

Doctors, chefs or hominin animals? Non-edible plants and Neanderthals

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Introduction

In 2013, Hardy *et al.* offered a broad behavioural context for the hypothesis that the ingestion of non-nutritional plants (yarrow and camomile) by Neanderthals was for the purpose of self-medication. Chemical traces of these plants had been detected in samples of dental calculus from Neanderthals at the site of El Sidrón, Spain, along with traces of bitumen and wood smoke, as well as starch granules that showed evidence of roasting (Hardy *et al.* 2012). Subsequently, the presence of traces of resin and a piece of non-edible conifer wood were also identified from these samples (Radini *et al.* 2016). Although not rejecting our interpretation for the presence of these two non-edible plants as evidence of medicinal plant use, two recent articles offer alternative scenarios for why and how those plants may have reached the mouth and, eventually, the dental calculus of the individual concerned. Buck and Stringer (2014) suggest that the plants were not deliberately ingested, and that the traces of yarrow and camomile were in fact embedded in the chyme, or stomach contents, of herbivore prey. Krief *et al.* (2015) propose two hypotheses: first, they suggest that the plants could have been used to flavour meat; second, while not ruling out the possibility that they could be medicinal, they argue on a technical point that the plants were not self-administered but were provided by a caregiver. Here, we examine these suggestions and consider their probability and feasibility as alternatives to our original proposal of self-medication.

Chyme is the partially digested liquid that consists of the food eaten, mixed with digestive enzymes and acids, found in the stomach, before it passes to the intestine. It has been an important source of plant food and carbohydrates, particularly in high latitude hunter-gatherer diets (Sinclair 1953), and was undoubtedly widely exploited in prehistory (Speth 2010). There are two ways to process and consume chyme: either through extraction from the stomach, or the entire stomach is removed and they are eaten together. Buck and Stringer (2014) combine ethnographic examples of both methods, although it is not clear which they are suggesting was used by the Neanderthal individual. The method of consumption of chyme is important in this context because it can substantially affect the amount of material, including characteristic yet relatively low abundance organic compounds, coming into contact with the teeth. Eating chyme and stomach combined would result in the chyme (and biomolecules within) passing into the digestive system of the hominin with a largely

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transient and minimal contact with the teeth. If, however, chyme was consumed separately, it would result in significantly more physical contact between any plant material and the teeth, with no stomach tissue providing a barrier to inhibit this contact. In ethnographic examples of chyme used as food, it is, however, usually eaten along with the stomach or intestines (see quotations in Buck & Stringer 2014). The consumption of chyme alone, separated from the stomach, which might allow a more intimate physical contact between food and teeth, appears more closely connected with rituals in ethnographic contexts (e.g. Peterson & Walhof 2002, cited in Buck & Stringer 2014). Once the stomach was opened to remove the chyme, a suitable container would be required to hold the liquid before it was consumed. There is currently no evidence in the Neanderthal archaeological record for containers, but Tannahill (1988; in Buck & Stringer 2014) describes recent ethnographic examples of the use of animals' stomachs when pottery was not available. This begs the question of whether Neanderthals are likely to have removed chyme from one stomach only to put it into another in order to eat it. If Buck and Stringer (2014) are suggesting possible ritual behaviour, further supporting evidence would be required. They then compare the presence, in coprolites, of phytoliths derived from chyme consumption, which they suggest demonstrates the potential for the survival of these items. This may be true, but it provides no meaningful insights into the probable survival of biomolecules in dental calculus. Phytoliths are microscopic silica structures; they are not comparable to biomolecules.

Even more problematic is the fact that neither yarrow nor camomile is sought out by herbivores. These animals graze on a wide range of species that then become mixed together in the stomach. Both plants are native to temperate regions and occur widely in grasslands and meadows; they were (and are) undoubtedly eaten by herbivores as part of the mix of plants consumed during grazing. In order for biomolecules characteristic of these plants to have become embedded in dental calculus through the consumption of chyme, the animal would, however, need to have eaten yarrow and camomile almost exclusively. In fact, reindeer (*Rangifer tarandus*) diet, which Buck and Stringer use as an example, comprises around 250 plant species (Nieminen & Heiskari 1989). Yarrow has a strong, bitter taste and is actively avoided by some herbivores; for example, sheep (Ginane *et al.* 2015). It is considered by gardeners to be a deer-resistant plant (Soderstrom 2008), whereas both yarrow and camomile are toxic to dogs, cats and horses (ASPCA 2015). Therefore, while herbivores most probably consume some yarrow and camomile as part of their mixed grassland diet, it is highly unlikely that they would exclusively eat large amounts of either of these plants at any one time; animals are adept at avoiding poisoning themselves when in their known environment (Engel 2002). Realistically, these plants would only have been eaten in small quantities as part of a grazing pattern that included a range of other grassland species. Although the chemical evidence is indicative of yarrow and camomile, these biomolecules form only a relatively small proportion of the whole plant (typically around 0.05–0.2%; Hardy *et al.* 2012). As such, it is not realistic to assume that consuming herbivore chyme, most probably still within the stomach and created from a wide range of ingested plants, would allow enough of these characteristic compounds, present in relatively low abundance, to become intimately associated with the mineralised dental calculus in sufficient quantities to be detected some 50 000 years later.

Finally, herbivores consume phytolith-rich grasses. Henry *et al.* (2014) suggest that if evidence for chyme consumption had survived in the dental calculus, it is very probable that other evidence for the ingestion of these plants, such as phytoliths, would also have been abundantly present, which was not the case. In the second article, Krief *et al.* (2015) propose that yarrow and camomile were eaten to flavour meat, an idea first suggested by Kaplan (2012a & b). Additionally, despite not ruling out a medicinal function, Krief *et al.* (2015) argue that these plants were not self-administered, but provided by a caregiver. To confuse the issue further, they provide tantalising but speculative observations suggesting that the ingestion of various non-edible plants by chimpanzees, when eating internal organs, is done with the intent of suppressing pathogenic agents (self-medication). They suggest that the pathogenic agents are acquired from the internal organs, which, they propose, are preferred over meat. This theory is based on their observation that the chimpanzees eat these parts first. More generally, the eating of leaves with meat or insects, which are not usually eaten alone, is a widespread, but not yet well-understood, phenomenon in chimpanzees.

Discussion

Krief *et al.* (2015: 464) suggest that the present authors “reject the possibility that these two plants (yarrow and camomile) were consumed for their flavour [...] based on the assumption that Neanderthals did not have complex tastes”. This is incorrect; we highlighted the fact that Neanderthals from El Sidrón had the bitter taste perception gene (*TAS2R38*) (Lalueza Fox *et al.* 2009), which in itself demonstrates taste complexity and a predisposition to eating plants (Hardy *et al.* 2012, 2013). Krief *et al.* (2015) interpret the remains as evidence either for food flavouring or that the plants were supplied for medicinal purposes by another individual. Both of these behaviours certainly could have occurred; for example, Hublin (2009) outlines a persuasive argument for compassion among Neanderthals. This, however, raises an issue that is central to the study and interpretation of archaeological remains. The reconstruction of the past, when based on archaeology, is largely undertaken through the interpretation of remains that are partial and incomplete. An understanding of the context of finds is therefore the single most important factor for interpreting archaeological material. For example, a pot found in a tomb may be interpreted as a burial good; if this same pot were found next to a hearth, or in association with remains interpreted as food, such as burnt animal bones, then it would be reasonable to consider it to be an item used in food preparation or cooking. As no one was present in the archaeological past, interpretation has to proceed from the cornerstone of context based on all of the available information; without this, the interpretation of archaeological remains would simply be reduced to guess work. Although the pot could credibly be linked to food preparation, it could not be used to argue for the presence of gourmet chefs. In this respect, there is no difference between the investigation of material found entrapped in a sample of dental calculus from a Palaeolithic hominin and any other archaeological material. We cannot say with certainty why the Neanderthal individual ate the yarrow and camomile because we did not witness it. We therefore proceeded according to the standard archaeological method and examined all available contextual information. In this case, the context was behavioural, and our conclusion of self-medication, which was first suggested in Hardy *et al.* (2012) and

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then developed in Hardy *et al.* (2013), is based on a detailed investigation into all possible reasons for why and how these plants might have been ingested. The extensive evidence for the deliberate selection and individual consumption of plants, not only among higher primates but also in the broader animal world, even among insects, for the purpose of self-medication, suggests that dietary selection among a wide range of animals and insects is based on medicinal, as well as nutritional, requirements and, at times, also on their reproductive state (e.g. Huffman 1997; Cousins & Huffman 2002; Singer & Stireman 2003; Krief *et al.* 2005; MacIntosh & Huffman 2010). It is highly unlikely that Neanderthals would not also have practised this type of dietary complexity, and we consider that it offers the strongest behavioural context for the direct ingestion of these plants. Self-medication is grounded in higher primate and, indeed, all animal behaviour, and even though it is perfectly possible that Neanderthals used plants to flavour meat, and it is possible that one individual provided the plants for the other individual to ingest as medicine, the behavioural context for these scenarios is not as strong or as well documented among adult higher primates, and not at all among other adult animals to our knowledge, as the evidence for self-medication. Of perhaps greater concern is that both Buck and Stringer (2014) and Krief *et al.* (2015) link the consumption of these plants to meat-eating. The perception of a predominantly meat-based diet is based both on the numerous animal bones found in Neanderthal sites, and the results of stable isotope studies that suggest Neanderthals were top-level carnivores (Bocherons 2009; Richards & Trinkaus 2009). Although it is well established that Neanderthals ate a lot of meat, the relative proportions of the carbon and nitrogen stable isotopes used from dietary reconstruction only detect protein, and the dietary role of plant foods cannot be estimated accurately from stable isotopes (Richards *et al.* 2000). The stable isotope results therefore do not mean that Neanderthals (or indeed any other Palaeolithic populations) did not eat plants; instead, it means that these have not yet been detected (Hardy & Buckley 2016). Neanderthals were not obligate carnivores (Hardy *et al.* 2013), and would therefore have been as dependent on plant consumption to survive, thrive and reproduce (Hardy *et al.* 2015a) as we are today. While the high protein diet of the Inuit is often used to demonstrate the human ability to survive on a diet consisting largely of meat, the Inuit also ate chyme, as Buck and Stringer (2014) have pointed out. They also ate tundra plants and kelp (Kuhnlein & Turner 1991), and had access to large amounts of marine mammal fat, which served to counter the high levels of nitrogen that result from a high meat diet. In addition, the Inuit have a series of adaptations, most importantly a change in the *CPT1A* gene (Clemente *et al.* 2014), that enabled them to have a high meat, low carbohydrate diet. It is not known if the Neanderthals also had this gene; they did not, however, have access to the high levels of marine mammal fat that are so essential in the traditional Inuit diet. It is now clear that even in the Lower Palaeolithic, plant foods rich in essential polyunsaturated fatty linoleic and linolenic acids were consumed (Hardy *et al.* 2015b). This growing evidence for plant use in earlier Palaeolithic periods suggests a broad ecological knowledge, as the most important feature of dietary plant selection is not what to select, but rather what plants to avoid. As no precedent existed for contextualising the ingestion of non-nutritional plants by hominins, including Neanderthals, higher primate behaviour was explored as the most appropriate proxy from which to try to offer an explanation for why they would have been selected and ingested by a Neanderthal. This follows McGrew (2010), who suggested

that it should be assumed that anything a chimpanzee can do could also have been done by the Last Common Ancestor six to seven million years ago. Although some anecdotal evidence exists for the selection of some plants solely for flavour, there is extensive and broad evidence for deliberate selection and use of plants by different higher primates for the purpose of self-medication (Hardy *et al.* 2013). This broad behavioural perspective places the use of non-nutritional plants by Neanderthals, and indeed other hominins, into an evolutionary context which suggests that detailed ecological knowledge, including the applied knowledge of plants, may be a fundamental part of animal behaviour linked to survival. This has important implications for understanding hominin and early modern human behaviour, particularly in the light of multiple well-documented examples of modern traditional human groups observing animals, and copying their behaviour specifically in terms of their abilities to select and eat certain plants to cure themselves of illnesses (Huffman 2016).

We can find no reason why hominins would have opted out of these highly successful and very longstanding animal survival strategies. In fact, any argument that excludes a broad use of plants by hominins would need to explain, in the first instance, why and how this ecological knowledge and behaviour might initially have been lost, then regained before the Upper Palaeolithic with its extensive evidence for a broad spectrum of plant use (Hardy & Kubiak Martens 2016). Neanderthals survived for around 300 000 years, and were able to adapt to a wide range of environments, making them a highly successful species; we suggest that this would have been impossible had they not known what to eat in order to remain healthy and reproduce successfully, while avoiding poisoning themselves in the process.

Buck and Stringer (2014) and Krief *et al.* (2015) have highlighted behaviours that may well have occurred, yet both arguments are centred on meat-eating. We suggest that in terms of Neanderthal and, indeed, all hominin dietary reconstruction, there is a need to move beyond just meat, and focus on essential physiological requirements, such as the requirement for carbohydrates for essential brain and body functionality (Hardy *et al.* 2015a). In this particular case, even though there may be many reasons why the Neanderthals may have eaten non-edible plants, some of which we may not even be able to imagine, the extensive evidence for animal self-medication offers the most persuasive argument based on the analysis of all the available contextual and relevant behavioural evidence.

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Received: 1 June 2015; Accepted: 24 September 2015; Revised: 5 October 2015