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Social Agency and the Dynamics of Prehistoric Technology

Marcia-Anne Dobres[1] and Christopher R. Hoffman[1]

Technology is not only the material means of making artifacts, but a dynamic cultural phenomenon embedded in social action, worldviews, and social reproduction. This paper explores the theoretical foundations for an anthropology of technology that is compatible with this definition. Because of its focus on social agency, practice theory provides an appropriate starting point for a social theory of technology. In addition, three other themes require explicit attention: scale, context, and the materiality of technology. Four case studies demonstrate how archaeologists are beginning to take technology beyond its material dimensions, and additional questions are proposed stemming from the theoretical issues raised in the paper. The purpose of this essay is to synthesize a diverse set of emerging ideas and approaches to understand better dynamic community-level social processes of prehistoric material culture production.

KEY WORDS: technology; social agency; worldviews; microscale.

INTRODUCTION

Throughout the history of archeology — both before the "revolutions" of Childe (e.g., 1934) and since — technology has figured prominently in explanations of culture process and culture change. Over the past few decades, archaeologists have become adept at reconstructing sequences of artifact manufacture for a variety of materials, providing a direct and empirical link for making inferences about the productive activities of past cultures. However, as a *concept*, technology is rarely examined closely by archaeologists or anthropologists, and the theoretical foundations for an anthropological study of technology have not developed as far as the methodological

[1]Department of Anthropology, University of California, Berkeley, California 94720.

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ones. In particular, key social dimensions of technology remain an underdeveloped topic. Technological acts, whether mundane or spectacular, are a fundamental medium through which social relationships, power structures, worldviews, and social production and reproduction are expressed and defined (cf. Ingold, 1990; Lechtman, 1977, 1993; Lemonnier, 1986; Pfaffenberger, 1992). This essay explores aspects of these anthropological issues for understanding technology and considers recent research beginning to demonstrate the potential for, and value of, studying technology as an integral and active part of social reproduction and change.

Archaeologists from a wide range of theoretical and topical backgrounds have begun to argue for greater attention to the dynamic social dimensions of past cultural life (e.g., Brumfiel, 1992; Chase, 1989; Cowgill, 1975, 1993; Gifford-Gonzales, 1993a; Hodder, 1982; Ingold, 1990; Marquardt, 1992; Peebles, 1992; Shanks and Tilley, 1987; Tringham, 1991, 1994), and it is clear that this trend began with the advent of processual archaeology (e.g., Binford, 1962; Schiffer, 1976). In recent years, increasing numbers of archaeologists and cultural anthropologists have recognized that technologies, too, are shaped by a complex set of variables. Although factors such as raw material constraints and environmental conditions help to structure technologies, dynamic social processes involving individuals and small-scale groups also play a major part (Ingold, 1990; Pfaffenberger, 1988; Schiffer, 1991). As is the case with language, kinship structures, and ideology, technology is a complex cultural phenomenon embedded in historically specific worldviews, strategic social action, and human agency more generally (Leone, 1973). This perspective, that technologies are informed by "cultural reason" (after Sahlins 1976), highlights production-related social action as cultural *praxis* (e.g., Kitching, 1988, p. 29; Petrovic, 1983; Sahlins, 1976, pp. vii-viii) as well as the values and meanings engendered in production activities (Chase, 1989, p. 50).

Scale, Context, Materiality, and Social Theory

To begin exploring the social dimensions of prehistoric technology as shaped by social strategies and worldviews, several factors taken together can generate a richer account of the technological variability encountered in the archaeological record. These are *scale, context, materiality,* and *social theory.*

First, as increasing numbers of archaeologists have begun to argue, there are many analytical and interpretive *scales* with which to investigate the past (Marquardt, 1992). An explicitly multiscalar research program can better grasp the complex interaction of factors operating at different scales and offers a flexible and appropriate framework for studying technological processes. Although the resulting accounts will not necessarily form a single explanatory "whole," microscalar and macroscalar understandings can complement each other. As discussed in this essay, technological analyses can investigate the contribution that seemingly mundane material culture production makes to the shape of prehistoric lifeways and culture change. The social dynamics that occur in the course of day-to-day artifact manufacture, use, repair, and discard, that is, microscale social dynamics involving individuals[2] and small-scale groups, are an underdeveloped topic in archaeological research (Cross, 1990; Tringham, 1994, p. 29). In this sense, "microscale" and "macroscale" refer not only to physical levels of analysis, but also to scales at which past social action occurred and to which archaeological explanation is directed. A microscalar perspective highlights the dynamic nature of prehistoric technological action within heterogeneous social communities and recognizes that prehistoric production was a meaningful and socially negotiated set of material-based *practices*, as well as a technical means by which to make things.

Normative accounts of the past, as Binford (1965, p. 205) once argued, tend to obliterate behavioral variability: "Culture is not necessarily shared; it is participated in. And it is participated in differentially." A microscale orientation can be used to account for archaeological variability (Clark, 1991, pp. 80–81; Straus, 1991) (1) to model the dynamic social processes involved in ongoing, day-to-day technological endeavors, and (2) to consider the differential participation of the actors and groups involved. However, as we envision it, the final goal of technological studies is not to describe microscale prehistoric *activities*, but to understand microscale social *processes*. Furthermore, dynamic social processes operating at the microscale may have impacted on, and/or substantially contributed to, more macroscalar processes (Boyd and Richerson, 1985, p. 290; Chase, 1989).

Second, the concomitant social, political, and economic *contexts* of past productive activities are an especially important dimension of technology. Technologies are not practiced in a cultural vacuum where physical laws take precedence. Objects are made, used, repaired, and

[2]Johnson (1989) provides an analysis of the long-standing dilemma in archaeological theory concerning the place of the individual in social groups and cultural systems. He distinguishes between the desire to identify specific individuals in the past (e.g., Noël Hume, 1982) and the more anthropological goal of understanding human agency. Of interest are the processes that interconnect individual agents, small-scale social groups, and larger cultural formations. The emphasis on human agency and on "social actors" in this essay is intended as an analytical and interpretive tool for considering microscalar processes in prehistory. Related points are given by C. Bell (1992) and J. Bell (1992).

deposited at a variety of sites, and the associated activities and social interactions that took place in those contexts form a meaningful and structuring set of background conditions (Hodder, 1986, pp. 139–142, 1987; Ingersoll and Bronitsky, 1988; Lewis-Williams, 1990, p. 133). Additionally, contextual information provides additional lines of material evidence useful for generating inferences about the social dimensions of technology.

Third, attending to the social dimensions of technology in no way forsakes a commitment to the *materiality* of technology. In fact, it is only through detailed empirical identification of technical attributes, sequences, and *chaînes opératoires* that a more comprehensive and anthropological understanding of prehistoric technology can emerge. Archaeologists need to demonstrate, rather than assume, that technical sequences unfolded in particular ways. However, description should not be the final goal of research on prehistoric technologies. Techniques of raw material modification are structured in social and dynamic contexts of material performance. The interplay of the symbolic and the material shapes the contours of all cultural behavior (Conkey, 1993; Moore, 1986), and technology plays a special role in this process (Kitching, 1988; Leone, 1973). The materiality of technology and the underlying technical rules of modification, identified through fine-grained empirical study, form the foundation for understanding the social dynamics of material production (Lechtman, 1977).

Fourth, and perhaps most importantly, the *social theory* employed in the interpretation and hence acquisition of technological data must be reassessed. To understand the social dynamics of technology, particularly those occurring at the microscale, a body of social theory is needed that can relate *technical* knowledge and action to *social* knowledge and action and to general social reproduction. Because it makes explicit the role of the individual and small interacting groups in the continuity and change of social structures, practice theory can provide a starting place for building an appropriate social theory of technology (Bourdieu, 1977, 1984; Giddens, 1979, 1984; Ortner, 1984). However, a number of limitations with this body of social theory must first be overcome. Archaeology, because of its explicit focus on material culture, continuity and change over time, and a broad range of social formations, is uniquely situated to examine and exploit the potential of practice theory.

These four elements, then — scale, context, materiality, and social theory — help draw attention to the complex nature of technological practice and simultaneously promote a comprehensive and human-centered approach (after Hall, 1977).

THE SOCIAL CONSTITUTION OF TECHNOLOGY

> Individuals are actively involved in the daily creation and recreation, production and reproduction, of the world in which they live. Thus, as they employ tools and techniques, work in social labor arrangements, make and consume products, and adapt their behavior to the material conditions they encounter in their natural and artificial environment, individuals realize possibilities for human existence. (Winner, 1986, pp. 14–15)

People create the world in which they live in both material and symbolic ways (Conkey, 1993; Sahlins, 1976), and technology is involved in this dynamic process on a daily basis. Through the activities and social relations involved in material production, people create things. These processes of material production and their end products, in turn, become material and symbolic structures through which the world is perceived and responded to (Moore, 1986). This general point was articulated by Marx and Engels (1970, p. 42) a century ago: "As individuals express their life, so they are. What they are, therefore, coincides with their production, both with *what* they produce and with *how* they produce."

Of central importance to an anthropology of technology [or material culture (Conkey, 1989)] is a focus on human agency and the "social life of things" (Appadurai, 1986; Heidegger, 1977). Highlighting the social agency of technological activities involves two basic premises: first, that technology is the meaningful engagement of social actors with their material conditions of existence; and second, that technology not only is the tangible techniques of object-making, but also makes tangible fundamental metaphors of daily social interaction (Childe, 1956; Lechtman, 1977, 1984). Without explicit attention to these dynamic processes, technology is all too often reduced to its "hardware" (Lechtman, 1993).

A dynamic view of technology brings to the fore the social activities, interrelations, and tensions involved in the ongoing modification of natural resources into cultural products (Ormiston, 1986). While technology clearly is material, it is enacted within culturally and historically specific contexts of dynamic social interaction and meaning-making (Conkey, 1991, p. 79). It is for this reason that microscale social processes central to the daily production of material existence become keys to understanding how technological systems work. Such microscale social processes are effectively studied in temporally and spatially discrete material contexts although such an orientation does not preclude cross-cultural comparisons (Brumfiel, 1992).

Technology equally concerns social interaction (e.g., divisions of labor), belief systems (e.g., origin myths and their relationship to the cultural and physical landscape), and practical knowledge of techniques and the environment (Lemonnier, 1986; Ridington, 1982, 1988). In fact, technology concerns all these dimensions simultaneously (see also Pfaffenberger, 1992; Schiffer, 1992, p. 131), and all are critical to social reproduction. The complex webs interconnecting the material with the social, political, economic, and symbolic experiences of human existence take on tangible dimensions.

Exactly *how* archaeologists can study these aspects of technology is no simple matter. At present, two primary approaches to the social dimensions of technology can be identified. Although these are not mutually exclusive concerns, an integrated approach has not yet developed. The first approach views technology as an expression of worldviews, and the second highlights dynamic social processes of technological activity.

The "worldview" perspective is interested in why technology takes the various specific forms that it does: What is it about a society's belief system and social practices that play a part in structuring the techniques and forms of organization of a particular technological system? What does an analysis of material techniques involved suggest about a society's worldview? The premise here is that "technologies are also particular sorts of cultural phenomena that reflect cultural preoccupations and express them in the very style of the technology itself" (Lechtman and Steinberg, 1979, p. 139). For Lechtman especially, but for others as well (e.g., Childs, 1991a, b; Hoffman, 1991a; Hosler, 1986, 1988; Johnson, 1989, 1990, 1993), the analysis of prehistoric technology becomes an entry point through which to consider emic dimensions, for example, the "mind-set," of physical phenomena involving raw material modification (Lechtman, 1977, p. 7). Forty years ago, Childe (1956, p. 1), following ideas credited to Marx, foreshadowed this position when he suggested that objects are always and exclusively "concrete expressions and embodiments of human thought and ideas."

The second approach is more explicitly concerned with how technology is part of the dynamic nature of social production and reproduction (Ingold, 1993), and as such it can draw inspiration from practice theory (e.g., Dobres, 1991a, 1993; Hodder, 1990). Because it is through social relations of production that technologies are enacted, empirical aspects of prehistoric raw material modification can be studied as a "window" into those social relations (Wright, 1993, p. 250). In archaeology, efforts to identify and understand forms of craft specialization (e.g., Costin, 1991; Cross, 1993) and technological organization (e.g., Nelson, 1991) are clearly relevant to these concerns. A focus on the social agency of technology pays particular attention to the microscale contexts of day-to-day production activities. These are the sociopolitical contexts in which technological decisions are made and given culture significance, and they are also arenas of social tension that require resolution on a day-to-day basis (Conkey, 1991, p. 80).

The premises of this second approach to technology and social agency are explored in more detail below. However, archaeologists are only now beginning to adapt practice theory to archaeological problems, including technological ones. Nonetheless, a desire to understand the role of daily social action and interaction involved in material production broadly characterizes the interest of many beginning to seek new perspectives for studying technologies (e.g., Adams, 1977; Cresswell, 1972, 1990; Larick, 1991; Lechtman, 1993; Lemonnier, 1992a; Schlanger, 1990). The technological worldview approach, on the other hand, has generated interesting and successful case studies, due largely to the pioneering efforts of two researchers: Heather Lechtman and Pierre Lemonnier.

Technological Worldviews and Systems of Representation: The Pioneering Work of Heather Lechtman and Pierre Lemonnier

The premise of Lechtman's work is the argument that technologies are "part and parcel of the mainstream of cultural inclinations and are irrevocably bound to the social setting in which they arise" (Lechtman and Steinberg, 1979, pp. 136–137). She accepts the view of culture advocated by processual archaeology, citing Binford's (1962, p. 213) classic definition. From her earliest statements Lechtman has championed the need to understand the social and contextual nature of prehistoric technology, even if the overall research goal is to comprehend large-scale historic developments and/or deterministic aspects of specific techniques (Lechtman and Steinberg, 1979, pp. 141–142). To answer even macroscalar questions, one must "ascertain the extent to which technologies have internal forces that drive them and the extent to which culture is determinative in shaping their content and structure" (Lechtman and Steinberg, 1979, p. 137). Her position is that technology actively reproduces society as much as it is employed by society as an adaptive "tool." To understand these sorts of processes Lechtman stresses the importance of detailed empirical research, and guided by the prescient teachings of C. S. Smith (1986), she was among the first to be trained in both materials sciences and anthropology (Goodway, 1991).

Lechtman developed the concept of "technological style" (1977, 1993; Lechtman and Steinberg, 1979, pp. 154–157), which she derived from a nexus of structuralist premises (e.g., Lechtman, 1977, pp. 6–7, 10–12). She argues that formally redundant techniques of manufacture arise from cultural actions because technology is part of the larger integration of cultural subsystems. Her research demonstrates the possibility of inferring nonmaterial dimensions of prehistoric behavior from the identification of the rule-bound similarities empirically manifest in material culture. She argues that normative structures are played out in techniques of manufacture, but they are not passively isochrestic (Sackett, 1982, 1990). That is, technological styles are not merely tradition-bound choices arbitrarily selected from the range of all possible solutions to technical problems (Lemonnier, 1992a; van der Leeuw, 1991). More is involved. "What lay behind the technological style were attitudes of artisans towards the materials they used, attitudes of cultural communities towards the nature of technological events themselves, and the objects resulting from them . . .technological performance was supported by a set of underlying values" (Lechtman, 1977, p. 10). The difference between Lechtman's "technological style" and Sackett's concept of isochrestic variation is that Lechtman is equally concerned with *how* prehistoric technology reaffirmed the very normative values and practices that simultaneously structured technology, in a recursive and dynamic manner. For her, the goal of technological analysis is to "describe socially meaningful behavior and to discover the rules behind such behavior" (Lechtman, 1977, p. 12). Prehistoric technological acts themselves constitute a symbolic system, and the enactment of prehistoric material production provided meaning and structure for the actors involved [(see also Lemonnier, 1991); Moore (1986) takes up this argument for material culture generally].

Lechtman's (1984, 1993) study of pre-Hispanic Andean metallurgy remains one of the finest examples of research able to infer the "emics" of ancient technological systems. Her detailed metallographic and experimental study of Mochica metal production revealed that, to effect a particular color (gold or silver) on the surface of certain metal objects, the Peruvian Mochica practiced a highly complex set of techniques based on "the incorporation of the essential ingredient — the gold or the silver — into the very body of the object" (Lechtman, 1984, p. 30). These techniques were preferred to those whereby the object was plated with a thin coating of the desired precious metal. The reason for this more expensive, time-consuming, and labor-intensive technology was that "the essence of the object, that which appears superficially to be true of it, must also be inside it. In fact, the object is not that object unless it contains within it the essential quality . . ." (Lechtman, 1984, p. 30).

Lechtman is able to substantiate her interpretation that a more general cultural ethos or ideological motif — that the essence must be embodied within — was expressed in and displayed through metalworking, with reference to multiple lines of evidence. What gives her argument power is that a similar set of principles, a "technology of essences" (Lechtman, 1984, p. 31), structured textile manufacture as well. Motifs on Andean tapestries could have been embroidered superficially but they were not. Once again, an elaborate technology was practiced, designed to weave the motif from within the very fabric itself and thereby bring it to the surface (Lechtman, 1993). It is this resonance of a "worldview" expressed in different manufacturing technologies that gives power to Lechtman's case study as well as to more general arguments concerning the structural relationship between cultural ideals and material expression.

Her successful application of detailed analytical methods combined with, and motivated by, strong anthropological interests is another compelling aspect of Lechtman's work. Indeed, without the laboratory information generated by metallography, experimentation, and associated analytic methods, the "technology of essences" would be a matter of speculation.

Pierre Lemonnier is also interested in technical systems and their inseparability from social logic and social relations. For him, technological activity consists of the interplay of five heuristically separated elements: (1) matter, (2) energy; (3) objects, (4) gestures in sequence, and (5) knowledge (Lemonnier, 1989a, 1992a, pp. 5–8; see also Michea, 1968). Above all, technology is social production (Lemonnier, 1993a, p. 3). In keeping with a strongly anthropological approach to the study of technical systems (e.g., Lemonnier, 1986, p. 147, 1992a), Lemonnier points out that material culture studies, and particularly technological analyses, typically study a single class of data and focus on material properties above all else. He argues that this reductionist strategy ignores the systemic quality of the objects and technologies (e.g., Lemonnier, 1992a, pp. 9–11). Instead, Lemonnier's position is that technologies are socially meaningful at many levels simultaneously. This fact, in particular, calls for an extremely broad anthropological perspective [see Moore (1986, p. 79) for similar arguments regarding material culture]. His long-term ethnological studies of contemporary production systems in Papua New Guinea [and on a variety of industrial technological systems (e.g., Lemonnier, 1989a)] demonstrate that the technical choices people make are central to meaningful social action despite their sometimes arbitrary appearance. Technical choices are dynamic strategies often related to social identity and difference (Lemonnier, 1993a).

Lemmonnier's perspective on technology reveals his intellectual debt to Mauss and Leroi-Gourhan (Lemonnier, 1986, p. 153, 1992a, b).[3] He suggests

[3]Lemonnier (1989b) makes the point that French social theorists were the first to establish an anthropology of technology through their interest in the "ethnology of gestures" [starting with Mauss (1936) and Leroi-Gourhan (1943, 1945, 1964, 1965) and later Haudricourt (1968) and Michea (1968)]. The journal *Techniques et Culture* is a regular forum for French work on the anthropology and sociology of techniques. We agree with Lemonnier, however, that until French "gestural scientists" embrace social theory and an interest in the kinds of processual questions long advocated by American archaeologists, they will not be in a position to achieve their goals. The general problem for French scholars has always been how to move from description to understanding (Cleuziou *et al.,* 1991).

that the study of the operational sequences through which material culture is created permits an understanding of techniques for what they can say about the social relations involved. A catalog of technical variability means more than recording the empirical outcome of different production sequences (Lemonnier, 1992a, p. 51). "The observation of technical variants [i.e., specific techniques] — the very ones represented by the discontinuities in material culture whose study forms the major part of archaeology . . . — often designates different social realities" (Lemonnier, 1986, p. 155, 1993a). Thus a contextual analysis is required for comprehending the socially constituted dimension of any technical fact.

Similar to Lechtman's claims, Lemonnier argues that technical procedures are "a set of cultural representations of 'reality'" (1986, p. 154, 1993a, p. 3), or what he comes to call "social representations" (e.g., 1989a, 1990, 1992a). The parallel we see in the work of Lechtman and Lemonnier has to do with how, symbolically *and in practice*, a technological system tangibly manifests worldviews and even contributes to their articulation. As ethnoscience has long maintained, "technical thought" is a fundamentally structured system of representation not limited to the basic experience of making and using objects. Lemonnier's interest is in the metaphorical and material links existing among a given technical system, the society's worldview, *and* the daily forms of social interaction involved in material production. Metaphorical and material links exist because techniques are social productions that express and define social identities.

Lemonnier has applied his theory of technical systems to a series of ethnographic studies among the Anga of Papua New Guinea (1986, 1992a, pp. 51–66, 1993b). His basic claim is that

> indigenous knowledge or reflection on techniques is translated by, among other things, implicit or explicit classifications of the materials treated, of the processes brought into play, of the means and tools employed, and of the results obtained . . . [and that] the technical choices of societies are thus established by means of "criteria" which are not at all material . . . (Lemonnier, 1986, pp. 155–156)

Lemonnier demonstrates that in many cases differences in the expression of "productive styles" are explained by virtue of one group overtly distancing themselves from their neighbors. This account is reminiscent of the style and ethnicity debate conducted by Wobst (1977), Sackett (1982, 1990), and Wiessner (1984), among others. In the case with which Lemonnier is interested, style is expressed in the operational sequences by which pig traps and bark capes are manufactured. Some of these technical differences are manifest in the actual operational sequences, while some are located in the end product of the technological endeavor. Tool functions and material constraints also structure and determine these technologies (e.g., Lemonnier, 1990), but they do not sufficiently explain the material variability observed (Lemonnier, 1993a).

One important point Lemonnier (1986, p. 161) makes is that neighboring groups are often well aware of each others' technological practices and this knowledge informs them as to which technological choices are to be held in common. The absence of any particular technical trait does not necessarily mean a lack of knowledge of it but, instead, may signify a strategy marking social difference. These choices are often expressed consciously and, as such, are active social strategies (e.g., Hoffman, 1991b, p. 30, 1994). In this case, Lemonnier highlights social agency at the scale of group consensus and explains the dynamic cultural properties of technological activity.

Lemonnier's (see 1990, 1992a, 1993a) general research on the Anga supports the claim that technologies help to reaffirm, represent, and give meaning to the socially constructed world of possibilities and constraints. These practices, in other words, have a "signifying character" related to Anga social reality (after Lévi-Strauss, 1976, pp. 10–11). On this point Lemonnier and Lechtman converge: Technological traits can be taken as empirical evidence for the "classifications of the technical universe" (Lemonnier, 1986, p. 173). This argument highlights the multidimensional nature of technology, making the case that it can be understood at many analytical levels simultaneously.

Whether one's interest is in uncovering the cultural principles of logic accounting for a particular prehistoric technical system (as, for example, in Lechtman's work) or in considering prehistoric technology as the "materialization of social thought" and a strategy marking group affiliation (as Lemonnier suggests), these case studies and the theories underlying them demonstrate that distinctive cultural predilections are expressed through technologies and technological choices (also essays in Lemonnier, 1993c; Leone, 1973). Furthermore, Lechtman's and Lemonnier's work clearly demonstrates suggestive links to other dynamic social processes: strategies of affiliation, social organization, divisions of labor, and fundamental cultural paradigms expressed in and made manifest through technological "styles."

For archaeologists desiring a human-centered approach to "recover mind" (Leone, 1982), the combined orientation advocated by Lechtman and Lemonnier provides a methodology and, at least, the outline of a theory of social representation in technological activities. At the same time, Lemonnier and Lechtman demonstrate that archaeologists cannot forsake attention to the material realities of technical systems, for "to suggest that technical behavior can be reduced to the exclusive production of meaning is an absurdity" (Lemonnier, 1990, p. 29). The relationship of ordinary day-to-day technological activities to the social construction and reproduction of "reality" highlights the material links among technological practices, material culture production and use, and the social enactment of cultural beliefs.

PREHISTORIC TECHNOLOGY AND THEORIES OF SOCIAL AGENCY

It has become increasingly clear that a robust social theory must be brought to the study of prehistoric material production if technological research is to understand the dynamic social processes involved, especially at the microscale. That theory should be neither *ad hoc* to material analysis nor *post hoc* to interpretation. A central requirement of a social perspective on prehistoric technology at the microscale is that it be explicit on the issue of social action and agency. A compelling theory of social agency can be drawn from perspectives articulated by Anthony Giddens (1979, 1984) and Pierre Bourdieu (1977, 1984). Within anthropology Ortner (1984) calls this orientation "practice theory" (also C. Bell, 1992, pp. 69–93; Roscoe, 1993, p. 112–113). However, because practice theory has been developed without explicit attention to the materiality of social agency, it can serve only as a point of departure for technology studies past and present.

As with a variety of social theories popular in anthropology and archaeology, "structure" is a central concept in practice theory, but it differs fundamentally from the concept as employed by British structural-functionalists (e.g., Radcliffe-Brown), classic structuralists (e.g., Lévi-Strauss), and cultural materialists (e.g., Harris, 1968, 1979). "Structures of social action" are the context-specific social and material parameters with which practice theory situates social agency. In practice theory, social structures are both the medium and the outcome of social interaction and are conceived of as the normative rules and social and material resources available to individuals (or agents, the term preferred by these theorists) and groups. At the same time, individuals are bound by cultural traditions and the social collective. These structures both enable and constrain social possibilities. This "duality of patterning" is concerned with social action and with the reproduction of society *above the level of the individual actor.* In other words, social structures are normative and historically antecedent to any individual actor [Bourdieu, 1977, p. 32; Giddens, 1984; this point is elaborated by Johnson (1989)]. "Structuration" (Giddens, 1979, 1984), then, is the set of material and social *conditions* that govern both the continuity of these structures and their possible transformation. Structuration is the making and remaking of structures. Bourdieu's (especially 1977, Chap. 2) concept of "habitus" is useful here because it emphasizes the socially constituted system of cognitive and motivating structures operating outside the "free will" of individual members of society. Habitus is the product of a social history within which individuals act reflexively — as agents of their own making.

Practice theory is subject-centered in its concern with social agency. What lies at the heart of a "theory of strategic conduct" is that all social action, individual and collective, is reflexive. Actors know something of the rules by which they are supposed to live, and they use that knowledge (*connaissance*) in day-to-day social interaction. Social action, technological or otherwise, is "a *mediated* understanding of how to proceed under particular conditions" (Edmonds, 1990, p. 56; our italics). This perspective gives primacy to "cultural reason" (*sensu* Sahlins, 1976; see also van der Leeuw *et al.*, 1991, pp. 146–149). Explanations of dynamic social processes must privilege the agents who make them possible.

Nonetheless, fundamental dimensions of social strategies impinge upon any given action and move practice theory beyond the specifics of the "individual," into the realm of the social collective. To be aware of society's rules, resources, and expectations, and to manipulate them to an intended advantage, does not guarantee success: (1) Individuals are unaware of certain aspects of their actions; (2) the implicit yet imperfect knowledge (of rules) a social actor applies to a given situation is often met with counter strategies; and (3) social action often results in unintended consequences, and in certain cases these can prove significant (Giddens, 1979, 1984). These three factors can, and often do, operate simultaneously. Human agents constantly rationalize their actions and act strategically within historically specific contexts and within culturally defined boundary conditions, but other forces impinge on individual agency: (1) other actors and larger social communities, groups, and affiliations; (2) the spatial contexts of the built and natural environment (especially Moore, 1986); (3) history (antecedent social conditions); and especially (4) issues of power played out in the social arena.

The reflexive nature of social action is central to practice theory because people are not robots who unconsciously follow fixed social rules (Bourdieu, 1977, p. 29) any more than they are "governed" by material and environmental constraints (van der Leeuw *et al.*, 1991). It is clear, nonetheless, that people are not always successful in their attempts to act in their own interests. Unintended consequences significantly contribute to the way social strategies are worked out, *especially over time*. It is on this particular issue that we see practice theory providing a necessary element for a microscalar theory of social action that can be linked to larger-scale social transformations (Chase, 1989; Hodder, 1985; Johnson, 1989; Shanks and Tilley, 1987).

The suggestion that humans are a species that thinks strategically is not new to archaeology. What distinguishes practice theory from the application of optimal foraging theory or "rational man" perspectives turns on two basic points. One lies in *interpretive goals*. A focus on social agency highlights the historicity of culturally specific technologies and places explanatory importance on the heterogeneous constitution of the social groups involved. This first point concerns how the social collective is conceptualized. In practice theory the social collective is comprised of individuals and small-scale groups interacting in ways that may be at odds with each other. Participants in group activities such as the production of material culture do not always work smoothly toward mutually agreed-upon ends. The resulting tensions and forms of contestation in such social arenas lead to contexts of power (Conkey, 1991), requiring further strategies of negotiation and resolution. Practice theory accepts the normative aspects of a cultural "system" but sees them as a set of background meaning-structures, or "habitus," in which social activities are conducted and different interests worked out. In the context of technological endeavors, for example, the goals of the agents and groups involved are decided through culturally reasoned strategies of action and interaction.

A second important difference is found in the *ontological premises* concerning what motivates individuals or a collectivity to act as they do in certain situations. Although both practice theory and optimal foraging theory envision humans to be able thinkers and strategizers, the former extends the range of factors that agents confront when making decisions. These go beyond basic environmental and biological factors, to include perceptions and lived experiences, as well as ideological and symbolic factors that serve as structures within which decisions are made (see discussion by Cowgill, 1993, pp. 555–557; Gifford-Gonzalez, 1993a; van der Leeuw *et al.*, 1991; also Weber, 1946). Rather than argue that humans "respond" to stimuli, which is a black box model for decision making, practice theory argues that agents make *culturally reasoned* choices. In different social contexts people make decisions accordingly.

Concerning Material Culture

Practice theory provides useful elements of a theory of social agency because it recognizes both the knowledgeability of social actors and the various limitations that constrain an individual's ability to manipulate "the system." Practice theory is concerned with boundary conditions (structures) and parameters that enable and constrain the organization of social systems, which in turn feed back to structure the interconnections of individuals and larger social forces. In her study of the spatial and social organization of village life among the Marakwet of Kenya, Moore (1986) has employed principles derived from practice theory to examine how material culture and architecture are strategically manipulated by individuals and variously organized groups interacting on a daily basis. At one and the same time, the built environment is understood as a material, meaningful, and structuring set of boundary conditions through which everyday activities and social relations take place.

In much the same sense, because practice theory is explicitly concerned with the microscalar processes of day-to-day social life and their relationship to macroscalar processes, it can serve as a point of departure for archaeological studies of the sociality of technology (Dobres, 1991a). The archaeological record is made up of empirical traces of the most ubiquitous of prehistoric social activities: artifacts of manufacture and use. Principles derived from practice theory can be employed to take the accumulated traces of prehistoric artifact production and make sense of them in terms of social relations (Chase, 1989; Cross, 1990; Johnson, 1989; Kirk, 1991; Shanks and Tilley, 1987; Tringham, 1994, p. 29). This will simultaneously enrich comprehension of the processes of prehistoric tool making and use and recognize the complexity of factors creating a technological system (Dobres, 1994a; van der Leeuw *et al.*, 1991). At the same time, detailed and empirical research conducted by archaeologists over the past several decades could substantially improve practice theory by linking it more explicitly to material concerns.

Looking Forward

Up to this point we have placed particular emphasis on the need to consider the social dynamics of technology at the social microscale. Practice theory, with its focus on agents and social action, provides a strong framework for such studies. However, practice theory is not limited to the microscale or to "thick descriptions" (after Geertz, 1973). As Brumfiel (1992, p. 560) has recently argued, "The discourse of social negotiation can be studied cross-culturally."

Similarly, once a theory of social agency is brought to technological analyses, the possibility of accounting for technological change over time takes on new and intriguing dimensions, because consideration of processes other than those operating at the macroscale are now possible (Brumfiel, 1992; Le Gros, 1988, p. 16). It is through human agency and "schemes of perception" (Bourdieu, 1977, p. 116), conscious or otherwise, that members of society change the way they make and use things. Research on evolutionary changes in technology would be well served by a theory of social agency that can account for these changes at the scale at which they occurred — daily social interaction.

> . . . . The creation of technology, the form that it takes, and the manner of its subsequent deployment, serve as powerful media through which people reproduce some of their basic categories of their social and material world. For that same reason, traditions of making and using may also serve as a point of departure in the negotiation of new relations and new meanings. . . . (Edmonds, 1990, pp. 56–57)

As we have argued, technology is an arena for dynamic social interaction. People engaged in technological activities continually adjust to the daily tensions and conflicts such activities engender. In so doing they both reproduce and, at the same time, change their lifeways [a case study turning on this point is given by Larick (1991)]. This orientation models the processes by which members of past social groups, engaged in everyday production endeavors, actively *took part* in changing their social structures and lifeways.

TECHNOLOGY RECONSIDERED: THE INSEPARABILITY OF PRODUCTION AND SOCIAL LIFE

The positions advocated above can be situated within an emerging multidisciplinary effort to push the limits of current approaches to technology. Substantive, and broadly similar, critiques have already been established in philosophy (Durbin, 1983; Winner, 1986), history (Cutcliffe and Post, 1989; Staudenmaier, 1985), and sociology (Bijker *et al.*, 1987; MacKenzie and Wajcman, 1985), more so than in anthropology or archaeology (Pfaffenberger, 1992, pp. 491-492).[4] There are two primary reasons to work through some of these concerns here. First, they reveal the implicit assumptions that currently underlie the study of technology, past and present, and make the point that because of these assumptions alternative approaches that could prove useful have not been fully explored. Second, the outlines of a more anthropological approach can begin to take shape when such assumptions are examined. Winner (1986, p. 39) suggests that philosophers of technology have spent too much time considering the social and political contexts of technology and not enough time on the technical objects themselves. For archaeology, the reverse is more often the case. While never forsaking the materiality of prehistoric technology, archaeologists can more fully and systematically investigate the social aspects of production

[4] A substantial compilation of these critiques is given by Lemmonier (1993a, c).

processes and consider technology the embodiment and expression of social relations, social meanings, and socially constructed reality (Dobres, 1991a; Edmonds, 1990, p. 56; Hoffman, 1991b; van der Leeuw *et al.*, 1991).

Somnambulism: The Contemporary Definition of Technology

The striking factor noted by scholars exploring the philosophical and sociological dimensions of technology is the standard practice that artificially separates made things from their makers. Of particular interest to this essay is also the artificial separation of the production of things from the social relations by which they come into existence (Kopytoff, 1986, p. 84). While perhaps heuristically useful, this separation effectively masks the social side of technology in favor of the material and functional sides.

Pfaffenberger (1988) has analyzed the history of this phenomenon and shown it to have been a central feature in the development of Western industrialism and its supporting ideological base. The social sciences, which include anthropology and archaeology, have matured within this historical context (Ross, 1991), and it is clear that during the past century the intellectual separation of producers from products has significantly affected the shape of research questions and analytical frameworks employed in the study of technology. Pfaffenberger's historical analysis is premised on arguments established by Winner (1986), who suggests that studies of technology are dominated by what he calls "technological somnambulism." Essentially, the argument is that contemporary technological research starts from the position that technology is about making and using objects first, and about belief systems and social agency only as a last-resort explanation. Technology is defined by material and measurable *things* (e.g., Basalla, 1988; Oswalt, 1973, 1976; as reviewed by Pfaffenberger, 1992, pp. 493–495), and social scientists take the relationship between technology and society to be deceptively obvious. This is somnambulism, because "we so willingly sleepwalk through the process of reconstituting the conditions of human existence" (Winner, 1986, p. 10).

Similarly, Lechtman notes that technology is most typically defined by its "hardware," and the properties of technology currently studied "associate with masculinity and with serious utilitarian activities" (1993, p. 402). Thus it can be argued that archaeological research places analytical and explanatory emphasis on the forms and functions of prehistoric tools more so than on the social relations of those productive activities (Ridington, 1982, p. 471, 1983). In a recent volume of the *Archaeological Review from Cambridge* devoted exclusively to the study of "Technology in the Humanities" (Schlanger and Sinclair, 1990), Ingold (1990) reiterates points Marx made over a century ago: The industrial West imagines technology to be a fetishized system of relations between things, outside the sphere of social relations (also Mitcham, 1980, pp. 298–299): " . . . What is in reality produced by relations among people appears before us in a fantastic form as relations among things . . . the Western ideology of objects renders invisible the social relations from which technology arises and in which any technology is vitally embedded" (Pfaffenberger, 1988, p. 242). Marx called this phenomenon "fetishism," while Ridington characterizes it as "artifactual chuvinism" — the intellectual privileging of products and artifacts over processes and artifice (e.g., Ridington, 1982, p. 471, 1983; but also Dobres, 1991a; Ferré, 1988, p. 14; Hoffman, 1991a; Ingold, 1988; Lechtman, 1993).

For archaeology, one result of the attention on form and function is the tendency to conceptualize prehistoric technology as having no central or integral part *in* society. Rather, technology is used *by* society (Lechtman and Steinberg, 1979, p. 138) as a buffer between nature and culture. Social relations are rarely considered central to, much less an essential part *of*, technology (Ingold, 1991; Lechtman, 1993). As another example, Basalla's opus on the evolution of technology advocates that "the artifact — not scientific knowledge, nor the technical community, nor social and economic factors — is central to technology and technological change" (1988, p. 30). From an evolutionary perspective, technology becomes an "it," and a means by which to control nature, adapt, and maximize fitness (Pfaffenberger, 1992, pp. 493–495). And in yet another formulation, Testart (1982, 1986, 1988), whose work has long been attractive to archaeologists, characterizes hunter–gather material technology as separate from and underpinning social organization. For Testart, the material aspects of technological capability determine social possibilities (see also Harris, 1968), and he still catalogs the presence or absence of tools and techniques to categorize social formations. Specifically, the "problem" Testart sees with Australian aboriginal society is the juxtaposition of an extremely complex kinship system with the *lack* of a storage technology [theirs is a technological system he describes as "lacking," "blocked," "simple," "deficient," "inferior," and a "backwater" (Testart, 1988, pp. 9–10); see response by Ingold (1988, p. 15)]. The problem, however, is not the Aborigines (Peterson, 1988), but the conceptual models Testart employs. As Morton (1988, p. 20) counters, "One senses that if hunter-gatherer experts spent as much time classifying modes of mythical consciousness and religious artifacts as they do technological items, the reconstruction of the past might be considerably enhanced."

Martin Heidegger's (1977) philosophical essay entitled *The Question Concerning Technology* is an attempt to explicate and situate modern technological society in its own historical contexts (see discussion by Ferré, 1988, pp. 63–69; Mitcham, 1980, pp. 317–322). Of particular interest to technologists of prehistory are his ideas on the dialectic of maker and thing (Heidegger, 1977, p. 13). According to Heidegger, technology is really about the relationship, or *process,* existing between the intentions of makers and the things they make. Heidegger's interest is in the "process of becoming," not the existence of products. This position is also advocated by Mauss (1936), whose ideas inspired Leroi-Gourhan's concept of the *chaîne opératoire* (e.g., Leroi-Gourhan, 1964, 1965). Mauss viewed techniques as firmly embedded in cultural tradition and wanted to understand technical acts *as they unfolded* (Schlanger, 1990). Certainly, products and processes are inseparable, but more attention needs to be centered on the social process"ing" of products.

Simondon (1958) critiques industrial society's zeal to anthropomorphize technology and investigates how this ideology serves to mask the human reality of technology. The artificial separation of technologies from the social relations that make production possible is often seen as operating hand-in-hand with two powerful forces in modern society: the alienation of people from their labor (as recognized by Marx) and the objectification of nature as an entity to be controlled by technology (e.g., see Bunge, 1979; discussion by Merchant, 1989; Keller, 1985). Technical progress is inevitable, even necessary to human evolution, and because technology operates outside of social relations, people believe that they are "powerless" in the face of technological change. This ideology serves to make them blameless for the results of their own technological creations. This is somnambulism. For many students of technology, the ramifications of this ideology as part of archaeology's intellectual history are profound.

Heidegger provides an example that shows how Western science is itself inextricably implicated in how the definition of a subject such as nature — or technology — is shaped by this ideology of separation. He argues that appeal to mathematical exactitude in studying nature is not because nature is so exact. Rather, the conceptual tools employed to study it are exact, thus creating an object of study — nature — that can be described exactly (Heidegger, 1977, pp. 118–128).

Heidegger makes two important points here that, while applied to the study of nature, are equally relevant for the study of technology. First, how any subject matter is perceived significantly defines the contours of study. In this case, how technology is defined structures what is studied *as* technological (Lechtman, 1993). The implication for archaeologists is that because technology is defined primarily as acts of making and using material culture, less attention is given to the social dynamics of technological activities and to the social relations they entail. In fact, separating the study of artifacts from the study of artifice reinforces this ideology of somnambulism and projects it backward in time (Dobres, 1991a).

Heidegger's second point is that in most studies of technology, fundamental categories (e.g., nature, culture, technology) and principles (e.g., efficiency, maximization, control) are employed uncritically. The universality of these assumptions is problematic at best, but for the study of prehistoric technology a curious disjunction results. A common assumption still lingering in hunter-gatherer studies is the notion that "primitive" people exist in balance with nature and have not (yet) domesticated "it." Yet at the same time, the conceptual and analytic tools called upon to study and interpret these "simpler" technologies are the same ones employed to describe and understand "complex" industrial technologies such as our own (e.g., maximization and efficiency). In so doing, "simple" societies are argued to practice technologies that in various degrees control nature and master it though principles of efficiency and adaptive fitness. Ironically, Bender (1985), Ingold (1990, p. 6; 1991), Ridington (1982), and Lee (1979) have all questioned whether such a phenomenon applies to hunter-gatherers, who are less likely to objectify what we call the natural world (also Merchant, 1989).

The Language of Technological Discourse, or Speaking of Techniques . . .

Even the language of archaeological research on prehistoric technology supports the artificial separation of technology and society. The scientific terminology archaeologists adopted in their conversion to positivist methodologies sustains a distanced relationship between the researcher and his or her object of study — between knower and known (Keller, 1992, pp. 27–28; Lewis-Williams, 1990, p. 134; Spender, 1980; Westkott, 1979). This is due in part to the emphasis on studying phenomena that are quantifiable and measurable, particularly in archaeometry, with its close connection to materials sciences and engineering, optimal foraging theory (e.g., Bettinger, 1980, 1987; Winterhalder and Smith, 1981), and principles of time-budgeting management (Torrence, 1983). Technological discourse helps to objectify and limit technology to things and relations among things such that people often drop out of the picture altogether (Ingold, 1993; Spector, 1993; Tringham, 1991; see also Wylie, 1991a). Brumfiel (1992, pp. 552–553) recently underscored this point in her assessment of some general problems and limitations of ecosystems theory and the reliance on flowcharts for archaeology in general:

> The emphasis on systems rather than social actors also determines the units that constitute the boxes or components in [a] flowchart, which are activities rather than agents, functions rather than performers. Social actors are reduced to invisible, equivalent, abstract units of labor power. . . . The motivations, decisions, and actions that actually link variables are not diagrammed, so that a small "black box" intervenes between each pair of linked components.

Ridington (1988) argues convincingly that an "interpretive language" such as that derived from hermeneutics, which he distinguishes from the etic language for academic theory, may be more appropriate for discussing or describing technology because of the centrality of human agents in a hermeneutic perspective (see also Hodder, 1986; Moore, 1986).

At present, studies of technological change do not propose models that make social actors or cultural reason instrumental (van der Leeuw, 1991). To explain change primarily with reference to the inherent mechanical properties of raw materials, principles of efficiency or need, or external forces (e.g., climatic, environmental, or resource changes) still fails to account adequately for *how* people effected and incorporated such changes into their production repertoires (Brumfiel, 1992; Cross, 1990, p. 2). Of course, change in archaeological vocabulary itself will not lead to a greater or better understanding of prehistoric technology. However, an understanding of how language shapes research and interpretation helps to highlight the discrepancies operating between what archaeologists attempt to understand — dynamic social processes — and the concepts they employ.

Reintegrating Society and Technology: Toward a Redefinition of Technology

To reintegrate what have been heuristically separated dimensions of human life — technology and society — is the general goal of many contemporary scholars interested in the study of technology. There is no real distinction between the material aspects of human life and the social, economic, political, or symbolic ones (Herskovits, 1960). As Marx, Heidegger, and the authors discussed above have suggested, human agents are central to the day-to-day creation, perception, and production of their material world (Mitcham, 1980, p. 318; Simondon, 1958). Environmental and other physical factors are background structures within which all social endeavors are contextualized, but in the day-to-day enactment of social relations involved in solving technical problems, social agency plays a key role in defining, determining, and articulating particular technologies and their operational sequences.

One means of achieving this reintegration is to accept a more complex definition of technology, one that goes beyond hardware and operational sequences. Ridington (1982), Ingold (1990), and Lechtman (1993) separately arrive at similarly broad definitions of technology. Based on ethnographic research conducted among contemporary hunter-gatherer societies, Ridington and Ingold argue that various socially constructed forms of knowledge, such as mythology, kin relations, and shared knowledge of local landscapes embedded in origin myths, serve as adaptive strategies that relate to, but do not serve to "control," nature. The processes expressed in and through material technologies are themselves social relations, knowledge, skill, and ideology. Ridington (1983, p. 58) argues that northern Canadian hunting groups hold their technology "in their heads," relying on a complex adaptive strategy that is "fundamentally cognitive" rather than material (Ridington, 1983, p. 57). According to his interviews and extensive ethnographic research, "material objects were seen only as the final material connection in the deployment of a strategy held in the mind" (Ridington, 1983, p. 57). The stress here is on technological artifice (see also Dobres, 1991a). In fact, the original Greek meaning of *tekhnê* was knowledge and skill, not material end products (Heidegger, 1977; Ridington, 1983, p. 56). On this basis Ingold (1990, p. 7) argues that "technique is embedded in, and inseparable from, the experience of particular subjects in the shaping of particular things."

In much the same vein as ideas once advanced by Malinowski (1948), Ingold (1990, p. 7, 1993) develops the argument that technology is the expression of practical knowledge and is effected through knowledgeable practice. To integrate knowledge, technology, and technique is to highlight the inseparability of knowledge, practice, and experience in all productive endeavors (see also Ferré, 1988; Mitcham, 1980, pp. 317–318; Schiffer and Skibo, 1987; and more generally, Childe, 1956). Simondon (1958) recognizes the dual nature of technology: as concerning material things and techniques and as the *concrétisation* of ideas. He therefore distinguishes between "concrete" and "abstract" technology, while Schiffer [(1992, Chap. 7), building on Schiffer and Skibo (1987)] has differentiated "technoscience," "socioscience," and "ideoscience." Again, Lechtman (1993) suggests that many aspects of prehistoric technology are, in fact, nonmaterial. She especially notes that the social organization of productive labor and the knowledge that technology entails are part of technology and not distinct from "hardware."

In addition to issues of knowledge and skill, the heuristic reintegration of technology and society would be well served by more consideration of the political qualities of technologies. Politics and ethics have emerged as important themes in several case studies of technology in contemporary

Western society (e.g., Bijker *et al.*, 1987; MacKenzie and Wajcman, 1985; Winner, 1986). As Winner (1986, p. 28) states, "Some of the most interesting research on technology and politics at present focuses upon the attempt to demonstrate in a detailed, concrete fashion how seemingly innocuous design features in mass transit systems, water projects, industrial machinery, and other technologies actually mask social choices of profound significance."

For example, in a study of low overpasses and bridges on Long Island, Winner (1986) has demonstrated some of the political aspects of public works technology in contemporary society. These structures were built consciously to prevent tall buses from entering the area, effectively restricting access by poorer classes limited to public transportation. In another study, Schiffer (1991, 1992) analyzes the "cryptohistory" of the portable radio, highlighting the intersection of nationalism, politics, and advertising in the changing technology of the pocket radio over the past 70 years. Finally in a prehistoric context, Lechtman (1993, p. 247) has recently extended her analysis of pre-Hispanic Andean metallurgy, arguing that "the relations of power inform not only the uses of technology but what is conceived of as technologically possible and appropriate." She further demonstrates how normative "technologies were used to cement and eventually to reinforce the changing relationships of power" in the Inka state (Lechtman, 1993, p. 250).

Technology is political in a variety of ways. For example, Heidegger (1977) highlights the consciously practiced politics of technology, while Giddens (1979, pp. 59, 78, 1984, pp. 9–14) considers political effects to derive from unintended consequences of social action, and Winner (1986) examines how the accumulated effects of technological endeavors become political. Foucault's (1977) powerful study of French prison architecture in the 18th and 19th century, the panopticon, empirically demonstrates that conscious politics, unintended consequences, and the accumulated effects of technological action operated simultaneously and all contributed to the form and function(s) of that particular technology.

> The things we call "technologies" are ways of building order in our world. Many technical devices and systems important in everyday life contain possibilities for many different ways of ordering human activity. Consciously or unconsciously, deliberately or inadvertently, societies choose structures for technologies that influence how people are going to work, communicate, travel, consume, and so forth over a very long time. In the processes by which structuring decisions are made, different people are situated differently and possess unequal degrees of power as well as unequal levels of awareness. (Winner, 1986, pp. 28–29)

Striking examples provided by Winner (1986), Schiffer (1991), and others (e.g., Bijker *et al.*, 1987; Cutcliffe and Post, 1989; MacKenzie and Wajcman, 1985) derive from modern contexts. It is ethnocentric to believe, and difficult to sustain the notion, that in other social systems such as those investigated by many archaeologists, technologies are not also used toward political ends. As a cross-cultural phenomenon, political interests are manifested in, and structured by, material production and exist in all human societies, "simple" or "complex" (see a similar argument developed by Cross, 1990; Schiffer, 1991, 1992; Shanks and Tilley, 1987).

For example, archaeologists can consider the potential political dimensions of lithic blade production or "art" in the Late Ice Age. Spatial analysis of flaking debris manufactured at the late Magdalenian site of Etiolles in the Paris Basin has been used to identify "training areas." These have been employed to infer a system of apprenticeship (Pigeot, 1987; discussed in detail below). The control of knowledge, like the control of raw material resources, can be an arena for the negotiation of social power (Dobres, 1988). For example, access to the material equipment (e.g., scaffolds) and technical knowledge (e.g., pigment "recipes") necessary for the production of Upper Paleolithic wall imagery at Lascaux (Leroi-Gourhan and Allain, 1979) or Niaux (Buisson *et al.*, 1989; Clottes *et al.*, 1990; Pepe *et al.*, 1991) was most likely *not* equally distributed among group members. Individuals may have differentially participated in these activities, some excluded either because of the particular knowledge such acts necessitated or because of the material nature of the production system. Or perhaps the help of everyone —young and old, short and tall, male and female —was required. The social and political aspects of material culture production need not be mere fanciful speculations relegated to concluding footnotes. They merit attention in conjunction with analyses of the material demands of such pursuits. In this instance, practice theory may provide a valuable starting point for considering these issues.

Research on the politics of prehistoric technology is only now commencing in earnest, as we review below. Nevertheless, to ignore or discount the connections operating among social action, intentions, labor organization, power structures, and material production not only limits multiscalar understandings, but supports the somnambulism long prevalent in Western approaches to the study of technology (Ingold, 1990, 1991, 1993; Lechtman, 1993).

Hawkes' Ladder of Inference (1954) notwithstanding, what is at issue is not solely an epistemological concern with "recovering mind" (after Leone, 1982). Regardless of whether archaeologists can empirically "prove" claims about prehistoric intentions or the politics of past technologies, the reified separation of what is in essence an inseparable and dialectic relationship between technology and society precludes an adequate understanding of the basic forms and processes involved. The resulting representation is a misleading and partial understanding of something much more complex (Christian and Gardner, 1977, pp. 100–101; Latour, 1986; Ridington, 1988, p. 107). A somnambulistic view of technology succumbs to the "fallacy of misplaced concreteness" (Ferré, 1988); the tendency is to confuse a significant part of something (e.g., techniques, tools, functions) with the whole from which that part is abstracted (e.g., society, social relations of production, practical knowledge, and so forth).

SOME CASE STUDIES: EMPIRICAL GROUNDING

The applicability of theoretical concerns discussed above can be demonstrated in four recently published case studies taken from prehistoric, historic, and ethnographic contexts. They concern lithic and butchering technologies, pottery production, architecture, and innovation more generally. In different ways each begins to explore historically specific community-level social processes involved in a particular technological system. These studies reveal interesting sociopolitical issues that we use as an entry point for proposing additional questions concerned more specifically with the social agency of technological production.

Stone Tools and Butchering Practices: The Magdalenian in the Paris Basin

Pigeot (1987) demonstrates how detailed technological studies of lithic debitage can address questions regarding the social organization of the occupants at an open-air habitation site in the Paris Basin ca. 12,000 B.P. ± 220 years (see also Audouze, 1987, p. 85; Pigeot, 1991). With the unusually explicit goal of reconstructing the social habitat of lithic production activities within a single discrete zone (U5) at Etiolles, Pigeot's analysis begins with a now-standard technical and refitting study of some 20,000 pieces of lithic debitage and culminates with an interpretation of the social organization of a series of knapping events (subsequent discussions by Karlin and Pigeot, 1989; Olive and Pigeot, 1992; Pigeot, 1990; Pigeot *et al.*, 1991). The researchers under Pigeot's direction demonstrate that the spatial distribution of a discrete series of manufacture events reflects the "sociology" and organization of living arrangements at Etiolles. The spatial and technical treatment of blade production events is analyzed to model the "daily life" of these late Ice Age nomadic hunter–gatherers.

Pigeot's work is squarely situated within the long-standing French tradition of research guided by the concept of the *chaîne opératoire* (Leroi-Gourhan, 1964, 1965; Lemonnier, 1992b; Pelegrin, 1990; Schlanger, 1990). But beyond this, Pigeot argues that the culturally specific choices evidenced in the knapping sequences were embedded within larger and ongoing dynamic processes of social reproduction. Her research is thus particularly amenable to explicating the social dynamics structuring those production activities.

Among the most intriguing of Pigeot's conclusions is that discrete spatial zones indicate different qualities of knapping competence (1990, p. 131; Olive and Pigeot, 1992). The "social stratification of technical competence" (Pigeot, 1987, p. 114) evident in core reduction and edge retouch techniques, combined with the spatially discrete distribution of these activities, leads Pigeot to identify zones of "expert" and "apprentice" knappers. This attempt to understand the relationship between the individual and the social community follows in the footsteps of Durkheim and Mauss, for Pigeot (1987, p. 113) argues that "derrière le geste, unique et anecdotique en soi, nous avons cherché le geste et nous avons constaté que le sens de ces motivations ne s'était pas toujours perdu."[5]

Ultimately, Pigeot's (1990, p. 131) "paléthnologie" study suggests that the apprentice activities identified were practiced by young members of the group, as she believes that technical competence was a function of age. She suggests that the advanced degree of skill required to produce the unusually long blades made at the site borders on craft specialization among some (older or more senior) members of the group. More recent work at this site (Karlin *et al.,* 1992; Olive and Pigeot, 1992; Pigeot *et al.,* 1991) compares this particular activity zone (U5) with another contemporary area (P15) and to one later in time (Q31). Pigeot and her associates make some intriguing suggestions regarding microscale changes in lithic production strategies and social organization during these later epochs of the Magdalenian, arguing for concomitant changes in the quality of raw materials employed, in technical skill, and possibly in the social organization of flint knapping. Pigeot acknowledges that one can certainly debate the specific social identities she proposes to account for the variability in techniques and spatial distribution of lithic production of Etiolles (e.g., see discussion by Olive and Pigeot, 1992, pp. 183–185). What cannot be disputed is the fact that the technology implies a social structure that can be researched legitimately.

[5]Translation: Behind each individual gesture we seek the motivation for that act, and we believe that such motivations are not always lost (in prehistory).

Concerning the Chaîne Opératoire *and Gestural Research*

The in-depth analysis of the *chaîne opératoire,* still a primary focus of French paleolithic research, is being adopted by increasing numbers of English-speaking researchers (e.g., Dobres, 1993; Knecht, 1991a, b; Knecht and White, 1992; van der Leeuw *et al.,* 1991; White, 1989a, 1993). Over the past few decades, analysis of a prehistoric *chaîne opératoire,* or chain of technical operations, has narrowed to an intense focus on the material stages of raw material modification (from initial procurement to subsequent repair). Distinctive of this methodology is the intentional separation of description from "interpretation" (Cleuziou *et al.,* 1991; Pelegrin, 1990, p. 116; Perlès, 1992).

Some workers, however, are beginning to broaden the uses to which the *chaîne opératoire* methodology is put. For example, Pigeot (1990, 1987) contextualized the gestural facts she "excavated" within the larger social dynamics of production activities. Others such as Pelegrin (1990) and Roux (1990) are moving in the direction of the psychological (i.e., "intentional") dimensions of gestural action. Roux (1990, p. 152) characterizes this emerging and broader concept of the *chaîne opératoire* by explaining that any technological act is the sum of technical facts, physical facts, and cognitive and perceptual motor facts (compare this to Lemonnier's position discussed earlier). Research such as that conducted by Pelegrin (1990), Roux (1990, 1991), Ploux (1991), and Perlès (1992) demonstrates that linkages can be identified among technical competence, technological sequences, and prehistoric cognitive processes [see also Pigeot (1991) on the general evolution of these phenomena].

Nonetheless, a key feature missing from this cognitive approach is the central theme of this essay: an interest in the dynamic strategies of social relations and the "cultural reason" of production activities, as well as in the social and political conditions under which objects are made. Some researchers are trying to get back to the broader social concerns once elaborated by Marcel Mauss (e.g., Perlès, 1992; Pigeot, 1987, *in passim*; Roux, 1992; White, 1989b, 1992), but without systematic appeal to an appropriate social theory of agency at the same analytical scale as the production activities under consideration, these attempts remain limited. We suggest that a social theory of human agency is necessary to contextualize the *chaîne opératoire* and make it anthropologically relevant.

> . . . However detailed our descriptions may be, they contribute little to our understanding of how societies were reproduced under particular material conditions so long as they are studied in isolation. By this I mean isolation both from their material and historical contexts, and from broader theoretical propositions concerning the relationship between human action, social practice, and social structure. (Edmonds, 1990, p. 58)

Practice Theory and the Etiolles Project

Pigeot attempts to determine whether or not (craft) specialization can be identified in the quality and skill of the *chaîne opératoire* identified from the Etiolles lithic assemblage. The goal of this research project is to demonstrate its existence archaeologically (e.g., Roux, 1991). But the sociopolitical conditions under which specialization might occur either are not addressed or are loosely intuited. Why should lithic production have taken the specific material form it did at this moment in prehistory? How did prehistoric craft/technical specialization relate to other concomitant activities of material production and use? Are the characteristics of differential skill in blade production used to infer the apprentice model found in *other* classes of data from the site? Must technical skill ("une hiérarchie des saviors") equate with "specialization," and if so, is there no room to consider the social power achieved by those with the knowledge, the *savior-faire,* apparently restricted to specialists? How was such exclusive knowledge controlled and maintained? How were the inevitable tensions inherent in the differential circulation and use of lithic resources at the site resolved? Or more importantly still, how did such specialized productive activities relate to social reproduction more generally?

Anthropologically driven questions such as these, disentangled from the artifacts under consideration, make a different use of detailed analyses of raw material modification in prehistory. As we discussed earlier, appropriate social theory must be applied to such questions, and the principles of practice theory are directly relevant to the goals of the Etiolles research program. In addition to aspects of practice theory, there is a substantial body of other social theory concerned with apprenticeship (e.g., Barcet *et al.,* 1985) that could have important implications for research and interpretation.[6]

In the case of the apprenticeship model articulated for the Magdalenian sites in the Paris Basin, "arguments of this nature carry with them a series of profound sociological implications which have to be supported" (Edmonds, 1990, p. 66). Such supporting evidence should be contextual and external to the class-specific material under analysis. For example, a recent study of the spatial distribution of reindeer remains around spatially related late Magdalenian hearths at the nearby open-air sites of Pincevent and Verberie provides corroborative information useful to examining and extending the social implications of Pigeot's lithic study (Enloe, 1992, 1993; Enloe and David, 1989). Situated well within the

[6]We extend our thanks to Thelma Lowe for having brought this body of literature to our attention.

processual tradition, Enloe's interest is to understand the social organization of food-sharing practices during this time period. He posits that the spatial distribution of food remains reflects something of the social relationships of the people eating at three hearths (an hypothesis similar to Pigeot's). He inferred these relationships by conjoining bone fragments found at the hearths in much the same way that Pigeot mapped the differential usage and movement of flint cores at Etiolles. Although these data have yet to be integrated, between the two studies one can glimpse the social dimensions of decision-making strategies in two of the most basic of prehistoric activities leaving material traces: stone tool and food-processing technologies [for an initial assessment of the Magdelenian in the Paris Basin based on these investigations, see Audouze (1987) and Audouze *et al.* (1989)].

These two studies attest to a reemerging interest in community-level frameworks for understanding technological variability (see, Perlès, 1992) with implications that go beyond the strictly material. Gifford-Gonzalez (1993a) makes a similar point in arguing that current bone studies overemphasize the immediate relationship of the act of hunting to the associated faunal assemblage. This bias overlooks the fact that social circumstances other than those concerning efficiency, maximization and optimal economic behaviors can and do affect hunting decisions. The argument that decision making during hunting and food-processing activities is shaped first by cultural considerations parallels our suggestion that to understand prehistoric technology in general requires looking beyond the immediate goals and end products of those activities and toward the social contexts that inevitably and significantly impacted their structure and outcome. In Enloe's work, as well as in the arguments set forth by Gifford-Gonzalez, the basic research methods have not changed substantially, although they have been refined to fit the specific analytical requirements of each project. What have changed significantly are the interpretive frameworks brought to bear on such research and, especially, the desire to situate and understand these activities within the larger meaningful social practices of which they were a part.

It is much to their credit that Pigeot and Enloe do not immediately appeal to adaptive or efficiency mechanisms to account for their data (although it is clear that the Etiolles researchers still feel compelled to identify direct "material correlates" of social processes such as craft specialization), but a robust social theory of agency could provide them with a stronger and more plausible inferential base for considering the social dimensions of stone toolworking and butchering practices. What we believe is required at this point to understand these data is the necessary infusion of social theory at the same level as the research question — the microscale (Cross, 1990; Tringham, 1994, p. 29).

Technological Change in Harappan Pottery Production and Prehistoric Gender Relations

One fundamental contribution a feminist archaeology has already made is unmasking the culturally specific gender biases inherent in not only the practice of archeology (e.g., Conkey and Spector, 1984; Gero, 1983, 1991a, b), but also the analytical categories and interpretations presented for various points of time in the past (e.g., Dobres, 1991b; Gifford-Gonzalez, 1993b; Moser, 1993; discussion by Wylie, 1991b, 1994). The engendered nature of human activities is not in doubt (Kohl, 1993, pp. 14–15), yet it is only now becoming an explicit analytical and interpretive interest in archaeological research [(eg., Mazel, 1989; Solomon, 1992; essays in Walde and Willows, 1991); but see Mason (1894) for a turn-of-the-century study still worth reading; discussion by Dobres, 1994b; Gero and Conkey, 1991; Hanen and Kelley, 1992)]. McGaw (1989) provides an extended discussion of general problems in technological research where assumptions about gender are employed uncritically. In archaeology, Gero (1991a) suggests that the long-standing interest in prehistoric lithic sequences of manufacture may be explained, in part, by their inferred (but unstated as such) association with men's activities in the past.

As a prelude to her own reanalysis of Harappan ceramic technological systems, Wright (1991) has recently brought to light some of the gender biases operating in research on ancient pottery production. Following a review of the relevant ethnographic and theoretical literature on the innovation and development of ceramic technology, Wright suggests that the participation of women in these production activities has been both underreported and underestimated. She attributes this not only to a lack of explicit interest in the technological stages involved in prehistoric pottery production (especially for the ancient Indus civilization where her research is centered), but also to implicit assumptions made about women's roles in the invention and specialization of ceramic technologies.

Wright (1991, p. 199) suggests that

> the complex reality of how gender interacts with and supports production sequences is glossed [in modern ethnographic literature] by a simple gender ideology that holds that pottery production is a male activity whereas, in fact, it is a male and female activity . . . pottery production is a craft that, more often than not, is dependent upon a cooperative labor force, in that in many societies — especially those that are small in scale and where production is for the market or non-household consumption — it is participated in by a group and not a lone producer.

That this cooperative process has gone underreported in the ethnographic literature is not surprising, given the fact that ethnographies rarely pay explicit attention to the material conditions of production, preferring instead to focus on the values and leaders those activities support.

Building upon a corpus of earlier research (e.g., 1984, 1986, 1989), Wright's reanalysis (1991) attempts to delineate the complex relationship among changes in early ceramic technologies and (1) related changes in food-processing techniques (and diet more generally), (2) innovations in storage technologies, and (3) concomitant changes in social status, especially with the advent of specialized production. She starts with the assumption that ceramic technology and innovation are inseparable from their cultural contexts and from the social relationships they entailed and then focuses analytic attention on pre-Harappan and Harappan artifacts from Mehrgarh, Mohenjo-daro, and Harappa (circa. 6000–1800 B.C.). Wright's second premise is that gender was a major structuring factor in the technologies themselves and deserves explication.

Wright suggests that initial attempts to fire clay at the pre-Harappan site of Mehrgarh may have been pursued by women for the following reasons. First, ceramic innovation coincided with developments in food production technologies (e.g., boiling, new storage capabilities for plant resources, and more durable cooking containers). Second, the earliest evidence of pottery production was spatially associated with dwellings and baking structures. Based on ethnographic analogy, Wright suggests that these were likely loci of women's activities.

Ceramic production at pre-Harappan Mehrgarh continuously changed throughout the period but was geared initially to production both for domestic needs and for exchange markets. At Mature Harappan sites (Harappa and Mohenjo-daro), similar "small-scale workshop units" continued to produce ceramics within domestic dwellings, but ceramics were now also produced in two other contexts: (1) in separate workshops or craft areas organized by a centralized authority (at Mohenjo-daro) and (2) in specialized craft production areas administered by kinship groups [at Harappa (after Kenoyer, 1989)]. Given the biases in the ethnographic literature, which fail to discuss adequately the engendered nature of ceramic production as a collaborative effort, Wright concludes (1991, p. 213) that "we have no reason to exclude either women or men from these units."

Evolutionary scenarios concerning the origins of the state often assume that specialized craft production moved into the hands of men and was controlled by elites. Some of the data Wright generates on ceramic technologies do not fit these expectations very well, in particular the early but sustained production of ceramics in small-scale domestic contexts even after more specialized production took hold. Wright's interest in the gendered aspects of early ceramic production has led her to ask microscalar questions about the spatial and dynamic social contexts of Indo-Iranian pottery manufacture, activities she sees as inseparably connected with other social activities such as food processing. This change of research orientation has brought to light empirical incongruities that challenge evolutionary explanatory models. In Wright's (for details see 1984, 1989) case, her new interest in microscale domestic pottery production is an extension of her more traditional interests in exchange and the development of complex societies in the ancient Middle East.

Her identification of three different kinds of production contexts raises some important questions, however. Just how clearly delineated were these different production contexts, these social "spheres"? Were the ceramics produced in these different contexts valued differentially? Were their makers valued differentially, too? Should we assume that production for exchange was "managed" by bureaucrats or elites, while domestic-level production was for immediate consumption only? Is there any empirical evidence to support this inference? If elites controlled ceramic production for exchange, what sorts of potentially conflicting goals and needs might have existed between individuals involved in small-scale household production and those producing for exchange? For example, how were raw material resources allocated, and is there artifactual evidence to help answer these questions? How were gender, kinship, and "class" identities articulated and played out in these various production contexts? How might these tensions have been resolved through technical choices? Could the collaborative nature of some pottery technologies have helped to mitigate the inevitable tensions production typically entails?

Consideration of some of these questions might help to refine further some of Wright's intriguing suggestions and help to generate empirical expectations that could provide additional support for her initial propositions. An exploration of some of the principles of practice theory might provide guidelines for a more multiscalar reconsideration of the nature of craft specialization, the development of complex societies, and the changing face of social relations both in historically specific settings and cross culturally.

On Technology, Architecture, and Mind-Sets

The work by Johnson (1990, 1993) is an account of innovations in house form and house construction techniques related to upheavals in socioeconomic life and religious belief systems in England, A.D. 1400–1700. Johnson's premise is that value systems are elaborated and articulated in the ways technological rules are materialized. His study of changing house form and technology from medieval to Georgian times provides an example of the complex ways that social and symbolic categories underlie and support the implementation of specific technologies and their end products. "The way a house is put together — its framing, technique of decoration, and details — is as expressive of the system of ideas to which it relates as the final form of the house itself" (Johnson, 1993, p. 109). This principle is similar to arguments articulated by Moore (1986).

Johnson's research on English houses builds on the original works of Glassie (1975) and Deetz (1977) but looks especially at the functions and meanings of changes in technological attributes of house frame construction. The archaeological patterns and changes he identifies over time suggest a general move from open and "corporate" social relations and associated worldviews to a more closed and segmented set of social relations. These broad sociological implications are associated with concomitant changes in several architectural features: changes in the location and use of hallways over time, innovations in bracing techniques, the degree to which framing structures were exposed or plastered over (to mask the actual segmentation taking place in upper floor construction), the nature of jetties used to support extended roofs, the reduction of "extraneous" lumber used as visible decoration, and even the shift from central and open hearths to stacked chimneys.

Johnson suggests that these are not simply stylistic changes correlated to tradition. Rather, they are the combined result of changes in social organization (the incipient development of paid laborers and changes in master/servant relationships) and accompanying changes in worldview (from "corporate" to "segmented"). More importantly still, they are actively played out in the conscious choices made on the part of certain individuals in designing their houses (Johnson 1989), as well as in unintended consequences resulting from their implementation. Johnson makes the case that features of house design structure social relations — both metaphorically and materially — by virtue of their materiality and by virtue of the way they reinforce newly emerging social relations contained in them. "Put another way, the very frame, the structure and body of the house, is itself the surface, the display, part of the system of social meaning" (1993, p. 119). House design changed during this period, from one revealing the "process" of construction through the outward display of technical features — to the house as a finished product, where the technical features were hidden.

Johnson takes his study beyond a descriptive analysis of changes that occurred in house form and construction techniques from medieval to Georgian times. Because technological systems are inseparable from social organization and meaning, he can successfully link formal and technical change to change in social organization and underlying symbol systems. In addition, this is one of the few archaeological case studies that explicitly applies principles derived from practice theory. People actively participated in the processes he outlines. Furthermore, because he recognizes the heterogeneous composition of the community (husbands, wives, masters, servants, young, old), he is able to address the multiple meanings of social interests ascribed onto the places people were building and inhabiting. The complex processes of social negotiation are understood to have been actively involved in attempts to maintain "tradition" during a period of socioeconomic and political upheaval.

From medieval to Georgian times, Johnson identifies three shifts in house form and related technology: (1) from openness to closure of architectural forms, (2) from the house structured to unify and centralize to the house segregating its inhabitants, and (3) from a congruence of spatial form, technical system, and symbolic meanings to their divergence. This last point is important: by Georgian times, house form and construction techniques diverge from the social relations contained within them. Technology becomes separated from the larger social system of which it is a part, to become reified and take on a "life" of its own.

In terms of some of the other interests discussed in this paper, Johnson's case study raises interesting questions about microscale social aspects of making and living in houses during this period of change. Were different people involved in determining the form of the house and the visibility of techniques used to construct it? This is a question about more than the relationship of owner to builder. It concerns the differential participation of social agents in constructing their material culture. How much did wives contribute to these technological innovations, perhaps, by offering suggestions or making demands at the time of house planning and construction? As different household occupations became room specific in later times, did the values of those tasks change as well? Did this segmentation change the status of the master's wife and/or children within the household? Was the power of wife augmented, reduced, or relegated to only some rooms? Is there evidence to suggest a rise in the conspicuous differentiation of one household from another, by virtue of the outward display of architectural features, whether ostentatious *or* masked? How were any of these social issues shaped by technology? Did the unintended consequences of these changes lead to particular social or functional changes within the house itself?

While no single study can hope to address "all" these questions, Johnson's research has set the foundations for a multiscalar study that promises to reveal far more than historic documents could possibly tell about the nature, causes, and results of major changes in social and economic life that lead to the development of western industrialism.

The Archaeological Study of Innovation: Three Brief Examples

As van der Leeuw and Torrence (1989a) point out, the topic of innovation has for the most part dropped out of archaeological interest despite the once-central role that it played in archaeological interpretation (e.g., Childe, 1925). As is the case with technology in general, innovation is implicitly assumed to happen in specific ways, to respond to certain forces, and to bring about certain developments. For the most part, interest in innovation in prehistory has centered on the identification and description of the innovations themselves. A large part of this problem is conceptual. Too often, innovation is treated as an isolated event — the invention or discovery of a new technique or material — rather than a process shaped by social and material forces. Archaeologists (e.g., Schiffer and Skibo, 1987) as well as specialists from other fields are beginning to reexamine these assumptions. In particular, the long-standing model of a solitary event of invention followed by its relatively rapid diffusion into other contexts has been critiqued. As a recent collection of essays shows (van der Leeuw and Torrence, 1989b), the process of innovation is a complex one, and generalizations are hard to come by except at almost mundane levels.

Anthropologists and geographers have recognized different stages in the process of innovation (Barnett, 1953; Hagerstrand, 1952; Linton, 1936; Rogers, 1963), making the important distinction between the invention or discovery of a new technique and its acceptance or rejection by the community at large. Subsequently, several scholars have attempted to articulate further the stages comprising the innovation process (Chapman, 1984; Renfew, 1978; Spratt, 1982, 1989). The combined importance of these studies has numerous implications for archaeologists. For instance, archaeologists need to be aware that evidence indicating that a technique was practiced does not necessarily signal its larger acceptance by that society. Techniques or technologies that did not enjoy sustained popularity may be relatively common in the archeological record. As Stig-Sørenson (1989) has demonstrated for late prehistoric Scandinavia, the acceptance of an invention such as iron-working may be delayed for centuries after its introduction. Because archaeologists tend to focus on normative behaviors, the occasional odd item in an assemblage, that might represent an experimental technique not adopted by the community at large, is often dismissed as "noise" (e.g., Gallay, 1992, p. 119). Another finding that has perhaps more far-reaching implications is emerging. Recent studies of technological innovation in historical, ethnographic, and ethnoarchaeological contexts demonstrate that the process of innovation often relies on conscious and strategic decision making. Future innovation studies should provide an arena in which approaches emphasizing social agency can be applied and tested.

Anthropologists studying technological change have begun to demonstrate that although innovation needs to be understood as a community-scale social process, the role of the individual, often peripheralized in actual research, is equally important. For example, in an ethnographic study of agricultural innovation in the middle to late 20th-century French village of Pellaport, Layton (1973, 1989) shows that individuals who introduce new methods (e.g., diesel tractors or seed drills) may be respected opinion leaders or the object of scorn and ridicule by members of the community. Or they may be both, depending on who is judging their activities. However, if established leaders adopt a new technique, it has a much stronger chance of survival. In Layton's study, farmers are well aware of the techniques being practiced on their neighbors' plot, but they evaluate these techniques on the basis of different sources of information, as well as personal expectations and individual assessments. This study elegantly demonstrates that innovation and technological change are not "waves" gently or violently washing over communities. Different members of society have different ideas about accepting change, to whom they will listen, and in what circumstances. Heterogeneity at the community level may very well be visible archaeologically, and a significant amount of material and technological variability could well be relevant at the scale of the community or the individual (Perlès 1992). Given this, processes of innovation are certainly politically and socially charged as well.

In another study, Costin *et al.* (1989) use archaeological data to demonstrate some of the ways that technological innovation is shaped by social and political factors. This side of the coin — how society shapes technology — is often downplayed in favor of accounts that consider how technological innovation changed or was accommodated by society. Costin and her colleagues document how ceramic, metallurgical, lithic, and textile technologies changed after the Inka empire annexed Wanka villages in the Upper Mantaro Valley of Peru (ca. A.D. 1350–1533). They identify two kinds of technological change: (1) in an effort to gain (further) control over production, elites promoted "top-down" change, which is recognized archaeologically by centralization and the promotion of state or elite symbols; (2) "bottom-up" change, on the other hand, occurred when commoners adopted and/or invented more labor-efficient technological practices. For example, the centralization of storage in *qollqa* complexes was a strong mechanism of state control over local production and, as such, is interpreted as an example of top-down change. As a second example of top-down technological change, local elites spatially controlled the production of local storage jars. Bottom-up changes, those initiated by commoners, included new strategies to exploit raw material sources found closer to their settlements.

There are two valuable aspects of this article that deserve mention. First, rather than focus on a single class of materials, this study was specifically designed to examine how several technologies (e.g., ceramics, metal, stone tools, and textiles) changed in concert. Second, these technological findings depend upon detailed laboratory research on materials from well-excavated and well-dated sites. The diversity of technological changes identified allow Costin and colleagues to show that communities coming under Inka domination responded with a variety of material and social strategies. When combined with studies of other aspects of Wanka society (e.g., Hastorf, 1991), archaeology can contribute much to understanding processes of technological change, while at the same time providing room for consideration of social and political factors at multiple analytic scales.

SOME CONCLUDING THOUGHTS

Technological choices and the organization of production activities are materially grounded but intrinsically social phenomena. For the past as well as the present, the relation between technology and society can be described as a "seamless web" (Hughes, 1979; Latour, 1986) that dialectically weaves together social relations, politics, economics, belief systems, ideology, artifact physics, skill, and knowledge. Technologies extend beyond hardware and need to be recognized as social activities made meaningful and enacted through processes of social agency.

How, then, do archaeologists proceed with such anthropological concerns? The four themes with which we introduced this paper provide an initial framework. Clearly, different research questions require the selection of an appropriate *scale* for inquiry, and we have emphasized microscale social processes involving the day-to-day production of material culture. As complex social arenas, the dynamic *contexts* of material production take inquiry beyond the study of technical attributes, to consider political and ideological aspects of technological knowhow and skill. Research on microscale contexts for technological activities also blurs the heuristic separation of society into "spheres." This blurring creates the necessary room for considering the issues of social agency that all technological activities engender. The very *materiality* of technology allows archaeologists to make plausible inferences about the choices made in the course of technological performance and to examine how people made artifacts, social relations, and meanings, simultaneously. But more than anything else, a *social theory* of technology privileging agency enables a significantly more anthropological understanding of this universal human activity. A methodological statement more programmatic than this would be both premature and unnecessarily restrictive given the context-specific processes that we have emphasized, as well as the lack of sustained attention to these issues until very recently.

A broad range of anthropological questions is implied by defining technology as we have here, and such an expanded view of technology necessarily incorporates a consideration of social agency, power, worldviews, and meaning. We look forward to future research, perhaps guided by some of the suggestions made here, that will explore the social dynamics of technology and technological change.

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