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ARTICLE

On the Use of Parsimony in Archaeological Reasoning

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Abstract

When evaluating competing hypotheses in archaeology, researchers frequently invoke the principle of parsimony, which states that simpler hypotheses should be preferred. However, the criteria for measuring simplicity and the rationale for labeling a hypothesis as most parsimonious often remain unclear. More broadly, the epistemic merit of parsimony and its relevance to archaeological reasoning are generally assumed but rarely clarified. This article explores how archaeologists use parsimony in ethnographic analogy and formal model selection. In the first context, it is usually uncertain how simplicity should be measured or why increased simplicity raises the plausibility of an ethnographic analogy. We contend that discussions of ethnographic analogy are better characterized under inference to the best explanation, where parsimony is only one heuristic among others. In the second context, simplicity is assessed by the relative complexity, rather than the quantity, of postulates in a model. This approach to parsimony, which does track plausibility under certain conditions, helps prevent false positives in archaeological interpretation. However, it also heightens the risk of rejecting alternative, complex causes. We argue that parsimony can aid in evaluating the relative likelihood of competing models and, more importantly, serve as a guide to clarify the complex histories of archaeological phenomena.

Resumen

Al evaluar hipótesis en competencia en arqueología, los investigadores suelen invocar el principio de parsimonia, que establece que se deben preferir las hipótesis más simples. Sin embargo, los criterios para medir la simplicidad y la justificación para calificar una hipótesis como la más parsimoniosa a menudo no son claros. Más ampliamente, el mérito epistémico de la parsimonia y su relevancia para el razonamiento arqueológico suelen darse por sentados, pero rara vez se explicitan. Este artículo explora cómo los arqueólogos utilizan la parsimonia en la analogía etnográfica y la selección de modelos formales. En el primer contexto, suele ser incierto cómo debe medirse la simplicidad o por qué una mayor simplicidad aumenta la plausibilidad de una analogía etnográfica. Sostenemos que las discusiones sobre analogía etnográfica se caracterizan mejor bajo la inferencia a la mejor explicación, donde la parsimonia es solo una heurística entre otras. En el segundo contexto, la simplicidad se evalúa en función de la complejidad relativa, más que de la cantidad, de postulados en un modelo. Este enfoque, que refleja la plausibilidad en ciertas condiciones, ayuda a evitar falsos positivos en la interpretación arqueológica, pero también aumenta el riesgo de rechazar causas alternativas más complejas. Argumentamos que la parsimonia puede ayudar a evaluar la probabilidad relativa de modelos en competencia y, más importante aún, servir como una guía para clarificar las complejas historias de los fenómenos arqueológicos.

Keywords: archaeological theory; archaeological inference; ethnographic analogy; parsimony; simplicity

Palabras clave: teoría arqueológica; inferencia arqueológica; analogía etnográfica; parsimonia; simplicidad

Archaeologists reconstruct the behaviors of past human populations from their material remains. This task is inferential. The nature of archaeological inferences and how they should be formulated has been the subject of much debate. In the 1970s, some theorists argued that archaeological inference building should be formalized according to the hypothetico-deductive method (Fritz and Plog 1970; Watson et al. 1971). Others argued that the realities of archaeological reasoning show that it is not a deductive process (Morgan 1973; Salmon 1975; Tuggle et al. 1972). One important consideration here is equifinality—there are typically many different processes that might produce any given pattern in the record (Lucas 2005; Morgan 1973; Perreault 2019; Read and LeBlanc 1978). For instance, we might stipulate that forager settlement type S tends to produce artifact spatial distribution type A, but we cannot be certain that settlement type S *always* results in artifact distribution type A, nor can we be sure that it is the *only* process that can generate artifact distribution type A. Consequently, it has been suggested that archaeological inference is more probabilistic in nature (Morgan 1973; Salmon 1975; Wylie 1982); that is, although finding artifact distribution type A does not confirm the occurrence of settlement type S, it does strengthen the plausibility of the hypothesis, given that we accept the generalization between settlement type and artifact distribution. In other words, the reasoning is *inductive*, and, more specifically, an *inference to the best explanation*.

In this sense, archaeological explanations need to be evaluated in terms of their relative inferential strength or weakness. A good archaeological explanation is one that we are highly confident is plausible. However, where multiple explanations are plausible—as is often the case in archaeology and other historical sciences (Chamberlin 1890)—we are confronted with the question of how we might rank them as more and less plausible. As we will elaborate below, there is a broad array of metrics we might use to rank competing hypotheses. One metric that archaeologists have used is the parsimony principle (Fotiadis 2018). According to this principle, when we are faced with competing hypotheses that can equally account for the data, the "simplest" hypothesis should be preferred. "Simplicity" here refers to the number and complexity of the entities, causes, and/or processes postulated in explaining the empirical data. An explanation is "simpler" than another explanation if it posits fewer and/or less complex entities, causes, and processes.

If parsimony is used to support a hypothesis against rival explanations, then we need to be very clear about the number and complexity of postulates in a hypothesis. Unfortunately, however, few studies outline the reasoning behind their appeal to parsimony (e.g., Bettinger 2009; Brantingham 2003). We see two main issues here. First, we are rarely offered explicit metrics for quantifying the number and complexity of postulates in a theory. Second, we are rarely offered comparisons that explicitly rank theories according to simplicity. It is therefore left unclear both why and whether some favored hypothesis is in fact the most parsimonious.

More broadly speaking, the epistemic merit of parsimony and its relevance to archaeological inference is typically treated as self-evident. Indeed, as Fotiadis (2018) observed, the adjective "parsimonious" is often used in lieu of "plausible," "probable," "likely," or "satisfactory" in the archaeology literature. However, given that the formation of patterns in the archaeological record is a complex causal system with many causal inputs (Bentley and Maschner 2009; Kohler 2012), it is by no means clear that the link between parsimony and plausibility holds at all. In the case of archaeological reasoning, the simplest explanation may not be the most plausible.

In this article, we provide a review of the role parsimony plays in archaeological inference building. We are particularly interested in the ways archaeologists use the principle to prioritize competing archaeological explanations.

We focus on parsimony reasoning in two general contexts. The first is the use of ethnographic analogies to construct archaeological hypotheses. In this context, we show that researchers rarely offer explicit metrics for understanding why one theory is simpler than another, and we are not offered clear comparisons between theories regarding the number or complexity of postulates. Moreover, when we start to think through how this might be done, it becomes unclear whether theories that are claimed by proponents to be parsimonious do in fact contain fewer and less complex postulates than their rivals. We think the core issues in these debates have little to do with parsimony, and in fact, they are better characterized in terms of the broader framework of inference to the best explanation. On this view, parsimony is just

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one of many heuristics we should take into account when ranking competing hypotheses. Indeed, we argue that the epistemic strength of ethnographic analogies stems less from simplicity and more from their empirical breath and explanatory power.

The second context we examine concerns the goodness of fit between model and data. In this case, we do think that parsimony reasoning can play a productive role in theory choice. However, simplicity here is more aligned with the complexity—rather than quantity—of postulates in a model. The application of parsimony is more akin to Morgan's (1894) canon in comparative psychology, insofar as it involves differentiating and prioritizing "lower level" causes from "higher level" causes. We outline a metric for understanding this process. We argue that this approach to parsimony does track plausibility under certain conditions, meaning that explanations with less complex postulates do represent more likely explanations. However, our approach brings certain constraints. We outline these and show that some debates appealing to parsimony reasoning meet them. We also show that the conservative approach is biased against alternative explanations and carries a heightened risk of incorrectly excluding higher-level causes in archaeological explanations (i.e., false negatives).

Parsimony and Its Epistemic Value

The principle of parsimony, which is commonly attributed to the writing of the fourteenth-century English theologian William of Ockham, states, *Entia non sunt multiplicanda praeter necessitatem*, which translates to "entities are not to be multiplied without necessity." Other commonly quoted statements about the principle include *frustra fit per plura quod potest fieri per pauciora*, or "it is futile to do with more what can be done with fewer." The notion of simplicity can be traced back to Aristotle, who said "nature does nothing in vain" in relation to his teleological view. This belief that nature prefers fewer causes—and that explanations of nature should therefore do likewise—played a prominent role in the development of Western science. For example, Newton's (1999 [1687]:398) Rule I of Reasoning in Philosophy is "we are to admit no more causes of natural things than such as are both true and sufficient to explain their appearance." Similarly, Galileo (1967 [1632]:397) stated, "Nature does not multiply things unnecessarily; that she makes use of the easiest and simplest means for producing her effects."

Prior to the twentieth century, justification for the belief that nature does not contain causes beyond those necessary to produce some phenomenon typically involved a theistic argument (Sober 2015): the universe is made by God, and the perfection of God is reflected in the simplicity of nature. Newton (Untitled Treatise on Revelation, Yahuda Ms. 1.1, National Library of Israel, Jerusalem, Israel; https://www.newtonproject.ox.ac.uk/view/texts/normalized/THEM00135) famously remarked, "It is the perfection of God's works that they are all done with the greatest simplicity. He is the God of order and not of confusion." Since the twentieth century, theistic arguments for simplicity have largely disappeared, and discussions regarding the value of parsimony now generally revolve around different methodological and epistemological viewpoints. For some, there is no a priori justification or empirical evidence for the belief that simpler explanations are more likely to be true than complex alternatives. Instead, the merit of parsimony is purely in its aesthetic and pragmatic effects (Huemer 2009; Quine 1963; Walsh 1979). Simpler explanations are more pleasing aesthetically, easier to verify empirically, and more useful for providing a unified treatment of the phenomena in question. The aesthetic appeal of simplicity has been attributed to biases in our cognitive perception (Lombrozo 2007; Pothos and Chater 2002), whereas the pragmatic appeal relates to the sociological realities of scientific practice. For instance, simple hypotheses are more accessible to experimental testing and confirmation than complex hypotheses (Quine 1963). This pragmatic view of parsimony is shared by some archaeological researchers. In his discussion of archaeological knowledge and inference, Fotiadis (2018:4) remarked that "the main merit of a parsimonious and elegantly articulated hypothesis is their perspicuousness. But perspicuousness is a pragmatic virtue, not necessarily an epistemic one; it does not by itself render a hypothesis more likely than rival hypotheses." Similarly, in his study of lithic raw material procurement patterns, Brantingham (2003:505) noted that "there is no guarantee that the simplest explanation is the correct one." However, Brantingham (2003:505) explicitly acknowledged the methodological value of parsimony: "the probability of producing a Type II error [*sic*] (i.e., false positive) is minimized by favouring the simplest model available and also that the opportunity for identifying and rectifying such an error is greater." This view

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aligns with Karl Popper's (1959) argument that simpler theories should be preferred because they are more falsifiable and therefore can be more quickly eliminated.

In contrast, there are several accounts that defend the epistemic merit of parsimony. For instance, given that parsimony is a prominent and long-standing heuristic of the scientific method, it can be argued that the success of science is itself an empirical testament that the principle does tend to lead one to the truth. From a Bayesian perspective, all else being equal, simpler hypotheses are held to have higher prior probabilities of being true than more complex ones (Jeffreys 1957). Others have contended that simpler hypotheses have greater explanatory power (e.g., Friedman 1974), or that they can better accommodate fewer possible sets of observations and make more specific predictions with greater accuracy (e.g., Forster 2002; Forster and Sober 1994; Sober 2000). With regard to predictive accuracy, scholars often refer to Akaike's theorem with regard to curve fitting and the trade-off between fit to data points and the simplicity of the mathematical function, which is typically measured in terms of the number of adjustable parameters it contains (Forster 2002; Forster and Sober 1994; Sober 2000, 2015). If our goal is to make accurate predictions over a general class of systems, more complex functions are more likely to "overfit" the data points and are therefore less able to fit to additional data or make accurate predictions of future observations. In comparison, simpler models with fewer variables have a lower risk of overfitting and a positive effect of leading to more accurate predictions of out-of-sample data. This is particularly acute in the case of archaeological inference, where we only have access to fragments of the target system (Perreault 2019).

It appears that archaeologists tend to agree with the latter view—that more parsimonious explanations are not to be preferred solely for pragmatic reasons; rather, they are preferable because they are more likely to be true. As mentioned above, archaeologists commonly use the term "parsimonious" in lieu of "probable" and "likely." Yet, very few studies actually explain the reasoning behind this link between simplicity and truth. One example is Bettinger (2009) and his discussion of macroevolution theory in archaeology. When deciding which hypotheses to prefer, he reasoned,

> When individual and group selection hypotheses provide equally compelling accounts of a given cultural behaviour, shouldn't the more parsimonious individual selection hypothesis be accepted? The answer naturally lies in what one takes to be the prior probabilities of individual and group selection, i.e., the likelihood that one is more common therefore more likely beforehand [Bettinger 2009:293].

However, even in this case, it is not entirely clear why Bettinger thinks that individual selection is simpler than group selection. Does individual selection involve fewer causes, postulates, and entities? Or is it a less complex process? Prima facie, it is not obvious that the answer to either of these questions is "yes."

Two things are required to justify this kind of reasoning. First, we need to be told how the metric of simplicity is defined and measured. Second, we need to be offered an explicit comparison with rival theories, showing precisely why one theory performs better than others according to some metric for simplicity. In the following sections, we consider these two tasks by reviewing how archaeologists apply parsimony in two broad contexts: ethnographic analogy and model-based analysis.

Ethnographic Analogy, Parsimony, and Inference to the Best Explanation

A context in which parsimony is commonly mentioned in the archaeological literature concerns the use and evaluation of ethnographic analogy. This involves applying analogical reasoning to draw inferences about past processes on the basis of observations made in the present (Wylie 1982). If a stone chip shares key morphological features with a flake made by a modern knapper, we infer that the stone chip was made in a way that is similar to that of the modern flake (Lin et al. 2018). Underlying this reasoning is a uniformitarian assumption that the observed similarities in material outcome warrant the existence of further similarities in processes leading to their formation in the past (Wylie 1982, 1985). An explicit formulation of analogic inference in archaeology is "ethnographic analogy," where observations of living societies are used as the analog source from which to draw inferences about past behaviors.

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One of the main ways archaeologists apply ethnographic analogy is through the so-called direct historical approach developed in the United States during the 1920s and 1930s. With roots in the historical particularism of Boasian anthropology of North America in the early twentieth century, the direct historical approach was based on the view that the archaeological record of the Americas is an extension into the past of contemporary Indigenous societies living in the same geographic region (Trigger 1981). Assuming that cultural expression is largely conditioned by historical inheritance and cultural continuity in a geographically limited area, then knowledge regarding the historical periods of a region can logically be extended back into earlier times (Strong 1935).

According to Lyman and O'Brien (2001), the direct historical approach works in two general steps. By working backward from historical records, archaeologists first assign ethnic identities to archaeological phenomena of a region and identify material culture traits to measure the ancestor-descendant relationships over time. This step links the analog source (historic/ethnographic account) and subject (archaeological phenomena) in a chronological order of assumed cultural inheritance. Once the link is established between an ethnographic group and an archaeological manifestation, archaeologists can extract a whole suite of cultural information from the ethnographic source and "use it to reconstitute the archaeological-subject phenomena into a dynamic cultural system" (Lyman and O'Brien 2001:316).

What happens when direct historical connections cannot be made between an archaeological phenomenon and a contemporary society? In these cases, it was suggested that a different analogy can be established on the basis of "the same general level of technological development, perhaps existing under similar environmental situations" (Willey 1953:229). The development of this alternative form of ethnographic analogy, termed "general comparative analogy" (Willey 1953) or "new analogy" (Ascher 1961), occurred at the time of interest in North American anthropology shifting away from culture history and toward cultural reconstruction (Lyman and O'Brien 1997). In particular, influenced by the works of people such as Steward (1955) and White (1959), anthropologists commonly regarded cultures as functionally adaptive systems operating at varying stages of evolutionary development (e.g., Parsons 1966; Sahlins and Service 1960). From this adaptationist perspective, societies manipulating similar environments through similar technologies ought to converge with respect to other sociocultural behaviors, such as settlement pattern, economy, and social organization. For this reason, to identify functional drivers of cultural change, it is necessary to compare cultural expressions from different geographic regions that share similar levels of technological development and that exist under similar environmental circumstances. This cross-cultural approach to ethnographic analogy became associated with the processual archaeology movement in the 1960s and 1970s, during which ethnographic correlations between behavior and material outcome under different environmental conditions were used to establish general regularities—or "middle range theories" (Binford 1977, 1981)—for connecting the static material record with dynamic cultural processes in the past.

Parsimony and Probability

So, what justifies the epistemic credentials of ethnographic analogy? When interested in assessing the accuracy of an analogy, many researchers point to parsimony. (Note, however, that there are reasons one might seek to pursue simpler explanations regardless of their accuracy; e.g., Currie [2019] and Nyrup [2021]. Thanks to an anonymous reviewer for raising this point.) For instance, when describing general comparative analogy, Stanish (2008) explained that there are invariant laws in the natural world that enable and constrain how people tend to engage and interact with the physical environment for a particular purpose: "Given this, and given the precept of parsimony, archaeologists can make high-probability interpretations of the function and use of . . . features in the archaeological record" (Stanish 2008:1363). Stanish (2008:1364) also stated that "the adoption of the principle of parsimony is necessary" for the direct historical approach, such that "if one excavates a round structure with similar features to a historic hogan in Arizona, and if there is no evidence of cultural disruption, then one can make a high-probability statement that the excavated structure functioned in the same way as the historic hogan." In another example, Hantman et alia (2004:583) invoked parsimony to justify their inference of cultural continuity between burial mounds in central Virginia circa AD 900–1700 and the colonial-era Monacan Indian people by stating that "the use of 'parsimony' and concordance with 'available historical data' make clear that we think the Monacan connection is the best and most logical one, pending other data." Likewise, d'Errico and colleagues (2012a:E3291) justified their interpretation of poison use at Border Cave in South Africa roughly 24,000 years ago as the "the most parsimonious," because the observed presence of caster-bean extract on archaeological notched wooden sticks is "virtually identical to those used by [modern] San for applying poison."

It is important to highlight the repeated mentioning of "high probability" in the quotes by Stanish (2008) outlined above. In fact, this sense of inferential probability is commonly brought up in discussions of direct historical analogy (Brumfiel 1976; Gould 1974, 1980; see Lyman and O'Brien [2001] for more discussion). Stanish (2008:1364) stated that "objects found in archaeological contexts of those same peoples' ancestors carry a high probability of having the same function." Similarly, in his review of Mesoamerican archaeology, Brumfiel (1976:398) reasoned that "because the degree of cultural continuity between prehistoric and early historic Mesoamerican cultures should be greatest, the likelihood of drawing a correct analogy should also be greatest when inferences have been based upon the ethnohistorical literature of the area." Likewise, Gould (1980:35) argued that direct historical analogies have "an inherently greater probability of being accurate approximations of behavioural realities than [general comparative analogies]."

If ethnographic analogies are claimed to offer high-probability explanations, and the parsimony principle is frequently invoked to justify these analogies, does it mean that this sense of inferential probability is derived from simplicity? What would be needed to demonstrate this is (1) a definition and metric for quantifying simplicity and (2) some explicit comparison between theories that shows one is simpler than another according to this metric. One way of approaching this is to formulate ethnographic analogies within an explicit phylogenetic framework, in which cultural traits are treated as heritable units subjected to evolutionary processes similar to biological traits (O'Brien et al. 2010). With this formal approach, historical continuity can be justified as simpler and more parsimonious than convergent innovation because it involves fewer evolutionary changes to explain the observed similarities. We will discuss this phylogenetic framework in more detail later with respect to model-based inference. For now, however, we note that explicit formulations of ethnographic analogy in terms of evolutionary phylogeny is relatively rare in the archaeological literature (Lipo et al. 2017; Mace and Holden 2005; O'Brien et al. 2013). Instead, applications of ethnographic analogies tend to focus on other "boundary conditions" (Ascher 1961) to warrant the analogic inference, such as the temporal, spatial, or environmental similarities between the ethnographic source and the archaeological subject. If we go by these conditions and work through the task of defining and evaluating simplicity, it is by no means clear that those theories claimed to be parsimonious rank lower than their rivals on plausible metrics for simplicity.

Let us consider the perceived higher probability of direct historical analogy over the general comparative analogy. If parsimony is the reason for believing that cultural inheritance has a higher prior probability of being true than convergent development, then the cultural continuity explanation ought to postulate fewer or less complex causes, entities, and processes than convergence. To infer cultural continuity, we need to assume that (1) the amount of time separating the ethnographic and the archaeological is short enough for cultural continuity to be reasonable, (2) the groups of people have largely remained in one geographic region over time, (3) the material traits we are measuring represent homologous traits that are culturally inherited, and (4) no major cultural change has occurred over time to disrupt the transmission of the homologous traits (see Lyman and O'Brien [2001] for more discussion about these assumptions). In contrast, to infer convergent development, the main assumptions would be that (1) the cultural traits that are being compared need to represent functional or technological responses to environmental factors, (2) the success/failure of these technologies have an impact on the fitness or survival of people such that there is pressure to enhance the performance of the technology (hence causing convergence; Stanish 2008), and (3) societies have the necessary capacity and resources to independently develop these cultural traits. Are there fewer causes, entities, and processes outlined in the former process (1–4) than in the latter process (1–3)? Are the postulates stipulated in the former process less numerous and less complex than those outlined in the latter process? It is by no means clear to us that this is the case.

Properly working through the task of quantifying the number and complexity of postulates in these theories is beyond the scope of the present article. The main point we want to emphasize above is that, if researchers want to invoke the principle of parsimony in the service of ranking hypotheses, then it is a project with which they must engage. Unfortunately, it is also a very difficult project. To illustrate some of the complexities involved, let us look briefly at the temporal aspect of the direct historical approach. Consider the amount of time that separates the ethnographic source and the archaeological subject. Although studies generally agree that direct historical analogy is most applicable when the source and the subject are close in time and space, how close is "close enough" remains open to question. We may intuitively believe that a time range of up to a few hundred years or even one or two thousand years is plausible to observe continuity in cultural expressions, because we observe historical continuity in technology and material culture over similar time scales in our societies today. However, it is also evident in our own society that drastic cultural changes can take place over relatively short time frames, sometimes leaving little to no notable material traces. What about a geological time scale of tens of thousands of years, covering environmental transformations from the last glacial period to the late Holocene, such as that stipulated for the continuity of San material culture into the Late Pleistocene of Southern Africa by d'Errico et alia (2012b)? What additional factors and processes about human behavior and societies do we need to assume in order to warrant an interpretation of cultural continuity over geological time?

The key point here is that if we measure simplicity by the number and complexity of postulates, it is by no means clear that direct historical analogy is simpler than general comparative analogy. Indeed, the inverse might well be the case. What is needed from researchers, then, is a clear articulation of the metric for simplicity they have in mind—and a clear comparison of theories based on this metric. Without this information, appeals to parsimony look epistemically unwarranted.

Inference to the Best Explanation

From this perspective, there appear to be significant issues associated with casting the inferential warrant of ethnographic analogy in terms of parsimony. It may well be the case that ethnographic analogy is best placed to explain similarities between ethnographic observations and the archaeological record, but it is by no means clear that appeals to simplicity account for why this is so. However, recall that parsimony, as we have mentioned, is used in the service of a broader inferential strategy: inference to the best explanation. This form of reasoning occurs when "one infers, from the premise that a given hypothesis would provide a 'better' explanation for the evidence than would any other hypothesis, to the conclusion that the given hypothesis is true" (Harman 1965:89). If we follow this process, the plausibility of a hypothesis is increased according to its ability to explain observational data. Inference to the best explanation has been shown to be pervasive in archaeology, and it forms the underlying standard of archaeological reasoning that transcends processual and post-processual approaches to archaeological interpretation (Campanaro 2021; Fogelin 2007; Hanen and Kelly 1989). Indeed, regardless of theoretical perspectives, a core activity of archaeology is to gather and examine a range of empirical evidence and then evaluate competing hypotheses to determine the best explanation for that evidence. In this respect, the task facing archaeologists—and the reasoning process involved—is no different from the one we find in most other sciences.

But how do we judge if one hypothesis is "better" than another? What exactly is this "better" metric? There are various answers to this in the literature. Lipton (2004) argued that the best explanation is the one that provides the most understanding of the phenomenon in question. As a result, it can be judged the most plausible. Other factors that make one explanation better than another may include explanatory breadth (i.e., the ability to explain multiple observed facts), depth (i.e., the ability to not raise more questions than it answers), power (i.e., the ability to apply to similar contexts), falsifiability (i.e., the ability to be refuted by empirical observations), modesty (i.e., the ability to not claim any more than is needed to explain the observed facts), and simplicity (i.e., the ability to postulate fewer and less complex entities, causes, or processes) (Fogelin 2007). An inference is better than another if it scores more highly on these various metrics than a competing inference. Here, simplicity is just one of several virtues, and a good inference to the best explanation should meet as many of these conditions as possible. Consequently, although parsimony can contribute to finding the best explanations, it is certainly not the

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only—or even the most important—criterion. It is merely one among a set of (potentially competing) theoretical desiderata. We think this is an important and underappreciated point. When researchers invoke parsimony reasoning *alone*, we need to be told why parsimony—and not any of the other metrics guiding inference to the best explanation—is the relevant heuristic. Indeed, in many cases, we suspect this is a mistake. Instead, archaeological reasoning should be more pluralistic in its understanding of what makes one explanation "better" than another. In the remainder of this section, we expand on this idea.

Returning to the historical analogy versus comparative analogy debate, we have seen that there is good reason to doubt whether parsimony reasoning offers us the resources for resolving this debate. Rather, given the way ethnographic analogy is commonly formulated in the literature, we suggest that issues at stake here are best framed in terms of inference to the best explanation. In particular, the key question is whether or not processes of cultural inheritance or processes of convergence based on socioecology best explain similarities between contemporary artifacts and archaeological artifacts. Answering this question is a difficult task, which in part relates to the lack of established baseline expectations about how human cultural processes manifest in the archaeological record. Consider the difficulty of distinguishing homologous structures from analogous structures in material culture. Although certain material features, such as decorative symbols and motifs on ceramic vessels, arguably represent arbitrary cultural expressions, it is less straightforward to make the same argument for technologies whose tool configuration and production process are heavily constrained by the physical properties of the material and the desired functional purposes (Moore 2020; Sackett 1982). As an example, for a wooden stick to be useful as a digging implement, it should be made of hardwood with a bevelled head. There are only so many ways to produce a beveled head on a wooden stick using a cutting edge. Consequently, if we are to find an archaeological digging stick made of the same wood and with the same beveled head design as an ethnographic example, can we be confident that these similarities are sufficient to warrant an interpretation of cultural continuity, even if these items occur in the same geographic location? The issue here is that due to constraints imposed by the physical properties of the material, there is a finite number of technological options available to solve particular problems. Of course, the chance for simple tools (e.g., a digging stick) to be reinvented independently is likely to be higher than that of more complex tools (Byrne 2007; Lucas et al. 2020). However, the challenge remains that morphological similarities in object classes can represent "spandrels" (Moore 2007) that may manifest independently without cultural relatedness. In order to strengthen our interpretative confidence, we need to have a better understanding of the baseline expectation of the range of material expressions that can emerge from the finite range of technological options available to solve particular problems. This question is increasingly being discussed and empirically investigated, especially among studies of cumulative culture in relation to Paleolithic stone tool variability (e.g., Moore and Perston 2016; Tennie et al. 2016).

An important feature of the above discussion is that parsimony plays no role. The question is not "Which theory is simpler?"; it is "Which theory can best account for the data at hand?" Consequently, we suggest that the debate is better understood in terms of inference to the best explanation rather than via parsimony.

At a more fundamental level, analogies are probabilistic and therefore neither valid nor invalid (Wylie 1982). As mentioned earlier, ethnographic analogy is applied based on "boundary conditions" (Ascher 1961). With direct historical analogy, the boundary condition is the proximity in time and space; with general comparative analogy, the boundary condition is the proximity in technology and environmental conditions. When these conditions are met, the analogy is applied to explain the archaeological data; when the conditions are not met, the analogy is not applied. In the latter scenario, the analogy is not falsified; instead, it is deemed inapplicable to the specific context in question. Instead of falsification, our confidence in analogic inference depends on its ability to account for multiple strands of independent evidence (Wylie 1989, 2002). In this sense, the epistemic appeal of ethnographic analogy relates more to its explanatory breath, given that the analogy can simultaneously account for multiple co-occurring similarities that exist between the source and the subject. Moreover, ethnographic analogy provides explanatory "power" to connect and make sense of various available evidence. This latter point about power fulfills Lipton's criterion that a good explanation should provide information that increases our

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potential understanding about the phenomenon we are trying to investigate. For instance, with direct historical analogy, similarities between ethnographic observations and archaeological phenomena are viewed to be best explained as homologous structures sharing common ancestry. This explanation offers potential understanding not only of the ethnic identity and lifeways of past people but also of cultural inheritance in the form of material culture and broader cultural transmission processes. With general comparative analogy, likeness in material culture is viewed to be best explained as analogous structures that converged in the form of functional responses to similar external drivers, especially when a prehistoric-historic cultural continuity cannot be demonstrated between the subject and the source. This explanation of cultural adaptation provides potential understanding of the generalities of how cultures interact and operate in relation to external environments.

Currie (2016) argued that, in its most basic form, ethnographic analogy is an application of the comparative method of human culture and material remains involving archaeological data. Although the parsimony principle is often invoked to justify the "likeliness" of ethnographic analogy in archaeology, we contend that the epistemic appeal of ethnographic analogy has little to do with simplicity and more to do with its perceived explanatory breath and power as inference to the best explanation. In fact, the view that ethnographic analogy provides compelling, "high-probability" explanations of archaeological data may, in part, stem from an intuitive perception that its applicability to archaeological data validates our preexisting beliefs regarding the role of cultural inheritance and ecological plasticity in shaping human behavioral regularities. Yet, because analogies are neither valid nor invalid, there is no license for all-encompassing acceptance or rejection of ethnographic analogies (Currie 2016). Instead, ethnographic data should be treated either as one line of evidence that archaeologists can employ to strengthen hypotheses (Currie 2016) or as inspirations for researchers to "imagine" new hypotheses that can account for the observed archaeological record (Lin 2014; Lin et al. 2018). In other words, although the reasoning process of ethnographic analogy follows that of inference to the best explanation, the analogies should not be treated as epistemically justified conclusions in and of themselves but rather as supportive means for generating and strengthening hypotheses that are *testable* with further empirical observations.

Parsimony and the Principle of Conservatism

The second context in which parsimony is often invoked in archaeology concerns the fit between model and data. In this context, "model" typically refers to formal explanations of archaeological patterning based on explicit processes. Here, parsimony is employed as a tool to favor the simplest model capable of accounting for the observed empirical evidence. However, as we will show below, notions of simplicity here are focused more on the complexity of postulates than their number. This approach to parsimony is often explicit among studies that apply evolutionary biology methods to explain archaeological variations. In this setting, cultural traits are treated as analogous to biological features, such that cultural variation over time can be explained by evolutionary processes of inheritance, selection, and drift. In the following section, we will first look at the use of cladistics in archaeology as an example of this approach to parsimony.

Archaeologists have used cladistics and parsimony to infer ancestor-descendant relationships among a range of artifact classes, including stone bifaces and projectile points, ceramic vessels, basketry, textile, and earth lodges (Buchanan and Collard 2007; Jordan and Shennan 2003, 2009; Lycett 2009, 2011; O'Brien and Lyman 2002; O'Brien et al. 2001, 2012; Tehrani and Collard 2002; Tehrani et al. 2010). Considering that material culture is a product of cultural information transmitted among toolmakers, artifact variation over time can be analyzed to reconstruct artifact lineages that reflect heritable continuity and shared ancestry. However, there are usually multiple phylogenetic trees that can account for the observed data. Consequently, there need to be ways for deciding which tree is the "best" phylogenetic reconstruction to select. In this setting, parsimony is formulated as an explicit model selection method that prefers phylogenetic trees enlisting the fewest evolutionary changes to explain the observed variation. In other words, shared ancestry and homologic branching are given explanatory priority over convergent evolution and homoplastic changes.

With cladistics parsimony, the preference for homologic over homoplastic explanations echoes the sentiment outlined earlier regarding ethnographic analogies—that is, direct historical analogy is seen

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as more probable than general comparative analogy. However, in the case of cladistics, simplicity can be more straightforwardly quantified and compared by the length of the trees and the number of postulated evolutionary events. The shortest tree with the fewest homoplasties is the most parsimonious and therefore considered the "best" explanation. As Collard and Shennan (2008:28) explained, "Where the fit between a cultural dataset and the tree model is close, we can invoke the principle of parsimony and legitimately conclude that the similarities and differences among the cultural units are primarily results of branching." Only when the fit between the tree model and the cultural dataset is poor can we "justifiably infer that borrowing or convergent evolution played a more important role in generating the similarities and differences among the cultural units" (Collard and Shennan 2008:28).

But evolution is not a parsimonious process. Because evolution is nondirectional, there is no guarantee that evolution always "takes the shortest path." If we select phylogenetic trees based on the parsimony criterion, the "best" tree may underestimate the actual extent of evolutionary change that could have occurred. What, then, justifies choosing the most parsimonious tree over others in cladistics? One can make a methodological argument. For example, in their archaeological cladistic study, O'Brien and colleagues (2016:73) stated that "the term 'parsimony' has nothing to do with whether evolution itself is parsimonious. Rather, it has to do with logical argumentation: it is more parsimonious to make as few ad hoc phylogenetic hypotheses as possible . . . [and] the simplest hypothesis is the one that is most easily defensible." As a pragmatic tool, parsimony "provides a logical basis for choosing among alternative working hypotheses, even when the most parsimonious one seems counterintuitive" (O'Brien et al. 2016:73). However, this seems like a worrying move. Presumably, the goal of developing cultural phylogenies is to provide an accurate description of processes of cultural change. If this is the case, and if we have no reason to think evolutionary systems are parsimonious, then our models should reflect this fact.

On the other hand, as Sober (1988, 2015) reasoned, it is possible for cladistics parsimony to mirror likelihood without presupposing that evolution is parsimonious. This is because the application of parsimony here involves an epistemological asymmetry: certain processes (e.g., heritable continuity) are considered more common and likely than others (e.g., evolutionary change through natural selection). Indeed, if we accept that biological (and cultural) entities are linked by heritable continuity, it would be improbable for similarities to derive from separate sources, especially among closely related lineages. Instead, it is more probable that similar features emerged only once from a single common ancestor (Sober 2015). Underlying this view is the idea that evolutionary events leading to character-state changes are not easy for evolution to produce. As O'Brien and colleagues (2001:1120) remarked, "Given that evolution is improbable to begin with . . . when faced with the problem of character polarity, we choose the option that requires the fewest evolutionary events." However, it is important to remember that cultural evolution is not *directly* analogous to biological evolution. The former involves vertical, horizontal, and oblique lines of inheritance, and it is influenced by unstable mechanisms such as social norms, habits, and conventions. This is thought to mean that cultural evolution is messier and faster than biological evolution (e.g., Ram et al. 2018). Under such circumstances, it is less clear that change over time must be attributed to standard evolutionary processes, such as selection or drift.

Moving on from cladistics, a similar approach to parsimony that involves explicitly prioritizing "simpler" causes over others can be seen in the application of population genetics–based methods. In general, these studies are interested in determining whether cultural patterns observed in the archaeological record are the result of selection. To assess this, researchers investigate the expected variation of cultural patterning under selectively "neutral" conditions, affected only by inheritance and drift. The development of neutral models has shown that material culture can vary considerably through cultural transmission and demographic mechanisms alone, such as population density and migration (Henrich 2004; Powell et al. 2009; Shennan and Wilkinson 2001). It is worth pointing out that there are questions concerning the theoretical justification and empirical applicability of these neutral models (Collard et al. 2016; Premo 2016, 2021; Vaesen et al. 2016), although these questions are beyond the scope of this article. What is important is that with this approach, the selectively neutral processes

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are viewed as simpler and are therefore prioritized over selection and evolutionary change for explaining patterns in the archaeological record (Powell et al. 2009). Collard and Shennan (2008:22) state the following:

> Where cultural patterns agree with the patterns predicted by a [neutral] model, we can invoke the principle of parsimony and discount the processes that are more complicated than the modelled process. In contrast, where the cultural and modelled patterns disagree, we can legitimately disregard the modelled process and seek a more complex explanation.

Neutral models are sometimes explicitly presented as the null hypothesis (Premo 2006; Raup 1987). For example, in showing that Neanderthal extinction can be explained by a simple process of repeated migration and neutral drift, Kolodny and Feldman (2017:1) posited that their model "offers a parsimonious alternative to those that invoke external factors or selective advantages, and represents a null hypothesis for assessing such alternatives." Also dealing with Neanderthal extinction, Vaesen et alia (2019) developed a demographic model to show that, even without competition with modern humans, Neanderthal extinction can be explained by the smaller population sizes of the extinct hominin: "An explanation solely in terms of the internal dynamics of the Neanderthal population, as the one presented here, serves as a null hypothesis against which competing, and less parsimonious, hypotheses are to be assessed" (Vaesen et al. 2019:10). The logic here, as summarized by Currie and Meneganzin (2022), is that the "null" consists of the simpler and more parsimonious explanation available. If the null cannot be rejected, then it is assumed to represent the best hypothesis for explaining the phenomenon at hand. Alternative, more complex scenarios should only be entertained when the null is rejected by empirical data. Note that this "null-based" approach differs from the way null hypothesis is typically used in science. According to Currie and Meneganzin (2022), in an experimental science setting, the null hypothesis serves to demonstrate that the observed effect of the independent variable is due to chance; consequently, accepting the null is a negative finding about the alternative hypothesis. From this view, neutral models actually represent competing hypotheses rather than the null. We will come back to this issue later when we discuss methodological biases with the "null-based" approach.

Morgan's Canon

At the beginning of this section, we suggested that the approach to parsimony we have seen in this context is not merely about tallying up and comparing the number of postulates among competing hypotheses. An example is the demographic explanations of Neanderthal extinction. If we judge simplicity solely by the number of postulates, "a purely selective, or a purely environmental, explanation is presumably just as simple as a purely neutral explanation" (Currie and Meneganzin 2022:20). Instead, parsimony is applied here in a way akin to Morgan's canon in comparative psychology, which states, "In no case is an animal activity to be interpreted in terms of higher psychological processes if it can be fairly interpreted in terms of processes which stand lower in the scale of psychological evolution and development" (Morgan 1894:53). According to Morgan, we should, by default, always adhere to a "principle of conservatism" (Sober 2015) by prioritizing lower-level causes or processes unless the evidence suggests otherwise.

The difference between a higher and a lower cause is usually framed in terms of complexity, with the lower cause being "simpler" and therefore more parsimonious than the higher one. For example, when inferring human cognitive evolution from archaeological remains, Coolidge and colleagues (2016:221) stated, "Strict parsimony must apply. The simplest cognitive system that can account for archaeological features must be given priority." In a general sense, this conservative approach of preferring simpler processes over more complex ones is relatively common in science. Scientists are generally more averse to committing type I errors, or false positives (Doan 2005)—that is, we tend to think that concluding that something exists when it does not is worse than missing something when it does exist. If we prefer the simpler explanation by default, we can guard against falsely attributing higher-level causes to the phenomena at hand. Such a position is further warrantable in cases where false positives can have substantial impact on the understanding and treatment of the phenomenon in question.

But what is the basis of the differentiation between lower/simpler versus higher/complex? This is a complicated question, and one that has motivated some to advocate rejecting Morgan's canon altogether (Fitzpatrick 2008). In what follows, we offer what we take to be a plausible way of applying the canon to archaeological inference, though there will undoubtably be others. In his original writing, Morgan (1894:59) reasoned that "any animal may be at a stage where certain higher faculties have not yet been evolved from their lower precursors; and hence we are logically bound not to assume the existence of these higher faculties until good reasons shall have been shown for such existence." We can conceptualize this evolutionary relationship in terms of "causal priority" (Starzak 2017)—that certain features and processes must be in place before others can develop. If faculty A needs to evolve first (i.e., ancestral) before faculty B can emerge (i.e., derived), then A is *causally prior* and hence lower than B (Starzak 2017). According to Morgan, the lower A should be prioritized over the higher B.

However, there can be issues with causal priority (Starzak 2017). Because evolution is nondirectional, a more ancestral feature may not always be simpler than one that evolved later (i.e., the lower A being more complex than the higher B). Consequently, we cannot assume a correlation between simplicity and causal priority. Moreover, it is possible for an organism to lose a simpler ancestral trait but retain a more complex one (i.e., having B but not A). In this case, preferring the lower cause would be incorrect.

Alternatively, we may justify Morgan's canon with the concept of "entailment" as outlined by Sober (1998). Put simply, process B is at a higher level than A if and only if the occurrence of B entails the occurrence of A, but not conversely (Sober 1998, 2015). At first glance, this notion is similar to causal priority, given that the lower A must take place before B can occur. However, unlike causal priority, the entailment concept means that having the higher B *must* require having the lower A, which then leaves no room for the possibility for the lower A to be lost (Starzak 2017). This entailment relationship is crucial because it allows the different levels of causes to scale with simplicity. This is because a proposition of the higher-level B is actually a proposition of A and B (because the occurrence of the higher B must entail the occurrence of the lower A), which is a more complex proposition than one that postulates A alone (without B). In this way, we can demonstrate that a lower cause is indeed simpler and more parsimonious than a higher cause. For these reasons, Sober's (1998) notion of entailment offers us a productive way of conceptualizing complexity.

In fact, we can further extend this idea of entailment to think about the relative likelihood of lower and higher causes. Let us assume, for the moment, that the probability for a lower process A and a higher process B is equally 0.2 (i.e., $\Pr(A) = \Pr(B) = 0.2$). The chance of having the lower process A alone without B ($\Pr(A \ \& \ \neg B) = 0.2 \times (1 - 0.2) = 0.16$) should be higher than having both lower and higher processes A and B ($\Pr(A \ \& \ B) = 0.2 \times 0.2 = 0.04$). This relative difference in likelihood between lower and higher causes will always hold if we have reasons to believe that the lower processes are equally common, if not more so, than the higher process (i.e., $\Pr(A) \geq \Pr(B)$). For example, we may assume that heritable continuity is common, whereas evolutionary change is rare, or that individual selection is more prevalent than group selection, as Bettinger argued earlier. Moreover, if the occurrence of the higher process entails having multiple lower processes, then it is possible for a hypothesis of multiple lower causes to still have a greater probability than a hypothesis involving a single higher cause. We can show this by assuming that a higher B entails lower A_1 and A_2, and that, again, all causes have an equal probability of 0.2. The chance of having B (entailing A_1 and A_2) ($\Pr(A_1 \ \& \ A_2 \ \& \ B) = 0.2 \times 0.2 \times 0.2 = 0.008$) would be smaller than having A_1 and A_2 without B ($\Pr(A_1 \ \& \ A_2 \ \& \ \neg B) = 0.2 \times 0.2 \times (1 - 0.2) = 0.032$]. The point here is that under the condition of entailment, lower-level causes and processes can be demonstrated to be not only simpler but also more likely.

With the entailment concept, we can begin to clarify how parsimony is used to rank competing hypotheses in this context. For example, going back to cladistics parsimony, homoplastic change represents a higher-level process because evolutionary selection entails having heritable continuity of traits, but having heritable continuity does not entail evolutionary selection. For this reason, homological explanations are simpler and therefore preferred over homoplastic explanations.

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In the same vein, in the applications of population genetics-based methods, selection as an evolutionary process entails having demographic variation and inheritance, but the reverse is not true. Consequently, demographic hypotheses are more parsimonious and should be prioritized as explanations.

As an anonymous reviewer has suggested to us, the proposal above links with various contemporary projects that apply Bayesian analytical methods to archaeological inference (e.g., Crema et al. 2014; Gjesfjeld and Jordan 2019; Kandler and Crema 2019; Marwick et al. 2023). This reviewer has also suggested that this opens up an intriguing possibility. If we follow our above proposal, one way in which to make parsimony assumptions explicit would be to make the probability estimates used in competing inferential models explicit. More broadly, researchers could provide both prior and posterior probability estimates on hypotheses. We believe the rigor and clarity of archaeological inference would be greatly increased were such practices to become commonplace. Unfortunately, the scope of this article prevents exploring these possibilities in more detail, but we think they represent an important line of future inquiry.

The Value of Conservatism

As mentioned earlier, an advantage of preferring simpler explanations is that we reduce the chance of mistakenly committing false positives in attributing higher-level causes to the phenomena in question. Many researchers in archaeology and human evolution studies find this conservative approach useful (Brantingham 2003; Tennie et al. 2017). However, on the flip side, conservatism heightens the risk of incorrectly omitting or denying the occurrence of higher causes, entities, or processes (i.e., false negatives), leading to potential oversight of interesting findings (Doan 2005). In fact, it can be argued that, with the conservative approach, alternative explanations are disadvantaged in the research design, especially if the simpler explanation is set up as the null hypothesis rather than as a competing hypothesis (Currie and Meneganzin 2022). As mentioned earlier, this is because accepting the more complex alternative requires us to first reject the null, but this is not the case the other way around. Using Currie and Meneganzin's (2022) words, the null hypothesis is "on the table" by default, but the alternative explanations must "jump" over an extra bar that is set by the null in order to be considered. Therefore, operationally, it is easier to uphold the simpler explanation than to entertain the possibility of alternative hypotheses. An implication of this bias is that it can create an impression that the phenomena in question are simple and explainable by singular causes, mutually exclusive of other alternatives. This issue can be problematic in archaeology, given that such impressions reduce the complex histories and contextual aspects of human cultural practice and archaeological formation into simple narratives.

A possible way to address these issues is to adopt the view that accepting a more parsimonious hypothesis does *not* justify denying the existence of alternative explanations. This position is grounded in two considerations. First, the formation of the archaeological record is a complex system involving multiple causal inputs. As such, we must entertain the possibility that more than one hypothesis may be simultaneously true (Chamberlin 1890; see also Elliott and Brook 2007). From this standpoint, denying the existence of alternative explanations beyond the most parsimonious one appears restrictive and counterproductive, particularly if our objective is to unravel the intricacies of formational complexity as a means to infer past behavioral dynamics (Dibble et al. 2017; Rezek et al. 2020). Second, with respect to the issue of equifinality mentioned earlier in the article, if similar properties of the archaeological record can result from different causal inputs, then we must be open to the possibility that any given archaeological property can have multiple causes. For example, modeling studies have shown that the "distance-decay" distribution of lithic raw material abundance commonly observed among Paleolithic assemblages can be explained equally by either varying forager movement tendencies or varying stone-tool discard rate, or a combination of both (Brantingham 2003, 2006; Lin and Premo 2021). Here, due to equifinality, accepting one causal hypothesis for explaining a phenomenon in question does not deny the possibility of other causal hypotheses. In this setting, although parsimony is used to identify superfluous causes that are not necessary to explain the empirical data, we should remain agnostic and open to the possibility that the superfluous causes exist.

Sober (2015) described this agnostic approach as wielding Ockham's razor as a "razor of silence"—that is, we remain silent and uncommitted to, rather than outright denying, causes that are unnecessary to explain the phenomena at hand. An example of the application of this approach to parsimony can be seen in Brantingham's (2003) neutral model of forager stone procurement. He states,

> If [the model output and the archaeological pattern] are consistent, then we must confront the difficult possibility that empirically observable features of the archaeological record such as raw material richness and transport distances may not be telling us much of anything about optimization of procurement behaviours, depth of planning, risk management strategies, and, ultimately, adaptive variability [Brantingham 2003:491].

In other words, accepting the more parsimonious neutral model does not deny past foragers of these behavioral complexities. Rather, with the razor of silence, it is not necessary to postulate these aspects of past human lifeways to explain *the specific archaeological pattern in question* (which, in this case, is the distribution of stone artifact abundance by distance to raw material source). If our goal is to infer these behavioral aspects, then we should be motivated to continue the line of inquiry by looking into other properties of the archaeological record.

Conclusion

Archaeologists often invoke the parsimony principle to support inferences about the past based on observations of the archaeological record. Proportionally few do so having considered the challenges of operationalizing that principle. Without clearly articulating the reasoning and treatment of parsimony, however, we risk turning parsimony into a mere rhetorical device rather than an epistemological tool. As we have shown in this article, parsimony is used by archaeologists in many different ways. In the context of ethnographic analogy, despite the regular reference to parsimony, it is not obvious how simplicity is measured or why simplicity justifies the plausibility of the analogy. Instead, we think that it is more useful to frame ethnographic analogy as an inference to the best explanation; its appeal stems from its perceived ability to best explain the observed data. However, whether ethnographic analogy offers the right answer or not for explaining archaeological observations is a different question that needs to be investigated empirically. In the context of model fitting, parsimony is applied more in the form of Morgan's canon—that is, lower causes are simpler and hence prioritized over higher-level ones. We found this approach to parsimony more workable. In particular, by utilizing the notion of entailment (Sober 1998, 2015), higher-level causes are demonstrably more complex and less probable than lower causes under certain conditions. This general conservative approach is common in archaeological interpretation and arguably justified to prevent false-positive conclusions about the past. However, we caution against the counterproductive use of this approach to deny the possible existence of alternative superfluous causes. Parsimony is a method for assessing the relative likelihood of competing explanations; it does not resolve which of those explanations is true. Instead, researchers should be motivated and encouraged to continue investigating the archaeological phenomenon in order to clarify the record's complex formational history in relation to past cultural and natural processes.

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