Chapter 3
Cultural Transmission and Innovation in Archaeology

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Introduction

Homo sapiens are reliant on material culture as a vital component of their adaptive toolbox more than any other hominid extant or extinct. High-fidelity cultural transmission is said to be the key to the long-term maintenance of these material culture traditions, yet we are left to infer and extrapolate the various modes of learning and teaching of ancient hominins from quantitative, cognitive, ethnographic, or archaeological models (e.g., Fogarty et al. 2011; Gärdenfors and Högberg 2015). Some workers have emphasized that effective social learning and the habitual use of much material culture may be a rather recent element in human evolution (Shea 2017; Corbey et al. 2016). Be that as it may, modes of high-fidelity transmission certainly reduce the costs of learning the many routines and the many forms of knowledge critical for any member of a given human society to function saliently. In the absence of such transmission, the persistence of the kinds of material culture traditions identified in the archaeological record would almost certainly be impossible. Yet, at the level of microevolution, a major paradox remains: if individuals growing up within such traditions merely learn their material culture routines from close relatives of the previous generations, how do genuine innovations emerge in the first place? In order to move toward potential solutions and to stimulate further research, this chapter seeks to review both aspects of cultural transmission and of innovation, the dual forces that (1) introduce variability into the cultural pool of ideas and actions on which selection can act and that (2) channel the bulk of learning along fairly constrained pathways circumscribed by tradition and chosen due to their low cost and high efficacy.

Different modes of social learning have been proposed as generators of innovations. One of these modes, intentional teaching, has received much attention as an evolved feature of uniquely human social learning that strengthens fidelity in cultural transmission while keeping costs low when learning

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complex, cognitively opaque skills such as the making of multicomponent tools, weaving, or similarly intricate techno-behaviors (d'Errico and Banks 2015; Gärdenfors and Högberg 2015, 2017; Haidle 2012; Kline 2015; Tehrani and Riede 2008). Unsurprisingly, cross-cultural research underlines that teaching is particularly emphasized in economic and cultural domains associated with high values (Kline et al. 2013). In addition, studies in cultural psychology indicate that different modes of teaching may lead to correspondingly different degrees of innovation among older children and young adults. Interestingly, some studies have also demonstrated that those differing degrees of creative flexibility can be transferred to other domains of activity beyond that originally taught (Greenfield 2004). Hence, intentional teaching can be thought of as a scaffolding that at once facilitates fast and efficient learning of norms and routines while also inculcating the potential for creative problem-solving within—and to perhaps a more limited degree across—the material culture domains in question (Lombard 2015). Similar scaffolding may be present in other primates (Musgrave et al. 2016) but is seen to lead to cumulative cultural evolution in humans when coupled flexibly with alternative social learning strategies (Dean et al. 2014). As important as learning modes and trajectories are, the acquisition of a certain skill through learning is one thing, innovating another. At present, no consensus on the role, on the mechanism, or on the drivers of innovation exists. In this chapter, we attempt to provide a view of innovation in relation to cultural transmission in the hope of sketching out productive avenues for future research.

First Things First: What Is "Culture"?

There are myriad definitions of culture, but here we offer a focused brief. Richerson and Boyd (1984), p. 430 define culture as "information acquired by imitating or learning from other individuals and able to affect an individual's phenotype, usually behavior." Further, this information must be shared within some scale of a population. As Cavalli-Sforza and Feldman (1981, p. 10) put it: "The feature common to all . . . 'cultural entities' is that they are capable of being transmitted culturally from one individual to another." Thus, culture is specifically something transmitted from individual to individual. It is "a system for the inheritance of acquired variation" that is directly altered by individual interactions at the *microscale*, that is to say, the observable on-the-ground interactions between individuals, within a group (e.g., Pagel and Mace 2004).

Yet, in archaeology, we rarely get a glimpse of individual (i.e., microscale) interactions without making some significant inferences as to what information transactions were probably taking place in the past. These inferences are based on the often incomplete material culture proxies that we have at hand. Certainly, we may infer from archaeological features or materials the activities that likely occurred at a given site, but we can rarely be absolutely certain of the specific personal interactions that may have accompanied any given instance in the past.

The fact is we will never be able to eavesdrop into the casual conversations or 'artist's shoptalk' that perhaps took place during the making of the first cave paintings at Lascaux or Chauvet (e.g., Clottes and Lewis-Williams 1998; Lewis-Williams 2004; Mithen 1998). We will never know the technical instructions given by one toolmaker to another as they prepped stone tools for butchering horses 400,000 years ago at Schöningen (Haidle 2009; Thieme 1997; Voormolen 2008). But maximal reconstruction is important, because aggregate cultural traditions that were consistently maintained over multigenerational time spans gave rise to cultural change over the long term at the macroscale, between populations. Indeed, under rare conditions of preservation and using detailed analytical techniques, instruction and learning can be made plain in the archaeological material even deep into the past (e.g., Fischer 1990; Högberg 1999; Grimm 2000; Milne 2005; see also Chap. 2).

As it relates to the archaeological record, Bettinger (2009, p. 275) notes of microscale evolutionary change that it "is relatively fast, but much of it is random, and therefore offsetting, over the long periods of macroevolution, at which scale change proceeds more slowly...small-scale events and processes are critical in generating the needed variation, but their individual outcomes are unpredictable and essentially random, depending so much on myriad historically contingent events". At the microscale, culture change is prone to appear random and unpredictable (because it is largely dependent on chance probabilities and the proclivities of individuals) simply because we cannot observe interpersonal interactions and their innumerable consequences directly. Yet, the changes that actually occur are essentially sources of variation, itself a product of historical contingency. In this sense what we see as the evolution of culture, regardless of scale, is a combination of chance, scaffolding, individual proclivities and vagaries, and historical circumstances.

Viewing cultures as complex assemblages of traits that are more or less coherently associated with one another can be modelled on population genetics, where any given population consists of individuals with genetic sequences that show much similarity but also differences. These are structured spatially and change over time as processes such as mutation, drift, and selection affect them. In the long run, these processes lead to changes that generate significant population subdivisions, which can then be captured using tree-building, phylogenetic methods. Substituting genes for traits, cultural dynamics in space and time can be understood in a like fashion (O'Brien et al. 2008; Shennan 2002). Yet, in this model, innovations are closely modelled on mutations and seen as little more than random. While the function of mutations and innovations in population-scale models is identical—and while it is appropriate to black box innovations as variation generators at that scale—this view adds little to our understanding of innovation per se.

Defining Cultural Transmission

If we view culture as a sum of phenotypic traits transmitted and shared between individuals, then the ways through which culture is transmitted become extremely important if we are to understand how culture manifests itself through processes of descent with modification over time and across space.

Cultural transmission is the movement of ideas—or cohesive sets of ideas—the recipes for stringing together thoughts and conceptualizing actions as well as the knowledge of the necessary materials needed to accomplish specific tasks, their whereabouts, and affordances. In archaeology, we have many models for imagining and describing these processes, e.g., *chaîne opératoire* or "operational sequences" as originally described by Leroi-Gourhan (1964, 1993; see also Riede 2006, 2011), what Prentiss and Chatters (2003) designate *resource management strategies*, or what Schiffer and Skibo (1987) refer to as *recipes for action* in regard to the manufacture of technology (but these can also indicate cognitive *recipes for action*). Similarly, Mesoudi and O'Brien (2008, p. 70) describe "recipes" of hierarchically structured behavioral knowledge that correspondingly set together "functionally interlinked behaviors" (i.e., cultural traits) that aid the accurate retention of information during learning (e.g., effectively easing vertical cultural transmission from one generation to the next). At the microgeographic scale, transmission explicitly refers to the interchange of information from one individual to another. More specifically, as a process of descent—it describes the passing of ideas temporally from one generation to another, most commonly between rather closely related individuals within a given population. As ideas move from one individual to another, these recipes for action may accurately retain information, lose portions of it, and become modified to varying degrees, remaining either intact, relatively so, or becoming erroneous in relation to the original source material. The level of fidelity depends on a staggering array of circumstances the depth of which often remains inscrutable. Generally, the simpler the information being transmitted, the more likely it is to be transmitted with high fidelity and, hence, to remain intact across multiple transmission events.

The actual dissemination of ideas happens in numerous ways and through diverse trajectories, from hands-on instruction to secondhand imitation and copying. Here, we understand that the transmission of ideas is subject to selective forces at both the individual and group level (Boyd and Richerson 1982, 1985; Richerson and Boyd 1984). To avoid guesswork and the loss of fidelity of information it often entails, cultural practices have unavoidably led to the development of complex communication strategies such as social learning, pedagogy, apprenticeship, systems of writing, and manifold media channels, and all of these have become hallmarks of the ways through which humans pass information between individuals at every scale.

Many societies, especially those that are politically complex and hierarchical, have also developed strong norms, where conformity in social behaviors and material culture also become linked to political conformity. Studies have shown that cultural transmission strategies appear to direct information from individual to individual with at least as much fidelity as generally attributed to biological inheritance systems (e.g., Boyd and Richerson 1985; Shennan 2002). However, in culture the tempo of transmission is often much faster and does not necessarily require biological relatedness through sexual reproduction—although the two are often aligned in traditional societies, making kinship a major factor in transmission trajectories (MacDonald 1998).

Synchronic Studies of Innovation in the Past Century

Innovation theory in the social sciences owes much of its foundation to economist Joseph Schumpeter's (1934) observation that innovation is an historical process—part of long cycles of change and continuity driven by past circumstances and dependent upon contemporaneous conditions. This goes along with the recognition that for something to be an "innovation" *as such*, it must not only happen but also successfully spread. To Schumpeter, for such diffusion to take place, the innovation must not only be reasonably replicable but its replication must also be deemed as advantageous by adapters ("entrepreneurs"; this school of innovation theory is studied more at business schools than in academe). Entrepreneurs make specific choices over others, because innovation is part, parcel, and process of the market economy. For social scientists, this means that identifying and classifying innovation also requires considerable recognition of the historical, economic, social, environmental, technological, and any other contexts at play in any observable instance of cultural change. Elements of Schumpeter's economic innovation model may be useful for archaeologists because it takes into account the diachronic perspective necessary to understand processes of change as historically contingent. However, Schumpeter's model of innovation diffusions may limit our understanding of the material record as it ignores the behavioral and life history aspects of innovation, focusing on the economics of individual entrepreneurial decision-making rather than innovation, diffusion, and adaptation as processes contingent on the given social and natural environment into which technologies and ideas are engaged (and which are often actually generated by phenomena such as copying errors and freewheeling tinkering). Indeed, in societies where one cannot make a living through innovation and where the costs of extensive trial-and-error exploration potentially represent significant burdens, innovative behavior—the search for novel solutions to problems, where potential future improvements need to be balanced against the immediate risks of failure—is not immediately incentivized or encouraged in any way. Hence, the Western ideal of the "inventive genius" is likely to be misleading when trying to understand microscale innovation in the traditional societies of the recent and deep past.

Rogers (2005, p. 12) defines innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption . . . if an idea seems new to an individual, it is an innovation." Again, this notion is most applicable to postindustrial revolution modes of thought, based on conscious striving for innovation, within a highly specialized civilization where leisure time and/or direct economic support from other sectors of society has allowed such a focus. It is entirely possible that practitioners were not so conscious of innovations before the modern era and that concatenated innovations normally took place so gradually over the *longue dureé* that they were not actually consciously noted by individuals within a given generation.

Others put a premium on a kind of hardwired *urge to create*. More in line with interpretational modes of thinking, Mithen (1998, p. 7) describes innovation not as the earliest stage in ontogenesis but as an inevitability of human creativity and imagination—a driver of change beyond function or even symbolism: "a universal human trait that is almost limitless." Interestingly, he elsewhere proposes that technological innovation was rare in human prehistory up until around 50,000 years ago, due to a general disability of earlier human ancestors "to integrate their knowledge of tool making with that of the natural world"—a literal inability to cognitively connect tool making with an understanding of the surrounding environment (Mithen 1997, p. 71; see also Shennan 2001, p. 15). However, attributing innovation to some innate creativity precludes a full understanding of it. In this sense, Mithen's view would provide a complementary argument for innovation as a form of random and constant "cultural mutation," which is a by-product of a proclivity all humans possess to a greater or lesser but at any rate innate degree.

Significantly, innovations are not evenly distributed across the human career, and unlike biological mutations, they often clump in time and space—through a form of temporal-spatial "punctuated equilibrium"—so, something else must be going on (for an insightful illustration of the dynamics of innovation in the form of word proliferation in small lexical populations, see, e.g., Greenhill et al. 2018). Specifically with regard to material culture, Riede et al. (2018) have recently drawn attention to the importance of including life-history perspectives and the material culture provided to children as part of their ontogenetic niche in our understanding of innovation. In this model, children and adolescents are free to play—that is, to experiment—with objects, object combinations, and their material and mechanical affordances until the onset of reproduction when experimentation becomes an activity that is predicted to be too costly. Hence, there emerges a trajectory of physical and cognitive development leading up to a "sweet spot" of innovation likelihood in late childhood and adolescence. Playful experimentation with objects here provides the counterpart to imitative learning. In this context, it is also important to understand that the material culture given to youngsters as part of a niche construction process (see Riede, Chap. 17) both facilitates innovation specific to the technologies at hand and also constrains it to these very same domains. In this way, innovation occurs in and further diversifies existing material culture traditions.

In archaeological parlance, the term "innovation" is generally used to describe the process or result of novel change to an existing form, where the new form appears to persist in place of the latter. But the connotation also brings with it a level of functional adaptivity, as the new trait has been "selected." As mentioned above, from an empirical perspective, we may not actually *see* innovation happening. We see the material consequences of the adoption of innovations at the macroscale (i.e., Binford 1962). However, Girard (1990, p. 7) points out: "'Innovation', from the Latin *innovare*, *innovatio*, should signify renewal, rejuvenation from inside, rather than novelty." By this definition, innovations do not indicate a "Eureka!" moment of invention or transmogrification but rather the occurrences of alteration from a previously static form to any other, often only very slightly altered, state. In this sense, innovation is not the emergence of something new so much as it is a process of diversification of something that already exists, through an often subtle process of descent with modification: basically, *phylogenesis* in action. Indeed, detailed studies of innovation in recent periods show the painstaking and often error-ridden process that is more akin to the novel combining of existing materials and technologies rather than some completely new idea or item suddenly emerging. Such processes can be documented empirically (see Ziman 2000) and simulated in the laboratory (Mesoudi et al. 2016). This is telling from an evolutionary perspective, since it places innovation not as we often think of it in archaeological contexts as the act itself of introducing a hitherto unknown and subsequently useful change—but as the events of trait accumulation and recombination, phyletic gradualism in real time, emerging as a result of human behaviors, proclivities, and historical happenstance. Here, innovations facilitate, perhaps even catalyze, instances of cultural cladogenesis, much like biological adaptations in living organisms (Allen 1989; Gould and Eldredge 1977) over the long term. Ultimately, as a process, innovation is a driver of cultural variation that can be dependent on decision-making and information transmission (Shennan 1989), but it can also arise by a serendipitous accident or as a result of copying error—leading to what theoretical biologist Stuart Kauffman called "the adjacent possible."

Diachronic Analysis of Innovation: The Archaeologists Weigh-In

Innovation has been defined in different contexts for different disciplines. Understanding the history of archaeological investigations into long-term processes of innovation is necessary toward developing a more rigorous archaeological theory on the subject as well as in developing methods for identifying it as a quantifiable phenomenon. Over the last few decades, some discussions of innovation in evolutionary anthropology and archaeology have even skirted defining the term at all, presumably since the concept has already received so much theoretical attention. However, there exists no clear consensus as to the exact parameters of innovation, per se. One major thread of contention has been the difference between *invention* and *innovation*, about which most evolutionary anthropologists now seem to agree, as being the difference between the emergence of what can be identified as a wholly new phenomenon (i.e., invention) on the one hand and a novel modification of something already in existence that proves adaptive and diffuses through a population by processes of selection (i.e., innovation), on the other.

A review of archaeological theory relating to innovation over the last 30 years, taking Van der Leeuw and Torrence's (1989) compilation *What's New?* A Closer Look at the Process of Innovation as a starting point and moving forward to current research on the subject, provides a selection of the different ways in which the term has come to describe both processes and products of specific types of change (e.g., Reader and Laland 2003) and sheds light on the variety of ways in which the concept has been most recently applied to discussions of the emergence of changes in material culture traditions and associated behaviors. Earlier works on the subject of innovation are comprehensively reviewed and summarized elsewhere, for instance, in Barnett (1953), Van der Leeuw (1989), and O'Brien and Shennan (2010).

In the introduction to their edited volume on the subject, Torrence and Van der Leeuw (1989) suggest that "[i]nnovation exists by virtue of an extant tradition to which it contributes something new". Rather than redefining innovation, they suggest that innovation represents the discernible material result of risk-taking in technological change, a process visible in the archaeological record as the result of choices and events that in some cases might be reasonably inferred. Bargatzky (1989) further suggests that innovation is "something which affects the overall performance of a sociocultural system at a certain time and which did not exercise this influence before—be it an idea, an object, an attribute of an object, or just a new interrelationship between objects . . . when innovation takes place, there is a readjustment of the system's elements and interrelationships, leading to a new system".

But rather than simply 'define' innovation and to add depth to traditional business studies of innovation, Layton (1989) turns to the ethnoarchaeological record to discuss innovators. Focusing on a community-scale analysis, he observes a case study from a small French farming village. Here, at the local scale, innovations are rarely the idiosyncrasies of individuals for very long, quickly altering at the community level the scope of change and the trajectory of future decision-making. He suggests that the diffusion of innovation is driven largely by content-based bias (see below) based on the perceived efficacy of a given technique or technology when it has been observed to be successfully or otherwise advantageous by neighbors. Another important take-home message from Layton's detailed study is that innovations can spread slowly, that there can be active resistance, and that not everybody in a given population adopts novel technologies in their own lifetime.

On another tack, Van der Leeuw (1989) offers a broad review of earlier innovation literature drawing on his own personal experience in craftwork, emphasizing that for an innovation to be defined as such, it must be perceived of as being worth the risk: that innovation involves the perception (and ultimately the acceptance) of risk. He contends that, as a conscious creative act, innovation is mediated by one's ability to assess the possibilities and outcomes of success, failure, and the possible consequences of both, based on one's previous knowledge or experience. For archaeologists, this is exceptionally difficult to infer since we cannot know the exact level of a priori information or understanding (as well as a posteriori expectations) that an individual in the past may have had. Ultimately, as others have observed, an understanding of the situational and historical contexts of a given event of innovation is necessary when attempting to model the complexities of such changes.

Wiessner (1997) situates the effects of innovation as a marker (along with increased variability over time) of individual or group expression. She describes how 'isochrestic' variation in material culture (that which is not afforded meaning) and 'style' (that which is given meaning) can be identified in the material record, thus placing the recognition of innovation as a proxy for changing social identities or economic status, for example (see Sackett 1982, 1986). In the past quarter-century, many archaeologists have sought a more systematic, comprehensive model for understanding patterns of innovation at the population level. A large number have turned to evolutionary theory to provide coherent explanations of pattern and process, in some cases with spectacular results. Shennan (2001) suggests again that innovation in relation to cultural evolutionary processes acts in similar fashion to genetic mutation in biological evolution—that it introduces variability. He also provides a model and formulas for testing how innovations diffuse mutation as in variable demographic contexts (see "Methods" section below). O'Brien and Shennan (2010, p. 3) emphasize the utility and the limitations of the "straightforward definition: something new and different," noting that innovation as a process is considerably more complex in terms of cultural evolution. This is because the spread of innovations introduces variation in existing systems, and as innovations represent changes to those systems, they offer a primary example of descent with modification in units of culture. Further identifying innovation with evolutionary processes, Ariew (2010, p. 22) argues that "innovations are appropriately explained by natural selection," while inventions are not, since processes of natural selection do not invent novel things, they alter already existing ones. Thus, natural selection leads to innovation—i.e., changes to existing forms. Thus, he calls for the development of more rigorous inferential logic in evolutionary anthropological studies and suggests that "a line between the explanation of innovation and that of invention" be more clearly established (Ariew 2010, p. 32).

Furthermore, Henrich (2010, p. 99) describes innovations as those inventions—"useful or adaptive novelties"—that are spread through a population. O'Brien and Bentley (2010, p. 311) propose that invention *and* innovation are "the key components of cultural transmission" as well as integral to complex technological systems (CTSs). Further situating innovation into the cultural evolutionary paradigm, Roux (2013, p. 313) observes that "according to the Darwinian approach, the social mechanisms underlying the spreading of innovative traits are twofold: either these traits become prevalent through a process of 'natural selection' . . . or through a process of copy . . . " While not a definition of innovation, Roux's observation brings us neatly to the subject of innovation's relationship to cultural transmission, as the diffusion of innovations as variants of units of culture relies on how they become spread through a population. Along these lines, Ellen and Fischer (2013) argue that innovation is but one microscale aspect of cultural transmission—that it is relational to learning and thought processes and the ways in which we communicate ideas between individuals. They state that "in studying cultural transmission we have to explore and attempt to synthesize hypotheses and data over a series of levels . . . the micro-level, applying to bodily and cognitive aspects of processes of learning and innovation and to interpersonal interaction" (Ellen and Fischer 2013, p. 3).

How Cultural Transmission Works: The Channels

In their seminal work on the subject, the late Luigi Luca Cavalli-Sforza and his long-term collaborator Marc Feldman (1981) characterize cultural transmission as occurring in three basic modes: "vertical," "oblique," and "horizontal." They set out a now well-established model in which vertical transmission represents the transmission of cultural traits from parents to offspring; oblique transmission describes information passed down to the younger generation from non-parental members of the *older* generation (e.g., grandparents, aunts, uncles, etc.); and horizontal transmission describes processes where information is transmitted between members of the offspring generation—i.e., information exchange between peers. Others have embellished these concepts further (e.g., Boyd and Richerson 2005; Shennan 2002), observing processes such as "random forces" affecting transmission of culture traits, cultural mutation and drift, and decision-making forces such as various transmission biases and effects such as cultural inertia, guided variation, and processes of natural and guided selection forces that dynamically inform how cultural information persists, changes, and gets around (Boyd and Richerson 2005, p. 69).

Transmission biases describe forces that lead to some cultural variants to be adopted rather than others (Richerson and Boyd 2005, p. 68) and can result in innovations getting introduced into cultural systems. Biases can regulate the rate of introduction of alternative cultural traits. Below, we provide an overview—drawing from a variety of sources—of the numerous forces and processes associated with cultural evolution (Table 3.1).

More on Innovation in Evolutionary Archaeological Contexts

Now that we have reintroduced the basic concept of innovation above, it is important to try to unpack the theoretical history of this term as it relates specifically to evolutionary studies in archaeology. Key to observing innovation in the archaeological record is temporality. A diachronic perspective allows for the identification of earlier forms and their modified later states (Shennan 2006). As Van der Leeuw (1990, p. 92) points out, identifying innovation in the archaeological record is a critical exercise in recognizing context—looking back in time in the hopes of "finding the *conditions of occurrence* of new phenomena . . . the *context* of the emergence of the present . . . ." Thus, in archaeology at least, innovation is defined by the context of adaptation: when later versions of an observably earlier phenomenon that has undergone alteration (the accumulation of newly derived traits) appear to provide an adaptive advantage and persist in a given niche, we can consider them to be "innovations."

Otherwise, potential changes in the material culture record are generally discounted as the background *noise* of past human behaviors and manufacturing mistakes (e.g., Van der Leeuw 1989, p. 301). In most cases for much of human history—at least up until the modern age in which innovation is as much a buzzword as a sought-after process of change—technological innovation was probably the result of accidental change or, at best, the result of stopgap measures that happened to prove more efficient or effective than the technologies that preceded them (but see Riede et al. 2018). Such novel changes—for whatever reason they occurred—without adoption and propagation (i.e., diffusion) are not innovations per se, when it comes to what we can identify in the archaeological record unless we are able to observe *descent* of one form to that of another. Thus, a theory of evolution is indeed essential for a material culture concept of innovation as adaptation. However, while innovative change may be adaptive in a specific context, their persistence over generations through inertia may prove maladaptive if those contexts change. Ultimately, certain innovations may not only be useless or ineffective (just like neutral or nearly neutral mutations; see Laue and Wright, Chap. 7, this volume)—they could prove downright disastrous from a fitness perspective. Also, the environmental or social

Table 3.1 Matrix of terms and definitions describing cultural evolutionary forces and processes, adapted from Richerson and Boyd (2005), Jordan (2015), and O'Neill (2015)

Random forces	*Cultural mutation*	Variation "due to random individual-level processes, such as misremembering" a stage of a process, as in a cultural recipe for action (Richerson and Boyd 2005, p. 69). Invention and innovation reflect processes of mutation in culture (e.g., Read et al. 2009; Shennan 2001). Note, however, that the provisioning of young learners with "qualifier toys" (Lancy 2017) can prime innovation through familiarizing learners with the mechanical and material properties of especially complex technologies whose proper function is an emergent property of its components, and where it is not obvious precisely which modifications may lead to a functional improvement (Riede et al. 2018). This priming makes such "cultural mutations" nonrandom
	Cultural drift	Change guided by random anomalies occurring in small or isolated populations (Richerson and Boyd 2005, p. 69)
	Cultural inertia[a]	The feedback loop of cultural traits within a specific culture that influences or directs the frequency of new or existing traits conservatively: what Richerson and Boyd (2005), p. 68 describe as "the process that tends to keep the population the same from one time period to the next." In common terms cultural inertia represents maintenance of the status quo, often the result of conservative modes of transmission that tend to reject change: e.g., frequency-based bias founded on the imitation of the most commonly observed behaviors (see below) or the building up—through pedagogy—of very specific sets of ideas and ways of doing things, e.g., cultural "scaffolding" (Tehrani and Riede 2008) or normative pressures
Decision-making forces	*Guided variation*	"Nonrandom changes in cultural variants by individuals that are subsequently transmitted. This force results from transformations during social learning, of the learning, invention, or adaptive modification of cultural variants" (Richerson and Boyd 2005, p. 69). Basically, this is Lamarckian cultural evolution: when a trait is deemed beneficial, it may be differentially (i.e., purposely) passed on to other individuals within the population
	Biased transmission: content-based (or direct) bias	"Individuals are more likely to learn or remember some cultural variant based on their content" (Richerson and Boyd 2005, p. 69)
	Biased transmission: frequency-based bias	"The use of the commonness or rarity of a cultural variant as a basis for choice" (Richerson and Boyd 2005), p. 69. Shennan (1989), p. 337 describes this as "the tendency, which may or may not exist in any particular case, for individuals to imitate the more common, or the less common, of two different versions of a behaviour pattern precisely because it is more common, or less common"
	Biased transmission: model-based bias (a form of indirect bias)	Choice of trait based on the observable attributes of the individuals who exhibit the trait (Richerson and Boyd 2005), p. 69. Shennan (1989), p. 337 points out that indirect bias "can be a sensible strategy for individuals to follow: imitating all the characteristics of individuals who appear to be locally successful . . . ." This is also referred to as "prestige-based" bias (see also "pedagogy" below)
Natural selection		"Changes in the cultural composition of a population caused by the effects of holding one cultural variant rather than others. The *natural selection* of cultural variants can occur at individual or group levels" (Richerson and Boyd 2005, p. 69)
Cultural selection		"Processes of cultural selection can . . . change through time not as a result of natural selection affecting people's survival and reproductive success but as a result of conscious and unconscious decision-making based on a variety of criteria" (Shennan 2002, p. 35)

(continued)

Table 3.1 (continued)

Social learning		In broad terms, a way in which information is acquired . . . *the mechanism of cultural inheritance* (Shennan 2002, p. 38)
	Cultural inheritance	The regeneration of phenotypic traits and processes through the direct or indirect transmission of information between entities (Avital and Jablonka 2000, p. 54). How cultural traits get passed down from generation to generation
	Cultural transmission	Generally defined as analogous to biological transmission. Generically, the movement of cultural traits from one place to another; at the microscale, from one individual to another. Describes ways in which information passes from one entity to another leading to descent with modification of cultural traits. The different ways in which cultural traits get passed between individuals and diffuse through and between populations
	Pedagogy	The capacity to learn and transfer information through guidance in a tutor-to-pupil format, as well as the act of doing so. Tehrani and Riede (2008), p. 319 describe it as a "correction mechanism" within social learning—a form of "relevance-guided transmission" in which a teacher uses cues (e.g., approval/disapproval) to guide specifically targeted behaviors and actions in order to maintain transmission fidelity of conventional/desired traits
	Propagation	Mainly microscale evolution of material culture traits *within* defined populations (Jordan 2015, p. 61)
Additional terms	*Cultural coherence*	Macroscale evolution of material culture traits *across* ethnolinguistic populations (Jordan 2015, p. 61). Describes how, within a single cultural tradition, processes of descent with modification make patterns of cultural transmission between groups clear
	Historical congruence	Macroscale evolution of material culture traits *across* ethnolinguistic populations (Jordan 2015, p. 61). Describes how different cultural traditions travel together in space and time; when linked, historical congruence of cultural traits represents the presence of empirically identifiable cultural cores or distinct sets of shared, derived traits that can be observed to be the same or very similar between groups, generally as a consequence of historical processes and contingencies

[a]While not technically "random," cultural inertia is subject to any number of stochastic forces interacting in such complex ways as to make it probabilistically random

contexts in which a given technology functions can change over time, sometimes turning a once adaptive feature into a feature that either has no or negative selective consequences (see Table 3.2).

This holds true not only in natural environmental contexts but also within the social environment. Girard (1990) even suggests that at times perpetuating novelty or change has been perceived as confounding and even downright dangerous. Perhaps it is for similar reasons that early hominin technologies like Acheulean handaxes remained in such more or less consistent form for over a million years (Shennan 2001, p. 15). Creativity is a risky business. Could it be that the mere ability to recognize (and accept) innovation when it occurs, be a hallmark of human cognitive abilities? From a Darwinian evolutionary perspective, innovation can be observed at both the micro- and macroscales as a catalyst of variation—a necessity for *descent with modification* to occur. Read et al. (2009, p. 43) state that:

> By coupling innovation (in the form of mutation in the genetic material transmitted) with differential reproductive success, Darwinian evolution connects patterning expressed at the level of the individual (novel traits) with patterning expressed at the aggregate level of a population (frequency of traits).

The same can be said of innovation of cultural phenomena, i.e., novel traits arising at the individual scale, whether by accident or creativity scaffolded within the strongly modified ontogenetic niches

Table 3.2 The difference between adaptive behavior and adaptations

	Is the behavior adaptive? *Adaptive behavior* is functional behavior that increments reproductive success		
Is the behavior an adaptation? An *adaptation* is a character favored by natural selection for its effectiveness in a particular role		Yes	No
	Yes	*Current adaptation* A current adaptation is an adaptation that has remained adaptive because of continuity in the selective environment	*Past adaptation* A past adaptation is an adaptation that is no longer adaptive because of a change in the selective environment
	No	*Exaptation* An exaptation is a character that now enhances fitness but was not built by natural selection for its current role	*Dysfunctional by-product* A dysfunctional by-product is a character that neither enhances fitness nor was built by natural selection

Adapted from Laland and Brown (2002, p. 133)

of human society, can only really be observed archaeologically beyond the level of "accident" or "creativity" when they are expressed more widely at some variation of a population scale.

For archaeologists, innovation is an important feature of cultural evolutionary processes, particularly technological innovations, since modifications to existing technologies that prove adaptive in a given context (i.e., niche) can be observed in the archaeological record in their temporal, spatial, and environmental contexts, allowing us to infer circumstances of their emergence and persistence. Richerson and Boyd (2005, p. 69) point out that the spread of innovations is usually the result of the diffusion of ideas that come with interpersonal contact between individuals: innovations spread in and between populations as individuals observe the use of new things among their neighbors, adopting hybrid forms and taking them into practice, especially when they are perceived as being more utilitarian than previous approaches or are consistently linked to individuals or groups that are otherwise successful (see also Rogers 2005, p. 11). Thus, recognizing innovation can provide insights into decision-making in processes such as tool manufacture or shelter construction in the past, as particular novel modifications to existing technologies may or may not have been innovative under differing circumstances. So, innovation is all about context. For example, in stone tool production, if manufacturing blades adequately provides *all* the necessary and effective implements required in a given subsistence context, then creating a biface (although the manufacture methods may be technically more multifaceted) is not necessarily innovative, unless the biface proves useful in some other way *and* biface manufacture gets passed on to successive generations (Fitzhugh and Trusler 2009). One person's microblade may be another person's waste, the circumstances in which innovations actually arise as the result of novel change can tell us a great deal about very specific conditions leading to *descent with modification* of material culture and the traditions they reflect.

Enemies of Innovation

Innovation as it appears as a feature of material culture evolution, like biological evolution, is not a teleological progress-oriented process (Ariew 2010; Dunnell 1980). Indeed, the ability of humans to foresee the efficacy of their experimentations with material culture is likely very limited (Mesoudi 2008). Cultural evolution is a contextual process driven by a multiplicity of historical and environmental circumstances and myriad possibilities, including everything from random chance to guided-variation to environmental factors, and beyond (Layton 1989). In nonhuman animals, the emergence of novel behaviors and especially of those behaviors involving some form of material culture appear strongly clued to the affordances of those objects and environmental cues (see Reader and Laland 2003). Much remains to be learned about animal innovations, but it is quite possible that much human innovation is structurally not so different from that of other great apes, for instance.

So, an innovation need not only prove adaptive at some point in the long term. In fact, it is probably imperative that this occur in the short term before the change in question faces greater probability of being discarded from the social or technological system (see Chatters 2009; Prentiss et al. 2009; Zeder 2009); it must also prove heritable in a broad sense. We differentiate between modified versions of things as one-offs on the one hand and others that prove for some reason heritable. Simply changing from one thing into another is not an example of innovation that can be observed in the archaeological record. At any given time, there usually is extensive variation in material culture at various scales (e.g., Bettinger and Eerkens 1999; Eerkens and Lipo 2005). It is only when selected variants get consistently passed on—diffusion to some degree must occur for innovation to be identifiable—that we can hope to identify "true" innovations. It is important to keep this in mind as we move toward macroevolutionary discussions of *descent with modification* (see chapters in the "Macroevolution" section, this volume).

Here, it is necessary to bring up an antithetical process to innovation, as we introduce examples of how information (and innovation) gets transmitted from generation to generation. As a mechanism for limiting the loss of fidelity of cultural information, pedagogy is the enemy of innovation (Tehrani and Riede 2008), although different pedagogical approaches also facilitate experimentation in different ways and to different degrees (see Briggs 1991). Arnold (2012, p. 276) observes that learning "the latitude for innovation" in complex craft systems is a significant part of the learning and apprenticeship period and depends on what is being taught or manufactured: "freedom to innovate is greater for purely ornamental objects than for economically functional objects," although given the salience of ornaments as social signals, this difference may also signify the variable functions that any single object can reference, i.e., their mechanical affordance as well as their value as a costly signal, a signal of group membership, status, or the like. In addition, we see great variance diachronically and cross-culturally to what degree conformity is valued also in the ornamental components of craft production.

Imitation itself inadvertently does not lead to innovation given poor enough imitation skills and some luck, but it is still a limiting mechanism since the idea behind imitation—in theory—is to successfully copy as closely (with as little copying error) as possible that which is being imitated. Learning by trial and error or self-teaching may be the best breeding ground for innovation, but these innovations are still subjected to going through the bottleneck of forms of social learning for any given change to get passed into common usage. Low copying fidelity is likely to result in deterioration of function or even loss of technological/cultural know-how rather than an accumulation of positive change (Henrick 2004; Mesoudi and O'Brien 2008). Because of this, innovation relies heavily on individual creativity (idiosyncratic variability), social learning, cultural flexibility, and chance. This notion of cultural flexibility has generally flown under the radar of cultural transmission studies, yet it is an extremely important factor when it comes to cultural descent with modification, because if the conditions are not amenable to accepting change in the status quo of any given cultural phenomenon, any innovation introduced (or attempted to be introduced) into the system is likely to be stifled and the individual(s) attempting to introduce it may even face negative consequences (e.g., Girard 1990; Rogers 2005; Schumpeter 2008, p. 132). In other words, the corollary of accepting the very premise for the evident prevalence of and evolved predisposition of *Homo sapiens* to pedagogy (Csibra and Gergely 2011), namely, that this highly efficient form of transmission minimizes the costs of learning while ensuring maximum fidelity, implies that innovative behavior is inherently risky and costly.

Innovation potentially reintroduces the Lamarckian concept of inheritance of acquired characteristics back into a predominantly neo-Darwinian epistemology (Daly 1982, p. 402). Simply put, the phenomenon of culture allows for the inheritance of acquired characteristics from one generation to the next. Choosing to adopt any particular modification to an existing system (social, technological, or otherwise) may necessitate a significant conscious or subconscious cost-benefit understanding of the uncertainties and potential consequences of that decision (e.g., Henrich 2010). But such risk-takers are essential for cultural change—particularly when it comes to innovation. As O'Brien and Shennan (2010, p. 11) put it, the more "loners," the more innovation, while the more conformists, the less innovation.

Innovation is perhaps the most difficult cultural evolutionary feature to juxtapose as an analogue to biological processes because it can be random *or* directed. Through diffusion, innovation is the macroscale expression of microscale creativity and happenstance under selective pressures and—at least in prehistory—was often likely exaptation, where a trait or group of traits evolved as an adaptation in one environment survived to function in a completely different way in an altered adaptive environment (e.g., Gould and Vrba 1982; Laland and Brown 2002). As an overall process, the closest analogy may be made with niche construction (Kuijt and Prentiss 2009, p. 264), in that innovation is a cumulative process dependent on adaptation to any number of given environmental circumstances and even triggers. Thus, to identify and attempt to understand innovation in the archaeological record, we must establish as comprehensive a context as possible for viewing the phenomenon at hand, whether it be a change in a complex material technology (e.g., Eldredge 2009; Mason 2009) or even within an existing cosmology (e.g., Steadman and Palmer 1995). For innovation studies in archaeology—as with so many aspects of archaeological interpretation—context is everything.

Innovation and Cultural Transmission in Archaeological Contexts: Three Cases Comparing Micro- with Macroscale Processes

Researchers applying cultural transmission theory inhabit what Stephen Shennan has characterized, possibly somewhat ironically, as "a broad church," with diverse and often seemingly only partially overlapping interests. One way to distinguish their concerns is to consider what cultural tradition is of primary interest to them and at what scale they are inclined to work at, both spatially and temporally. For example, language phylogenies are often used to test hypotheses about the history of populations, often over vast supra-regional expanses—explicitly macro in scale. Meanwhile, a study of a material culture tradition may be made in a more limited geographical area as a starting point but then throw light on their congruence with social traditions and languages at *that* specific social scale. Conversely, an interest in the history of a social tradition could be the primary goal, even if language and aspects of material culture are the starting point. However, when we attempt to synthesize these approaches with the "diffusion of innovations" school (e.g., propagated by Rogers and focusing primarily on industrial or postindustrial societies), the picture becomes even more complicated.

A possible key to reconciling the schools and forging a new synthesis is to identify common interests and viable methodological approaches that will serve in effective analyses and better-informed research, at any scale. Furthermore, studies that seek to empirically identify emergent patterns in the transition from the microscale to macroscale cultural processes would be seen to be of benefit to all. Because there are some aspects of cultural transmission that can be understood only by direct, synchronic, behavioral observation of social actions, individual agency or intent (as with participant observation of on-the-ground social learning processes on the part of social anthropologists or the recording of recent memories of these processes), and others that are best apprehended by archaeology (tracking the development of material culture products across widely distributed populations across geographic space and over generations through patterns of decent with modification), a seamless integration of both of these approaches is most effective when brought to bear in a single case study. Innovative practices can be analyzed by unpacking individual, agent-based activities, with a specific focus in time and place (methodological individualism, which sees societies built up from the sum total of the individual actions of rational, self-interested actors at the

Fig. 3.1 Investigating the dynamics of innovation

microscale). On the other hand, the patterns and processes of cultural change and continuity can be observed on the population level, over generations (population dynamics which determine long-term patterns of cultural evolution at the macroscale). Workers have emphasized specific zones of this wide spectrum, but actually most archaeological data warrants scrutiny of their implications across all scales (Fig. 3.1).

Workers currently applying cultural transmission theory in ethnoarchaeological fieldwork-based empirical studies offer a more explicit rendering of the emergent patterns involved in moving from the micro- to the macroscale. These inform studies in both the cultural transmission *and* the diffusion of innovations schools. The following first two cases involve primarily material culture traditions, with implications for both social traditions and language, and both focus on emergent patterns of cultural transmission as the scales are steadily increased; the third case analyzes social traditions over a relatively vast scale in time and space and suggests that material culture studies could potentially follow.

Case 1: "They Do It Over There, But We Don't Do It Here" (Bowie, D. 1981 Fashion. *Scary Monsters*)—How TRIMS Can Ring-Fence Coherence at the Microscale Analysis of Cultural Transmission

Enduring lineages of socially learned material cultural traditions are frequently recognized by archaeologists, with some traditions spanning many thousands of years. It is maintained here that these large-scale patterns are an aggregate result of individual, agent-based behaviors. This means that the cumulative effects of specific dynamics of social learning and innovation at the "microscale," meaning between individuals *within* populations (e.g., *who* is doing the learning, from *whom* they decide to learn, *what* they are interested in learning, *when* they want to learn it, and *why*), will have a cumulative effect and generate the emergent patterns of cultural transmission that can then occur *between* populations (the latter being the "macroscale" of analysis, specifically dealt with in Chap. 20 of this book). Population thinking in general has provided a useful framework for understanding both these scales of analysis.

Durham held that a clear distinction between cultures could be created not only by geographic isolation and subsequent independent development alone but also by other TRIMS (*transmission isolating mechanisms*) within the cultures themselves (Durham 1992; examined in Tehrani and Collard 2002, 2013). Analogous to RIMS (*reproductive isolating mechanisms*) in biological speciation theory, TRIMS are any mechanisms that inhibit relations between different populations or different cultures within the same populations (see Tehrani and Collard 2013) and could be based on any range of ecological, psychological, linguistic, religious, or other cultural factors that clearly define in-group/out-group relations. Populations can be separated over time by ecological divisions, as happens with divergent patterns of migration or gradual geologic change; however many ideological TRIMS can be propagated rapidly through social learning and grow or decline in relative frequencies, depending upon historical contingency. Xenophobia, racism, religious intolerance, nationalism, and other socially learned forms of community solidarity or divisive social alienation and anomie (where closed, "imagined communities" are modelled by establishing "others" who are not a part of the "in-group"; see Anderson 1983) all can cut off the flow of cultural transmission between groups. The result of this is that cultural traits are clustered in such a way as to maintain specific combinations of cultural traits which are more like separate species branching away from each other, than gene pools within biological populations. In these situations, patterns of cultural evolution could be amenable to phylogenetic analysis. These kinds of branching splits do not require geographic isolation, and it is reasonable to assume that they actually could occur between groups that are co-resident in the same population in the same geographic place (Collard et al. 2008; Tehrani and Collard 2013). A growing number of empirical cases have indeed demonstrated the strong coherence of material culture traditions at the microscale, or within populations, for an interesting variety of reasons. When there are coherent branching patterns between co-resident groups, as opposed to merely a "blur," it is possible to then reconstruct which groups have been closer to each other in terms of descent with modification, supporting inferences about their mutual histories together without written records and even without surviving oral histories.

In an explicit test of the presence of postulated in-group/out-group transmission isolating mechanisms (TRIMS), Tehrani and Collard (2013) hypothesized that patterns of craft diversity between tribal populations in southwestern Iran would exhibit greater branching (phylogenetic) structure than patterns of craft diversity between clans belonging to one of the tribes, where more blending (ethnogenetic) patterns were predicted to be observed. According to Durham (1990, 1992) TRIMS can take the form of ecological boundaries and mutually unintelligible languages. However, in this case, based on ethnographic knowledge, the primary TRIMS predicted to create alienation between tribes, but at the same time more in-group coherence within the tribes, were (a) constant warfare between the tribes and (b) strictly observed endogamous marriage practices, which both would have constrained the movement of people, and ideas, between tribal populations.

In Tehrani and Collard (2013), patterns of textile diversity between four tribes were sampled during ethnographic fieldwork and from a published work based on an extensive museum collection. Secondly, designs for five clan groups within *one* of the tribes represented in the dataset, the Bakhtiari, were also collected. Phylogenetic tests on the respective databases found a significant phylogenetic signal in the inter-tribal data, but not in the intra-tribe data.

Therefore, this test supported the TRIMS hypothesis: that each tribal unit within itself was possessed of more culturally coherent entities in contrast to each other, because of strong in-group/out-group affiliations. This supported the hypothesis that endogamous marriage practices and warfare at the tribal level (the macroscale, between populations), as opposed to the smaller clan units within the single tribe, which were not aggressive with each other and could intermarry (the microscale, within one tribal group), constrained cultural transmission between the larger groups. While aspects of ecology, language, social customs, xenophobic ideology, and phenomena such as warfare can structure TRIMS, this work suggests that it is also possible that material culture itself can function as a TRIM among contemporaneous communities, in an ongoing reciprocal relationship with specific forms of human behavior. People can more easily reinforce in-group/out-group distinctions, for example, if they wear visibly different clothing and carry other material appurtenances that clearly distinguish their self-identity. Furthermore, entire man-made architectural habitats can function to keep social groups apart, but the results described here indicate that ideological (and powerfully symbolic) aspects of smaller-scale, portable material culture traditions might also function in similar, if more subtle, ways.

Tehrani and Collard (2013) caution that these patterns of cultural evolution and the specific mechanisms that may underpin them are applicable to this historically contingent situation only and do not equate to a universal rule valid across differing patterns of the evolution of culture at different social scales of analysis. However, to date there has been very little research done which actually compares and attempts to connect patterns generated at the different scales of analysis, and this particular study moves research further in this direction by examining a material culture lineage across populations but also comparing the same traditions within groups embedded in a single population in the study. The work suggests that similar studies could be done elsewhere.

Since this research uniquely compared cultural evolution patterns of the same material culture tradition at both the microscale and the macroscale, it begs a further question. If more borrowing and blending of material culture traits can occur at the microscale, and branching patterns are more likely to emerge at the macroscale in an extended cultural milieu—in some cases, at least—then is it possible some extreme views taken in the ethnogenesis versus phylogenesis debate actually are formed by biases based on specific researcher's experience in anthropology or archaeology, the actual social scale they habitually study at (e.g., archaeologists who study diachronic processes vs. social anthropologists who may spend 18 months garnering a highly detailed, synchronic snapshot of one small society through participant observation within that group)? It is relatively rare for workers to span both scales, as in this specific case.

Case 2: Building Scale—Tracing Cultural Transmission

Over three extended fieldwork seasons, Jordan (2015, p. 150–184, 213–216) sought to understand the propagation of Khanty hunting ski design traits, initially at 29 basecamp sites along rivers within the Iugan River basin, south of the Ob River in northwestern Siberia, a subregion with an area of approx. 40,000 k^2. These wide skis function more as snowshoes in the wilderness, and not downhill or cross-country skis, as in the West; they are designed for hunting in remote areas and enable people to safely cross extended, shoulder-height banks of snow in pursuit of prey. Across these basecamps Jordan (2015) interviewed the makers and owners of the 50 skis in his sample, specifically enquiring about the social learning processes involved in making the complex equipment (via *indirect bias*; all men and women, who worked together to make the skis in specialized roles, learned primarily by watching their fathers and mothers). However, Jordan (2015) explains that the functional qualities of these skis were under constant, intense scrutiny by their individual owners out in the field throughout the hunting season. This is because any lack of high-performance of the skis, or abrupt structural failure in deep snow in obscure places, could put the hunter's life at risk or at the very least cause days-long setbacks to food procurement. Here there was observed a constant two-stage learning process between the generations: while there was a strong vertical transmission of design methods from parents to children, there was also a degree of personal tinkering (guided variation) involved in the ongoing maintenance and design development of the skis. These new modifications may or may not be passed on to others by way of vertical, oblique, or horizontal routes of transmission, but if they were, they could become an inherited part of the tradition.

In studying the skis themselves, Jordan (2015) also compiled a database of the observed presence and absence of 41 material culture traits for the 50 skis which he then analyzed by way of both network and phylogenetic methods. These returned strong signals of coherence in this tradition, within this subregion. This was attributed to the strong functional requirements for the skis; however there was greater variation tracked in the more recently introduced cloth ski covers used to keep snow off of the hunter's boots.

Jordan (2015) also consulted ethnographic literature from over a century before his fieldwork (e.g., Martin 1897), in order to provide a form of baseline data on the historical design of skis in the area, for comparison with the contemporary database. Here he found wider variation in the design, and a second different design, one with an upward-protruding narrow platform or "fin" carved from the same block of wood as the body of the ski, included to support the feet and raise them above the level of the skis, keeping them more free from the accumulations of snow passing over the ski. This second design appeared to have gone "extinct" by the early part of the twentieth century, once affordable cloth for making the protective ski covers was available for the easier-to-handle contemporary design.

Jordan (2015) then further extended the geographical range of the ski study twice more at a roughly exponential rate (which could be expressed as 10^3), firstly to a much wider region encompassing five more major Khanty groups across adjacent river basins, and ultimately from this area across all of Siberia to the Far East. For further historical baseline reference, he consulted Levin and Popatov (1961) in order to understand wider baseline historical developments.

Again, employing network and phylogenetic analyses to the wider Khanty regional groups, there was significantly more variation found between ski designs from these six major groups, including the first group examined from the Iugan River basin. This is a similar finding to Tehrani and Collard (above), in that the canalized coherence of groups in smaller areas creates a strong contrast when compared with groups in adjacent areas. However, in this particular case, Jordan (2015, p. 176) attributes these variations to the restrictions of physical geography as TRIMS (*transmission isolating mechanisms*; see case study above), as opposed to warfare or marriage practices, that it is the isolation between the different river basins that has led to the respective specific canalization/coherence of traditions in each separate basin area and this isolation also may have impacted the patterns of other cultural traditions, such as the noted significant variation in Khanty dialects.

Through a similar analysis of ski design at the all-Siberian scale, the combination of traits for all contemporary skis in the database displayed wider variation still, but all were clustered more closely together than with the second, "archaic" design, which appears to have gone extinct everywhere with the arrival of affordable cloth. Jordan (2015) explains this development in terms of "trade-offs"; the contemporary ski design was easier to manage than the archaic design, the archaic design being more difficult to master, but the latter was traditionally quieter and much more effective in approaching prey. However, once the contemporary design was enhanced with protective cloth covers (which rendered it quiet as well), the contemporary design was selected for very rapidly because it was easier to use *and* now equally as silent.

Here it has been possible to describe and better explain a process of relatively rapid cultural change across a vast continent by beginning with careful observations of micro-processes of cultural transmission in one subregion alone and then increasing the scale of analysis on a systematic basis.

Both of the above cases demonstrate how patterns of cultural transmission and the diffusion of innovations can best be apprehended by thinking on a constant, multi-scalar spatial and temporal basis. Researchers working with the macroscale often cannot directly address the microscale and vice versa. Tehrani and Collard (2013) and Jordan (2015) drive home the benefits of seeking to understand emerging patterns across the scales. The following case extends the brief to further cultural traditions, and an even larger geographical range.

Case 3: Do Cultural Traditions Marry Well?

As mentioned above, patterns of macroscale language evolution are generally used as the basic lattice for historical reconstruction and congruence studies, where different cultural traditions can be mapped on to each other to see if there are congruent parallels between them (e.g., language and the evolution of architecture; see Jordan and Mace 2006; Jordan and O'Neill 2010). However, it is possible that language and material culture traditions can be demonstrably impacted by other discernible suites of tradition, such as social customs (Jordan and Mace 2006), and it is proposed here that these can be analyzed even at the grandest possible scales of cultural evolution.

Fortunato and Mace (2009), building further on work published by Fortunato et al. (2006), wanted to trace the relationship between the evolution of wealth transfers at marriage on the one hand and marriage systems on the other, in Indo-European societies across all of Eurasia. Building on the findings of other scholars, they had predicted that bride wealth (wealth transferred from the groom or his kin to the bride's kin) and dowry (wealth transferred from the bride's kin to the bride) should be correlated with polygynous vs. monogamous marriage, respectively.

This hypothesis is based on a functional explanation provided by behavioral ecology (addressing one of Tinbergen's "why" questions, 1963), which focuses on the survival value of behaviors in relation to the environment (the human social environment included). In parental investment theory, necessarily limited resources for provisioning children's future will be allocated to maximize the parents' own reproductive success. Because men invest less in gametes than women, they are likely to deliver more grandchildren for the investing parents in polygynous societies. This would predict an emphasis on investment in male children (therefore the payment of bride wealth). However—in societies where polygyny is not allowed, the difference in reproductive success is more balanced. Fortunato and Mace (2009) found that in Indo-European societies that observed monogamy, changes in wealth transfer practices were correlated with changes in marriage systems.

The case suggests the possibility that, along with language trees, trees based on the evolution of social traditions themselves could be a viable starting framework to work with in reconstructing population histories, and historical congruence with material culture traditions could be pursued in the future. This particular case deals with binary relationships of social traditions involved; however overall, "...one important use of phylogeny is to make manageable the overwhelming complexity of populations and cultures" (Boyd et al. 1997). A phylogeny of social traditions which compares different social groups would have to include many more variables in order to stand on its own as a language tree does. But the promise of further integrating analyses of data on language, social customs/traditions, and material culture suggests further fruitful work with congruence studies that can be done.

Final Thoughts

Throughout human prehistory, there have been both inventions and innovations that have literally changed the ways in which our species has evolved. Likewise, the ways and degrees to which information has passed from generation to generation have varied in both mode and scale. Thus, observing the cultural transmission of new and novel ways of doing things is really a question of establishing context. That said, identifying invention, innovation, and indeed their transmission over time and across populations is often difficult to tease out of the archaeological record with any level of certainty. Add to this the fact that long periods of technological conservatism are the norm rather than the exception throughout the vast majority of the human story, and the challenge becomes greater. Where we can recognize novel inventions and innovations of existing traditions in prehistory—as during major transitions such as the emergence of the Neolithic, the Upper Paleolithic, and the Middle-Late Stone Age, moving back in time—each is hallmarked by a new set of adaptations that in the specific contexts of their place and time, changed the game board completely. But of course, we can only observe such major shifts in retrospect and only when provided with enough context of what came before and after to recognize their significance. This need for context is because where changes are visible in the archaeological record, they are likely often the results of very complex processes and compounding contingent scenarios that are difficult to illuminate clearly and even more difficult to model comprehensively.

Cultural adaptations, as seen from the point-of-view of *la longue durée*, are the results of life histories at various scales: interactions between individuals, communities, populations, and the environments in which they live. Furthermore, we must factor in adaptation as being very often punctuated by regional cataclysms or other dramatic and often rapid environmental changes to preexisting conditions, driving natural selection of cultural variants. Even individual proclivities and happenstance can cause changes within a cultural system and over time become the "normal" way of doing things. This complexity is what makes the evolutionary study of cultural transmission and technological innovation so fascinating—and why it continues to generate new insights. Simply put, there is still a lot for us to try to understand.

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