massey 1957), including one from the 16th-century (Derricke 1581 [1883]) and one dating back to Herodotus in the 5th-century BCE (Rawlinson 1859: 52–53). But, curiously, the archaeological literature is almost totally silent on the subject....

WHY IS WET-COOKING IMPORTANT?

Determining when wet-cooking developed is more than just idle curiosity. Richard Wrangham and colleagues have made a convincing case that cooking played a transformative role in the behavioral and biological evolution of early *Homo* by increasing the range of foods these early ancestors could safely eat; reducing the time needed to chew them; reducing, deactivating, or eliminating pathogens and their exotoxins; and increasing the overall digestibility of the foods—both plant and animal. Together, these and other benefits of cooking vastly increased the energetic and nutrient yields of their foods (Boback et al. 2007; Carmody and Wrangham 2009; Carmody et al. 2011; Dietz and Erdman 1989; Johns 1996: 73; Johns and Kubo 1988; Stahl 1989; Wandsnider 1997; Williams and Erdman 1999; Wrangham 2001, 2009; Wrangham and Conklin-Brittain 2003; Zink et al. 2014).

I would argue that the introduction of wet-cooking represented another inflection point in the evolution of human culinary technology. Wet-cooking would have further expanded the range of edible plant foods available to our ancestors, as well as opening the door to the creation of medicinal decoctions and infusions (Etkin 1994; Johns 1996; Johns and Kubo 1988). It would also have been particularly effective in deactivating spoilage enzymes such as pectinase and lipoxygenase; and leaching out or partially to completely deactivating anti-nutritional and toxic phytochemicals such as saponins, tannins, flavonoids, alkaloids, trypsin inhibitors, oxalates, phytates, lectins, cyanogenic glycosides, and many others (Dietz and Erdman 1989). Most importantly, wet-cooking would have significantly increased the availability and digestibility of starches well beyond what could be achieved by roasting, both by breaking down plant cell walls and by enhancing and accelerating the gelatinization of the starch (Alvarez et al. 2001; Carmody and Wrangham 2009; Dona et al. 2010; Dreher et al. 1984: 54; Englyst and Englyst 2005; Holm et al. 1988; Johns 1996; Kong and Singh 2008; Stahl 1989; Tester and Sommerville 2000; Williams and Erdman 1999). It is well known that wet-cooking can lead to significant losses of vitamins, some through heat-induced degradation (see Williams and Erdman 1999), but most through leaching of the water-soluble vitamins into the surrounding liquid. However, if the food is being prepared by stewing, not simple boiling, a substantial portion of the leached vitamins are recovered by consuming the broth (Bognár 1993). Boiling would also have softened meats and many tough fibrous plant foods more effectively than roasting (Alvarez et al. 2001; Dominy et al. 2008; Zink et al. 2014). And, finally, it would have allowed humans to capture the fatty drippings that would have been lost to the flames when meat is roasted over an open fire (Wandsnider 1997: 21); and for the first time our ancestors could systematically exploit the lipids, not just from the marrow, but also from within the cancellous tissue of the bones (i.e., grease-rendering), an important, perhaps critical, source of non-protein calories for Late Pleistocene humans as they colonized the more northerly latitudes of Eurasia (Speth 2010; Speth and Spielmann 1983; see also Binford 1978; Bocherens et al. 2005:79; Costamagno 2013; Eidlitz 1969; Marean 2005; Outram 1999; Pasda 2013; Saint-Germain 1997; Starks 2007; Stefansson 1944).

BOILING IN PERISHABLE CONTAINERS WITHOUT USING HEATED STONES

Using the presence or absence of FCR in the archaeological record as the litmus test for boiling technology is likely to be a "red herring." As already noted, boiling can be done quite effectively without fireproof containers, heated stones, or boiling-pits. However, as would seem to be the case for many of my archaeological colleagues, I too was unaware of this possibility until quite recently. I first learned that one could cook this way in 2010 on a trip with my son. Having grown up with no TV at home, he made up for lost time on such trips whenever we stayed in motels. While he was watching one or another program, I usually worked on my laptop, glancing occasionally at the television to see what he was looking at. On one such occasion, he was transfixed by an episode of *Survivorman* on the *Discovery Channel* (2008, Season 2, Episode 4, Part 3, Day 3, *African Plains*), a program in which wilderness survival expert Les Stroud had to use his wits to stay alive and functioning for several days, alone in the bush, having with him only the cameras he needed to record his daily activities and a very minimal assortment of modern items that he either brought with him or scavenged along the way. He had to improvise almost everything. What caught my attention on that particular occasion was that Stroud had decided to boil polluted water to make it potable, but the only container he had was an empty plastic water bottle. To my utter astonishment, he filled it with water, suspended it over an open fire with the flames licking at the bottom of the bottle, and proceeded to bring the contents to a rolling boil without destroying the container, noting in passing that so long as the portion of the bottle that came in contact with the flames was filled with liquid the bottle might blacken and deform somewhat but it would not burn or melt. Stroud needed neither heated stones nor a pit to accomplish this.

Needless-to-say, I was amazed. I had never before seen or heard of anyone direct boiling in a plastic bottle (or, as I was soon to discover, in paper cups, bark trays, hides, and even leaves). Despite an abiding interest in the evolution of human foodways over the past four decades, I had never encountered a single explicit mention of direct boiling in the archaeological literature. Why were archaeologists seemingly so unaware of it? That one episode of *Survivorman* up-ended a truism that I, and it would appear my archaeological colleagues as well, had inherited over the generations—humans could not boil until they stumbled upon the idea of stone-boiling and that did not occur until sometime during the UP.

So when I got home from that trip with my son I began combing the literature to see what I could learn about direct boiling in perishable containers. I was amazed at how much there actually was. What follows is just a sample, arranged in approximate chronological order. Herodotus in the 5th-century BCE (in translation in Rawlinson [1859: 52-53]) describes boiling the meat of an ox in its own hide using its bones as fuel. E.B. Tylor (1871: 40–41) notes a practice similar to the one described by Herodotus among 19th-century Celts and among the Assinaboines in western North America. In an early 20th-century wilderness survival manual, Horace Kephart (1906: 231) provides instructions for direct boiling in a birch bark bucket. Alanson Skinner (1911: 557, 1912: 30) describes both paunch boiling and cooking in birch bark containers among the Cree, Ojibwa, and Blackfeet, and Frances Densmore (1928[2005]: 389) echoes Skinner's observations for the Ojibwa. Others who describe the practice in one or another context include Wallis and Wallis (1955: 70), Angier (1956: 84), Chiang (1976: 524), Loving (1976), Rambo (1982: 116), Pookajorn (1985: 210), Anderson (1993: 104, 108), Watson (1993: 313), de Laguna (2000: 120), Treuer (2001: not paginated), Mehl-Madrona (2003: 213), Burnett (2011: 128), and Ellen and Latinis (2012: 32). And, as indicated by the quote at the beginning of this paper from Jean Auel's (1980: 81) classic novel *Clan of the Cave Bear*, she too was well aware of the feasibility of paunch and hide cooking without using heated stones, although judging by her acknowledgments she learned about it from wilderness survival experts, not archaeologists. Perhaps the most comprehensive look at the ethnohistoric distribution of wet-cooking in Native North America, both with and without heated stones, was presented over half a century ago by Harold Driver and William Massey (1957: 229–231), and their conclusions are worth quoting in full:

> "In the Sub-Arctic, in adjacent parts of other areas bordering on it, and among the Omaha, Alabama, and Comanche, paunches were suspended over a fire for direct fire boiling.... They are said to have lasted from a few days to a month. Apparently they lasted at least long enough to cook the meat of the animal of which they were a part, and a new one was, of course, obtained with each moose or caribou slain. It was necessary to handle the paunch with care and see to it that the fire was not too hot. This seems to have been the exclusive boiling method in a few localities, for example, at Lake Seul, in Ojibwa territory between Lake Winnipeg and Lake Superior. Boiling directly in a bark container suspended over a slow fire is also characteristic of the Sub-Arctic plus a few tribes in adjacent parts of other bordering areas.... The frequency of direct fire boiling in paunch or birchbark vessels, as compared with stone-boiling in the same vessels, is not known. However, from the distributions of the latter, discussed below, it seems likely that stoneboiling was more frequent among the northern Athapaskans in the western Sub-Arctic, but that the two were about on a par among northern Algonquians in the eastern Sub-Arctic."

Of the very small number of experimental studies that have been undertaken of direct boiling in perishable containers (e.g., Ryder 1966, 1969), by far the most interesting and informative one was published in 1985 by Margaret Holman and Kathryn Egan. While their experiments were focused on testing competing ideas about traditional Native American procedures for boiling down maple sap into syrup, their findings are directly relevant to the issue of boiling in the Paleolithic. They compared the effectiveness and efficiency of three different vessel types (metal kettles, low-fired ceramic vessels, and birch-bark trays), and two different heating arrangements (direct heat and stone-boiling). They used direct heat alone to boil down the sap in the kettle and some of the bark containers. Because the authors thought their replicated ceramic vessels were too friable to withstand direct heat for the duration of the experiments, they kept the sap boiling in these containers using heated stones. And in one of their experiments, after heating a birch-bark tray for several hours directly on hot coals, they ended it by adding heated stones.

What is of particular interest in their experiments is the fact that the bark containers maintained their integrity throughout, which lasted for more than five hours, even though they were placed directly on the coals (though carefully kept away from direct contact with flames to avoid burning off the rims exposed above the level of the liquid). The results of these experiments are surprising and probably not what most archaeologists would have intuited. The authors found that direct heating with the bark trays required less fuel and less time than applying heat indirectly by stone-boiling. Karen Harry and Liam Frink (2009) came to very similar conclusions about the high fuel costs of stone-boiling in a series of experiments they conducted using replicas of early arctic pottery (see also Akridge 2008:1460; Nelson 2010: 240). Holman and Egan's experiments also showed that producing syrup in flat-bottomed bark trays was only marginally less efficient in time and labor than using a metal kettle.

> "It is evident that stone boiling sap in a ceramic pot is not at all efficient…. After 6 hours and 25 minutes, the sap in the ceramic vessels was only 18.5% and 48.0% sugar. This is far from the average of 65% in real maple syrup. By comparison, the sap processed in birch bark trays came very close to the syrup in 5.33 hours, and 6.25 hours. The process of rotating hot stones from the fire to the vessels is, of course, tedious but it is not difficult in the sense of using a great deal of energy. Given enough workers and a routine, it would be possible to do. However, an expenditure of at least twice as much time and fuel would be required." (Holman and Egan, 1985: 67)

COULD HUMANS BOIL PRIOR TO THE UPPER PALEOLITHIC?

Unfortunately, at this point we must venture into the realm of conjecture, since in the absence of FCR we have no effective way, as yet at least, of "seeing" boiling in the archaeological record. There have been several attempts to find ways to determine whether bones have been boiled, such as would occur in the process of rendering grease, but the results to date have not been very encouraging, particularly for the remote time period of concern to us here (Munro et al. 2007; Roberts et al. 2002; Taylor et al. 1995). But given that the basic principle is so amazingly simple—e.g., boiling water in an unmodified large leaf, concave piece of bark, or tortoise shell—it seems improbable that humans prior to the UP would not have been aware of it. Neanderthals, in particular, are likely candidates, although the evidence is both very limited—starch grains shaped by moist heat recovered from dental calculus on a Neanderthal from Shanidar Cave (Henry et al. 2011: 487), and quite circumstantial—stripping bark from birch trees in order to destructively distill tar for use as a mastic on MP stone tools (Cyrek and Cyrek 2009; Grünberg 2002; Koller et al. 2001; Mania et al. 2004; Mazza et al. 2006; Modugno et al. 2006; Palmer 2007; Pawlik and Thissen 2008, 2011a, 2011b; Regert et al. 2006). While the discovery on MP stone tools of triterpenoids produced by pyrolysis of birch bark does not prove that Neanderthals were manufacturing and waterproofing bark containers, it does at least show that European Neanderthals as early as the late Middle Pleistocene were deliberately removing bark from birch trees, and thus had recurrent access to an ideal material for a wet-cooking technology (Palmer 2007). Another possible piece of the technology—putative bark-peelers made from proboscidean ribs—may also have been present in the MP, an intriguing though as yet untested idea raised a number of years ago by Sandgathe and Hayden (2003).

As an aside, archaeologists have underscored the complexity and sophistication of the hafting mastics made by Middle Stone Age (MSA) "modern humans" in South Africa (Wadley et al. 2004, 2009; Wadley 2010). Without in any way meaning to detract from these marvelous African discoveries, the production of birch tar mastic by European Neanderthals is easily as complex as those being documented in the MSA. Birch tar can only be produced by a process of destructive (dry) distillation, *in the absence of oxygen*, and with temperatures maintained for several hours between a minimum of 340 ºC and a maximum of about 400 ºC (Koller et al. 2001; Peters et al. 2005: 335–337). As a perusal of the Web will quickly reveal, "backyard" experimenters can readily produce the tar by using an arrangement of metal containers (the same process can also be accomplished with ceramic vessels). A small lidless soup can is set into the ground so that its rim is flush with the surface. A large cookie tin is filled with tightly rolled-up birch bark and sealed with a tight-fitting lid. A small hole is punched through the bottom of the tin at its center. The bark-filled tin is then positioned over the soup can so that the hole is aligned directly above. Dirt is piled around the base of the tin to prevent oxygen from entering at the contact between the two containers. Fuel is then piled around and over the cookie tin and ignited. The tar produced by destructive distillation of the bark drips through the hole into the underlying can. If the fire gets too hot or oxygen gets into the system the tar is destroyed. No one to my knowledge has yet adequately figured out how Neanderthals would have accomplished this complex feat of pyrotechnics without the aid of metal or ceramic containers (see Osipowicz 2005; Peters et al. 2005: 336–337; Palmer 2007; Meijer and Pomstra 2011; Groom et al. 2015). It is also hard to reconcile the evidence for such complex technological know-how with ongoing debates about whether Neanderthals had systematic control of fire (e.g., Sandgathe et al. 2011).

Aside from the limited evidence from Shanidar for starch grains deformed by moist heat, and the circumstantial evidence provided by the fact that Neanderthals were working with birch bark (and they certainly had access to hides and paunches), is there any other evidence that might point to wet-cooking prior to the UP? Unfortunately, the honest answer is "not much." One such bit of evidence was suggested years ago by C. Loring Brace and colleagues (Brace 1995; Brace et al. 1987), who documented a decline in Neanderthal tooth size that began about 100 kya, a trend which they thought might reflect the emergence of "obligatory cooking." Wrangham and Conklin-Brittain (2003: 41–42) instead suggest that the decline, rather than denoting the first real commitment by humans to cooking, may instead "...prove to result from later modifications in cooking technique, such as the adoption of boiling."

WHY STONE-BOIL?

Holman and Egan's (1985) interesting maple syrup experiments suggest that stone-boiling was more tedious and labor-intensive than direct heating in birch-bark trays, a conclusion echoed by Harry and Frink's (2009) boiling experiments in the Arctic. It also took longer and required more fuel, and it led to a dirtier, grittier product in the end because of ash that was almost inevitably transferred along with the heated stones from fireplace to container, not to mention the debris from the thermally-shocked stones. So what advantages might stone-boiling have had? An obvious one of course might be the absence of suitable bark. But as the examples provided earlier clearly indicate, one can boil in skins and paunches, and those materials would have been available to foragers anywhere that big-game hunting was an integral part of the economy—and that was certainly the case for Neanderthals, who rank as "top predators" in the eyes of most Paleolithic archaeologists.

Perhaps, then, one benefit of stone-boiling is that it might extend the use-life of hide or paunch containers. Hides and paunches shrink when suspended directly over flames or hot coals, an informal observation made many years ago by Ryder (1966, 1969) and looked at in detail by Cheshire (2014) and Witnauer (1962). However, no one to my knowledge has done follow-up experimental studies to determine if the amount of shrinkage is reduced to any significant degree when the cooking is done indirectly using heated stones. If big game were acquired only episodically and unpredictably, which seems to be the case among many ethnographically-documented foragers (see Speth 2010: Chapter 5), there may have been extended periods each month when hunting did not provide enough hides and paunches to simultaneously fulfill the household's or the group's needs for cooking containers on the one hand, and for clothing, shelter, and other material necessities on the other. In such circumstances, stone-boiling may have provided a means of extending the use-life of hide and paunch containers by reducing the amount of shrinkage, as well as the cumulative damage caused by repeated direct exposure to intense heat and flames. This is obviously an aspect of boiling in perishable containers that can be tested experimentally.

Container volume—quite likely a loose correlate of the size of the commensal unit—may have been another factor influencing the choice of cooking technology. Large bark containers are flimsy without buttressing of some sort around the vessel's mouth and perhaps additional internal support in the form of ribbing, as exemplified for example by birch-bark canoes (Adney and Chapelle 2007). Thus, without structural support the volume that one could effectively heat by direct boiling might be limited to comparatively small amounts (Munson 1989). Hide and paunch containers are also flimsy, again constraining the volume of the cooking container. In order to heat large volumes of liquid, such containers must be supported in some fashion. One way to accomplish this is to hang the hide or paunch from posts set in the ground around the perimeter of the hearth. Another way, one that might simultaneously extend the container's use-life and provide ideal support, is to place it in a pit. But once this step is taken, the contents can only be brought to a boil by applying heat indirectly—in other words, by stone-boiling.

CONCLUSIONS

The evolution of the myriad cultural means by which humans acquire and transform potentially edible resources into foods lies at the heart of our phenomenal success as a species. Our ingenuity and seemingly limitless inventiveness have permitted us to find ever more effective ways of processing foods in order to soften and detoxify them and greatly enhance their overall nutritional worth. The control of fire, and with it the beginning of cooking, are arguably the most important developments in the evolution of human foodways, a point clearly recognized and underscored a century and a half ago by Charles Darwin in his seminal work—*The Descent of Man* (1871). Regardless of when humans first took control of fire, a topic of continuing debate, once they did, they could cook. Though cooking was a momentous innovation, the techniques available to our ancestors for much of the Pleistocene would have been limited to simple heating and roasting. The next major inflection point in the evolution of culinary technology would come much later, when humans figured out how to wet-cook (i.e., boil, simmer, steam, steep, blanch), a suite of related techniques that further increased the digestibility and nutritional worth of foods, and made grease-rendering possible. It also may have opened the door to a wide range of medicinal decoctions and infusions that could be made from plants (see for example the interesting recent discussion of Paleolithic medicinals by Hardy et al. 2012).

Wet-cooking becomes clearly visible in the archaeological record when humans began to make pottery, an invention which did not happen until the very end of the Pleistocene at the earliest. Prior to that, wet-cooking had to be done in some sort of perishable container, such as a paunch, hide, bark tray, or waterproofed basket. Unfortunately, these materials seldom preserve from such remote time periods, so we have to infer the existence of boiling technology indirectly, using the first appearance of FCR as the traditional "smoking gun." FCR does not become prominent in the Eurasian archaeological record until the UP, adding wet-cooking to a long list of contributions presumably made by cognitively-advanced modern humans.

The principal goal of this paper has been to alert Paleolithic archaeologists and others to the fact that one can boil effectively and efficiently in perishable containers made from all sorts of flammable materials—including bark, wood, hide, leaves, even paper cups and plastic bags—

placed directly on the fire and without using heated stones. So long as the container is kept filled with liquid it will not ignite, even when heated with a blowtorch. The only vulnerable part of the container is the rim itself, the portion of the vessel that is not constantly in direct contact with the liquid. In other words, given its inherent simplicity, wet-cooking could long pre-date the first appearance of FCR in the archaeological record. Moreover, experimental studies show that direct boiling is more efficient than stone-boiling, bringing the liquid contents to a boil more quickly, using less fuel, and yielding a much cleaner product at the end—free of ash and thermally-shattered rock debris. It would thus appear that stone-boiling is not a revolutionary new discovery that we owe to modern humans, but quite likely the intensification of an already existing technology. Intensification could have been triggered by an increase in the size of the commensal unit, necessitating the use of larger, flimsier cooking containers. Big hide or gut containers would have been easier to support if placed in subsurface pits, but this way they could no longer be heated directly. The inception of stone-boiling might also be a response to a need to extend the use-life of perishable containers by heating them indirectly rather than exposing them to the fire. Such a need might arise from competing demands for hides, some to be sacrificed for cooking, others needed for clothing, shelter, and personal gear.

The evidence for wet-cooking prior to the UP is still very limited and largely circumstantial. The discovery of birch tar used as a hafting mastic on stone tools from three MP sites in Europe, one dating to the late Middle Pleistocene, shows that Neanderthals were actively using birch bark, one of the ideal materials for making cooking containers. And they certainly had access to ungulate hides and paunches, both of which make serviceable containers. Perhaps the best evidence to date for MP wet-cooking are starch granules extracted from the dental calculus of one of the Shanidar Neanderthals. These grains are distorted in a manner that is diagnostic of cooking in the presence of moisture.

Obviously, none of the evidence we presently have at our disposal proves that humans prior to the UP were capable of wet-cooking but, given the relative simplicity of the technology and the wide availability of suitable materials, it seems very plausible, if not highly likely. The problem now is for archaeologists, paleoanthropologists, and specialists in other fields who share an interest in the evolution of human diet and culinary technology to focus their collective efforts, imaginations, and technological know-how on finding ways to "see" wet-cooking in the Paleolithic record.

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