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Debate Response

Cultural inheritance and technological evolution: a response to Bentley & O'Brien

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In response to Bentley and O'Brien's (2024) article, I wish to focus on a specific aspect of cultural inheritance—that of technological innovation in later prehistory. In essence, I agree that "inherited social practices and knowledge" (2024: 1407) are indeed the backbone of technological transmission. Many examples can be cited where technological expertise (potting, metalworking, etc.) is passed down within a family or through apprenticeship schemes. For example, the first Ming Emperor of China (Hongwu, reigned AD 1368–1398) initiated in 1381 a census (the 'Yellow Book') in which households were classified for taxation purposes into one of four categories: general, military families, artisans and salt-producers. Artisans were classified by trade and the implication is that the family trade was fixed and inherited (Huang 1974: 32). This system continued until at least the end of the Ming dynasty (AD 1644).

Such transmission explains technological *continuity* but not necessarily technological *innovation*. An evolutionary model might see the gradual refinement of techniques, materials and practices accumulating to deliver technological improvement, but combining this with a punctuated equilibrium model probably gives a better representation, as suggested by the term "cascades of innovation" (Bentley & O'Brien 2024: 1410). Periods of gradual improvement are punctuated by radical innovations shifting technology to a different position; arguably, the transition from bronze smelting to iron smelting is one such example, although the debate continues about whether this is evolution or innovation. In such a model, the question becomes what provides the impetus for these transformative events?

Two aspects of the article by Bentley and O'Brien impinge on this line of thought. Firstly, I challenge the implications of the statement that "Contemporary scholars are surrounded by thousands or millions, of times more material objects, ideas and social contacts than most humans who have ever lived" (2024: 1410). While this is patently true in terms of material objects, and possibly true of social contacts, in terms of the totality of mental and visual stimuli, it is a questionable statement. Our ancestors lived in a rich world of nature, where both animate and inanimate beings contributed to the course of human lives. Most of modern society has lost this interaction. Moreover, the boundaries between this and the other worlds were variably permeable, resulting in the intervention of deities in human affairs, and much cosmological, magical and mystical activity (Pollard 2023; Pollard & Gosden 2023). In other words, what seems irrational from a modern Western scientific perspective may not have seemed irrational at all in antiquity. Consider the practice of alchemy, which is completely rational when considered from an Empedoclean perspective (Pollard 2023).

Bentley and O'Brien assert that modern scholars "project … our agency onto the past" (2024: 1410). I agree with this statement, but not, I think, for the same reasons as the authors. Rather I suggest that there is a tendency to view technological innovation through a modern lens, where the primary drivers are technological determinism and/or economic contingency. This may not always have been the case in antiquity. For example, to understand the adoption of copper alloys for tools in the Early Bronze Age we must consider perceptions of symbolic power. It is widely accepted that the earliest driver was *not* technological advantage but more likely to have been symbolic or even magical (Pollard in press).

What might be the source of these episodes of innovation in technology? The first possibility is inheritance from outside—the importation of technologies from elsewhere, either peacefully by observation and replication, or by varying degrees of imposition. Another obvious answer is individual genius—a creative spark that ignites an innovation in the treatment of raw materials or processes. Other suggestions might be more realistic. Perhaps the most likely is one of unpredicted outcomes—an artisan follows what he or she thinks is the usual procedure, but for some reason the outcome is unexpected. The innovative spark here is threefold: firstly, recognising the advantage offered by the unintended outcome; secondly in working out how to replicate it; and thirdly promoting the product or process in such a way that it finds a market. Another mechanism can be broadly described as experimentation. For example, the typical developmental sequence of copper-alloy usage in Europe and Western Asia—native copper, unalloyed smelted copper, arsenical copper and tin bronze—originally thought of as being geologically determined (following the structure of a theoretical copper vein deposit) is now generally ascribed to a desire to produce alloys that are harder than pure copper, which is certainly one of the consequences. The actual mechanism is, however, potentially more diffuse. Howarth (2018) has assembled a database of more than 10 000 analyses of bronzes from Western Asia from the eighth to the early first millennia BC. This dataset illuminates broad technological trends. Metal before the mid-third millennium tends to be dominated by pure copper, but there are also copper alloys containing two or more additional metals above one per cent, but some containing up to five or six additions. These alloys largely disappear after the mid-third millennium BC. One interpretation of this evidence is that the pre-third millennium represents an 'experimental stage' of smelting ores, where the recipe is 'take some green rock, and add a handful of other magical earths', or, perhaps more simply, smelt handfuls of mixed ore and see what results. This runs counter to the traditional view of the intentional search for 'better alloys'.

However, any technological innovation is irrelevant if the product is not adopted by a sufficiently large number of people, as suggested in the 'flickering candle' model (Pollard & Gosden 2023: 47), whereby a technological innovation is generated but not taken up and ultimately lost. For example, a nomadic group in southern Africa 50 000 years ago might accidentally smelt copper from malachite around a campfire. The discovery would splutter out, however, largely because the cultural norms did not support metallic objects and also because the size of the social network was insufficient to sustain the production of copper. Moreover, we are also unlikely to know about this, partly because finding the remains of

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the campfire is unlikely but also because archaeological conservatism would argue that metallic copper in such a context was 'impossible'.

In summary, technological innovation is an important aspect of cultural evolution and is best described by a model that combines gradual inherited accumulation with punctuated innovation. This innovation could be driven by several factors, including importation, capitalisation of unexpected outcomes and experimentation, but it is essential to not retrospectively fit modern motives to ancient intentions, especially bearing in mind the widely differing world views that were prevalent in antiquity.

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