Introduction

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Technologies—complexes of skills, practices, and artifacts aimed at practical goals—are passed on from generation to generation, forming traditions that can persist with a high degree of stability, sometimes for millennia. These traditions have proved essential to the success of the human species in populating all but the most hostile ecosystems of our planet. They have made it possible for human populations to respond to ecological challenges in locally adapted ways—for instance, by collecting and processing foods or by transforming a variety of materials to produce artifacts such as shelters, clothing, weapons, and tools of all kinds. These traditions also play a key role in shaping social relations within and among human populations. Communication, transportation, and economic systems depend on culturally developed and transmitted technologies to properly function, persist, and evolve through time. Simpler technical traditions are also found in other species, providing the strongest evidence for the claim that culture is not uniquely human.

Technology involves both techniques and artifacts. Techniques involve complex practical actions (often employing artifacts and aimed at producing material changes in one's environment) and the skills needed to perform these actions. Yet, in the study of cumulative technological evolution, techniques have received much less attention than artifacts, notwithstanding a few programmatic discussions (Charbonneau 2015, 2016, 2018; O'Brien et al. 2010; Mokyr 2000; Manem 2020). Research on technological evolution has instead adopted artifacts as the key units of technological change (in line with Basalla 1988).

Still, the study of techniques as units of human cultures has attracted considerable scientific interest across several fields. Following in the steps of André Leroi-Gourhan and his successors, the French school of prehistory has developed the systematic study of techniques by applying the notion of *chaîne opératoire*, an analytic practice by which learned skills are decomposed into their operational and functional units. *Chaînes opératoires*, and similar means of parsing action and decision sequences involved in the production, use, refitting, and discarding of material artifacts, are now common across archaeological science (Bleed 2001). The evolutionary study of the cognitive, motor, and anatomical prerequisites for learning and deploying complex techniques is also a growing field within paleoanthropology and paleoarchaeology (Haidle 2009; Lombard and Haidle 2012; Roux and Bril 2005; Stout 2002, 2011) and cognitive science (Osiurak and Heinke 2018; Stout 2013).

In adopting artifacts as the key units of technological change, the study of cultural evolution has been primarily focusing on the study of change in artifact morphology, diversity, and function. The driving model for technological evolution has been one where individuals copy the artifacts they observe with high enough fidelity to ensure the enduring stability of the tradition (Boyd, Richerson, and Henrich 2013). Through the accumulation of small, random copying errors, the shape and functions of these artifacts would gradually change, with little involvement of individual intelligence (Boyd, Richerson, and Henrich 2011; Henrich 2016). High-fidelity copying also ensures that those modifications in artifacts that are adaptive are preserved, slowly building up increasingly sophisticated and complex technological traditions. This morphocentric model of technological evolution (Charbonneau 2015, 2018) is particularly manifest in the work of evolutionary archaeologists, focusing on morphological similarities and differences within prehistorical artifacts as bearers of phylogenetic signals (Lipo et al. 2006; O'Brien and Lyman 2000; cf. Manem 2020). Most historical case studies of technological evolution also emphasize change in artifact form, such as the evolution of sound holes in European violin design from the tenth to the eighteenth century (Nia et al. 2015), Turkmen carpet design up to the eighteenth century (Tehrani and Collard 2002), or the evolution of valved cornets in the last two centuries (Tëmkin and Eldredge 2007). Laboratory experiments on cumulative cultural evolution have also followed this trend, being nearly exclusively focused on artifact evolution (Miton and Charbonneau 2018; cf. Strachan et al. 2021).

Of course, cumulative changes in artifacts are central to the process of technological evolution, but so are changes in the technical traditions that are necessary for producing and using those artifacts. Unlike artifacts, most techniques cannot be rigidly copied generation after generation. Technical actions must flexibly vary, if only to allow the successful implementation of the technique in different contexts of production (e.g., starting a fire under varying conditions of sun, rain, or wind; building a shelter on flat, steep, dry, or wet land). As complex and structured (hierarchically organized) actions, techniques often offer various degrees of freedom to their users, who can adapt them to solve novel problems and adjust to changing social and ecological circumstances, often within their individual lifetime but also over intergenerational timescales. Moreover, while actions can be observed and copied, the tacit skills and expertise that make these actions possible and effective cannot be directly copied but only inferred and reconstructed anew (with or without the help of pedagogic demonstrations and teaching), a process that calls for cognitive flexibility. How does this flexibility in the use, transmission, acquisition, and adjustment of techniques affect their evolution?

The Tension between Rigidity and Flexibility

The very existence of long-lasting technical traditions implies the persistence of the relevant knowledge content behind those traditions—knowledge that needs to be learned faithfully enough and carried on stably enough to endure as the same technique (Charbonneau 2020). For technical traditions to persist, those using the techniques must do so according to the defining features of the techniques. There is no point in transmitting specific means to carry out some practical action if users simply decide to do it their own way; a tradition reinvented at every generation is no tradition at all. On the other hand, there may be a range of possibilities between strictly copying and fully reinventing at each generation. In some cases, at least, it may be that what is transmitted is a range of indications sufficient for the full skill to be faithfully "re-produced" (with a hyphen and in the sense of produced again) rather than strictly speaking "reproduced" (in the sense of copied). Copying is not the only way to secure recurrence (Sperber 1996; Claidière, Scott-Phillips, and Sperber 2014; Miton, forthcoming).

For technical traditions to be culturally successful, they must be transmitted in ways that secure their effectiveness. While techniques play several roles beyond the functional—they can serve as social or ethnic markers, sources of prestige, tools of power, to name a few examples—failure in properly transmitting key functional aspects of a technique can lead to its functional disruption, decreased performance, or even the transmission of unusable "practical knowledge." Users of techniques must not only learn the specific functional features of the techniques, but they must deploy them appropriately for the technique to be useful at all. Here it seems that techniques effective enough to be worth transmitting demand rigidity, this time in their use.

However, if techniques are to serve as adaptive means for a population to survive and thrive, they must also allow for some amount of flexibility. For one thing, environments are not static. Populations have to adapt to novel circumstances in ways that both take advantage of their technical traditions and adjust them to a changing world (Pope-Caldwell, this volume). Such changes can be the result of exogenous factors—changes in the natural environment (for instance, desertification) or in the human environment (for instance, intergroup conflicts)—or of endogenous factors (for instance, increase in population size, changes in social organization, or new dietary norms). Such changes may call for technological invention, modification, and innovation.

A popular model of technological evolution is that of the accumulated error model (Eerkens 2000; Hamilton and Buchanan 2009). In this model, transmission and use remain quite rigid, but some slight modifications are unintentionally introduced in the traditions through miscopying, allowing just enough difference to occasionally produce novel technical variants that can track ecological and social transformations in adaptive ways, with some form of selection process ensuring the successful diffusion of the novel adaptive means (Boyd and Richerson 2005). When invention is achieved in this way, as an effect of copying errors introducing variants and selection of variants, transmission and use of techniques remain mostly rigid.

Populations can also add novel technical variants to their repertoire, either by inventing completely novel techniques from scratch or by recombining existing techniques in order to produce new ones (Charbonneau 2016; Lewis and Laland 2012). In the case of combinatorial invention, the new tradition preserves aspects of the earlier tradition (at least within the composite invention; see Manem, this volume), and to that extent it relies on some piecemeal rigidity and flexibility. In the invention from scratch case, novel technical variants are the output of individual discovery, but the transmission process based on social learning may itself remain rigidly faithful.

Studying technological innovation and evolution as iterations of a process of high-fidelity copying followed by selection works rather well for some artifact traditions, especially morphologically standardized artifacts that remain inert until used. In contrast, techniques are, by their very nature, interactive processes involving both their users and the dynamical physical world that surrounds them. In order to be effective, techniques must be adaptable to the local circumstances of their use, sometimes on the fly, sometimes from one day, one month, or one year to the next, and this means, in large part, that they need to be flexible enough to deal with the heterogeneity of the materials found in the environment and the various demands and constraints imposed by the contexts within which they are deployed.

If artifact forms can be standardized, the raw materials used to produce those forms are themselves rarely homogeneous. When pressure-flaking an obsidian core, lumbering a tree, or treating ore to form an alloy, the user must cope with the heterogeneous physical and chemical properties of the materials, which demands that the user adapt to the density, shape, mixture, quantity, and grain of the materials to be transformed. When cooking, one must usually adapt to variations in ingredients of the same type, such as the ripeness of vegetables or the tenderness of meats. When building a shelter, one often needs to balance constraints imposed by the ground's density, hardness, and slope, together with the local wind stream, precipitation patterns, light direction, and shading patterns, and so on. This is also true of contexts where the natural resources used are not themselves physical objects, such as adapting to fast-changing meteorological circumstances (e.g., the sailing of a vessel in a context of changing winds and water currents; see Astuti, this volume). The availability of the materials can also fluctuate, causing the user to adopt strategies dealing with limited, absent, or alternative materials in fruitful ways, such as using some ingredient that can serve as a "good enough" replacement for an original recipe.

Materials themselves are often reactive to users' actions. This is especially true of organic materials. Milk has several properties that vary with its source, age, and handling history, making the production of traditional dairy products as much the implementation of an ancestral recipe as an active process of contingent adjustments (e.g., needs for controlling its microbiota). Techniques involving animals, such as hunting or horseback riding (Miton, this volume) must deal with additional dynamically changing degrees of freedom and constraints. Animals (even those of a same species) often have different body shapes and sizes, muscular capacities, and more importantly, mental dispositions and capacities, both as individual members of their species (e.g., intelligence or temperament) and as abilities developed over time (e.g., mood or developmental stages).

Techniques, in their use, must be plastic enough to allow their users to flexibly implement them in the face of these varying and dynamic circumstances. Successfully using a technique therefore requires more than stereotypically following a predefined, standardized recipe. It requires, on the one hand, the user's capacity to recognize and adapt to local contingencies, and on the other, for the technique itself to allow enough degrees of freedom to accommodate the varying production contexts within which it is deployed. This, then, suggests that any two uses of a very same technique may vary in terms of the actions used, their order, and their function, depending on context. This intrinsic entanglement of the expression of a technique with the materials and ecological circumstances in which it is deployed makes the causal contribution of differences in behavior resulting from culture, individual learning, and ecology difficult to disentangle (Tenpas, Schweinfurth, and Call, this volume).

The requirement of flexible expression of techniques when used challenges the idea that techniques can be transmitted through rigid copying processes. Rigidly copying an observed action sequence may be of limited use since next-generation users (or even users of the same generation) will themselves rarely encounter the exact same conditions that shaped the specific expression of the technique they observed when learning it from others. Effective learning requires the learner to move beyond the observed sequence of action in order to parse what is contingent to the local learning situation and what serves as the key, traditional features of the technique. When the technique consists of a single action, or very few simple actions, copying might plausibly do the work, considering that there is a limited number of ways a single action can vary and remain functional. However, this assumes that single actions are limited in their dimensionality—an assumption that relies more on the coarseness of the grain of analysis at which actions are described than on the range of variation any given action offers (Csibra 2008; Charbonneau and Bourrat 2021). In any case, learners must be capable of moving past specific actions and understand their functional meaning within the whole sequence to which they belong and grasp which aspects of the action ensure its functional relevance to the overall functional economy of the action sequence (Gergely and Király, this volume). In other words, learning techniques involves not copying a stereotypical action sequence but rather capturing its hierarchically organized decision structure and learning to recognize the often unobservable, tacit cues used by the expert models when deploying the technique. This suggests that the cultural transmission of techniques is a reconstructive process working with incomplete informational inputs because the decision and perceptual cues key to mastering the skill are not themselves directly observable but must instead be inferred from, for instance, context or learned by trial and error. Reconstruction appears to be an inevitable part of the transmission process of technical knowledge (Strachan, Curioni, and McEllin, this volume) and, as a consequence, of the successful long-term stabilization of technical traditions (Stout, this volume).

Of course, some variation in technical actions, especially among novices, may be an effect of imperfect, low-fidelity copying. Much more importantly, variation is a necessary component of the acquisition and use of techniques: through observed variation in an expert model's behavior, the novice gains a better understanding of the range of actions that can yield the expected effect of the technical behavior. Instead of approaching variation as a form of deviation from what ought to have been learned (e.g., as a form of copying error or noise in transmission), variation in the expression of techniques should, in most cases, be viewed as what makes them useful and learnable in the first place (Roux et al., this volume). Moreover, the fact that variation is an intrinsic part of the expert use of a technique and of learners' acquisition of technical expertise suggests that this intrinsic flexibility may in itself be a promoter of innovation. For instance, while experts may be capable of mastering a technical skill very precisely by flexibly adapting to the context of production, they are also those who can potentially deviate from the common use of the techniques and exploit their mastery to flexibly produce novelties (Roux et al., this volume; De Munck, this volume). If so, then this poses the question of what brings experts to decide to exploit variation in innovative rather than conservative ways. Novel ecological challenges can serve as a stimulation for innovation (Pope-Caldwell, this volume; Tenpas, Schweinfurth, and Call, this volume); so can new economic demands, such as the growth of a market for new products (De Munck, this volume; Manem, this volume; Roux et al., this volume).

Finally, the social and interpersonal setups mobilized for the transmission of technical knowledge must also be flexible (Boyette, this volume; De Munck, this volume; Ongaro, this volume). Ethnographic research has documented a broad diversity of ways in which technical skills are acquired within populations (Lancy, Bock, and Gaskins 2010; Rogoff

2003; Lew-Levy et al. 2019). While some technical skills can be acquired through observational learning with minimal engagement of the model, in many societies these skills are learned through the direct engagement of the learner in the context of use of the technique or of peripheral activities (Lave and Wenger 1991; Paradise and Rogoff 2009). Peer-play also offers many opportunities for learners of a younger age to progressively build their technical expertise (Boyette 2016, this volume; Chick 2010).

Technical skills can also be passed on through various institutional forms of education, from informal and *in situ* activities (Lancy, Bock, and Gaskins 2010) to well-organized hands-on learning as in apprenticeship (De Munck, this volume; Sterelny, this volume). Decontextualized learning contexts such as those found in the classroom add to this diversity, with classroom learning itself varying in its organization and cognitive demands from one cultural (and historical) context to the next (Sternberg and Grigorenko 2004; Sterelny, this volume). This diversity of learning contexts and coordinated interactions illustrates the fact that humans are adaptable learners who are able to flexibly exploit different social configurations to ensure the successful transmission of vital skills, with each context often imposing different cognitive demands on the part of both the learner and the model or teacher (Charbonneau et al. 2023; Strachan, Curioni, and McEllin, et al., this volume).

If transmission, use, and innovation are intimately intertwined in this way, the model of invention as a process of solitary discovery seems unfit, giving way instead to a more socially situated alternative where novel ideas emerge in individuals who are themselves entrenched in deeper social relations and interactions (Cutting, this volume; Ongaro, this volume). To spread, an innovation must be accepted within a population, and for this, individuals must make sense of the novelty and flexibly integrate it within their own practices without this being too much of a challenge to, for instance, their sense of ethnic identity (Astuti, this volume; Ongaro, this volume). Producing and adopting an innovation is rarely if ever a strictly individual process (Cutting, this volume). For instance, while all individuals in a community may rigidly be reluctant to adopt on their own a novel technical variant, the community as a whole may be more flexible and deliberately adopt a novel way of doing things, overriding and overcoming individual reluctance (Ongaro, this volume). In other words, rigid individuals may, nevertheless, form flexibly open societies.

To sum up, the evolution of technical traditions appears to involve both rigidity and flexibility. On the one hand, for technical knowledge to be stabilized in the form of long-lasting traditions, it seems that it should be used according to the specific features characterizing that technique and that those features be transmitted with high fidelity, with some but not too much space for change if the traditions are to remain of functional value. On the other hand, the very plastic nature of techniques ensures they can be adapted to the specifics of their context of use, the circumstances under which they are transmitted, and the specific demands for adaptively producing and adopting novelty.

How is the tension between these two contrary demands—rigidity and flexibility in the use, transmission, and innovation of techniques—reconciled? While this question is key to our species' success, little scientific attention has been paid to it so far. This volume aims to foster a better understanding of ways in which this tension is solved and how these solutions differentially affect the evolution of technical traditions.

How the Volume Is Organized

To better understand this tension between rigidity and flexibility, we asked experts from a wide variety of disciplines and with different perspectives to provide both theoretical discussions and empirical case studies. While the contributors have been developing the notions of technical rigidity and flexibility in several ways and their individual chapters can be read independently of one another, they have all made original contribution to the common theme, often addressing each other's ideas. In a concluding discussion, the philosopher Kim Sterelny considers these contributions and their common theme in a simultaneously broad and precise evolutionary perspective.

The volume has three thematic parts:

1. Timescales of Technical Rigidity and Flexibility
2. From Rigid Copying to Flexible Reconstruction
3. Exogenous Factors of Technical Rigidity and Flexibility

There is some unavoidable arbitrariness in any such organization. While every chapter makes its main contribution to the theme of the part to which it belongs, they all also contribute to the themes of the other parts. They reflect the discussions that took place online among all the authors. We hope that this volume will foster a wider conversation and a greater interdisciplinary integration in the study of rigidity and flexibility in the evolution of techniques.

Part I, "Timescales of Technical Rigidity and Flexibility," reflects a consensus among the contributors that the tension between technical rigidity and flexibility must be simultaneously addressed at different spatiotemporal scales. As one contributor put it during our online discussions, "Larger scale processes are instantiated by the accumulation of smaller scale processes, while the smaller scale processes are constrained by the persistent context of the larger scale processes." For instance, flexibility in use and learning at the scale of an individual lifetime may result in rigid and stable traditions at the population level over the longer term. Similarly, rigidly preserved traditions may fuel flexible innovations at different timescales. Addressing this complexity demands an integrative interdisciplinarity in expertise and methods. The study of micro-interactions between individual learners and expert models and the examination of long-term cultural and technological evolution require quite different tools and methods, but they are mutually relevant and must be linked. This first part illustrates this methodological diversity and the challenges it raises for the development of an integrated picture.

The four first chapters forming part I have been ordered in terms of the timescale they study, from the shortest to the longest: technical change within a generation (Roux and colleagues), change following a single generational overturn (Astuti), and change over several centuries (De Munck) and millennia (Manem).

In an original piece of methodological interdisciplinarity, Valentine Roux, Blandine Bril, Anne-Lise Goujon, and Catherine Lara (chapter 1) investigate the relation between skill, expertise, and innovation by running a field experiment among potters inspired by laboratory experiments in cognitive psychology. They show that the most skillful individuals, who produced less variation in their pots thanks to their finer motor skills, were also better able to adapt their skills in order to produce novel pot forms. The authors argue that flexibility—defined as "the ability to cope with changing circumstances and unexpected variations and to find a motor solution for any situation and in any condition"—is acquired by experienced potters through extensive training with familiar production activities. This gives experts a much greater understanding of the task and therefore allows them to adapt to novel and varying situations better than less skillful individuals. At the same, this very experience with socially identified and shared techniques for making familiar pots helps explain the enduring stability of technical traditions.

In an ethnographic study spanning some 30 years, Rita Astuti (chapter 2) describes the change in the way Vezo fishermen of the village of Betania in Madagascar rig their canoes. Her chapter provides a case study of the adoption of a novel technique (and sail implement) within the timespan of one generation. Central to her case study is the fact that the Vezo, as a group, define themselves not by common ancestry but by their way of living, which involves sailing, fishing, and maritime coastal trade. This might suggest that techniques related to these activities would be rigidly maintained because they are key to the group's identity. Yet, after only a few years, the common sprit sail, a novelty to the Vezo, diffused within the population, eventually becoming the universally shared technique. Astuti reports how the people involved weighed the pros and cons of the novel technique compared to the traditional one, and she examines what narratives the Vezo deployed to explain the change while keeping their social identity intact.

In his contribution, Bert De Munck (chapter 3) traces the transformations of craftsmanship over several centuries from the late medieval to the early modern period in Europe. One view of craft guilds is that of a journeyman going through years of training and learning on the shop floor, where craft apprenticeship serves to ensure the faithful acquisition of a specialized and esoteric knowledge defined by rigid standards and procedures. In this view, incorporated craft guilds enforce highly rigid forms of learning and through their exclusivity serve as obstacles to individual creativity and the free diffusion of innovations. Yet the guild artisan is also associated with the idea of individual creativity and authenticity, in contrast to the image of the alienated factory worker's mechanically repetitive work. Rejecting the dichotomizing view opposing artisanal crafts and mass production, De Munck delves into "the complexity and hybridity of the artisan's manifold histories" and shows how craft guilds managed to balance the needs for rigidity and flexibility. His historical analysis focuses on the evolving ways by which apprenticeship was organized and institutionalized within craft guilds and how it adapted to cultural, political, and epistemological transformations as well as to economic and technological ones.

In a methodologically innovative contribution, Sébastien Manem (chapter 4) borrows cladistics methods of phylogenetic analysis originally developed by evolutionary biologists and studies the long-term tensions between rigidity and flexibility in the use and innovation of ceramic techniques. He deploys these methods with a twist: rather than focusing on artifact morphologies, as evolutionary archaeologists typically do, Manem instead adapts those methods to track phylogenetic signals in *chaînes opératoires*—the series of operations that transform raw material into finished product. Taking the evolution of ceramics of the Duffaits Bronze Age culture over several millennia, Manem argues that technical invention and innovation is made possible by a form of "slippery flexibility," where a novel technical variant is first used to manufacture some parts of ceramics while traditional methods are rigidly maintained for the other parts. By decomposing the *chaînes opératoires* in fine-grained, modular technical parameters, his analysis shows that we can reconstruct several important processes involved in technical innovation, including the pressures involved for flexible individual inventions and those stymieing the evolvability of technical traditions.

Part II, "From Rigid Copying to Flexible Reconstruction," contains contributions that take as a central question the nature and impact of different forms of cultural transmission. Each contribution, in its own way, moves away from the idea that high-fidelity copying is the proper general model of skill transmission, let alone of cultural learning altogether. Instead, each chapter approaches the question of skill transmission by arguing for more flexible and versatile forms of learning, where skills are not less copied-as-seen than reconstructed through a multiplicity of processes. While reconstructive, these processes result in the rigid stabilization of technical traditions in some contexts and fuel innovations in others. A common assumption of the chapters grouped in part II is that cultural learning is not merely social because the knowledge acquired is provided by others, with expert models pouring information into naive learners serving as receptables. Rather, cultural transmission should be understood primarily as an interactive process where experts materially and socially construct a rich learning environment (as Boyette and Stout emphasize in their respective chapters) or where teachers and learners are strongly involved in directing and participating in skill acquisition (as Gergely and Király argue, as do Strachan and colleagues). Each of these contributions ends up, in its own way, rejecting the common analogy between genetic and cultural inheritance (where inheritance is secured by copying) and the framework it imposes on the evolution of techniques—for instance, by treating cultural learning as a strictly unidirectional form of information transmission (Boyette; Strachan and colleagues), by adopting a dichotomy between inheritance and innovation or between individual and social learning (Boyette; Gergely and Király; Stout), or by assuming clear one-to-one lineage relationships between learners and those they learn from (Boyette; Stout).

György Gergely and Ildikó Király (chapter 5) challenge the widespread view that children acquire technical skills through passive observational learning and imitative copying and that, moreover, these rigid, high-fidelity learning mechanisms are specially adapted for capturing causally opaque actions—instrumental actions the function of which is not apparent to the learner—displayed by expert models. They argue against the dichotomy between high-fidelity transmission and innovation, which are often referred to as the two engines unique to the human species of the cumulative improvement of technical and technological knowledge. They develop a series of laboratory experiments showing that human cultural learning is a process of selective, inferential, and relevance-guided emulation (i.e., that children are specifically geared to learn on the basis of ostensive cues given to them by their models and are thereby capable of flexibly choosing, as they learn, alternative instrumental actions to those exhibited by the models). In this sense, both transmission and innovation are built in and part of the very same cognitive mechanism—relevance-based emulation—which is a learning mechanism that can be flexibly deployed in various contexts making possible both instrumental improvement of the learned actions and their faithful reconstruction.

James W. A. Strachan, Arianna Curioni, and Luke McEllin (chapter 6) take on and challenge the idea of observational learning (or copying) as a paradigm case and instead recast social learning in terms of action coordination. They argue that while observational learning may be a useful *minimal working example* for transmission experiments, the methodological gains offered by such experiments impose significant costs on the generalizability of their results. While transmission experiments generally force a unidirectional information flow from expert model to learner, many (if not most) learning interactions involve bidirectional information flow, where learners and models adapt to one another. This bidirectionality introduces a coordination dimension to social learning, which must be explained in terms of cognitive mechanisms of action coordination and joint action. These mechanisms, they argue, provide a better understanding of both technical flexibility and rigidity. Coordination mechanisms are versatile in that they allow individuals to adapt to various situational contexts and interactional demands such as role assignment or online error corrections, providing the ability to learn technical know-how in various learning setups. Coordination mechanisms, they argue, can also lead to rigidity because technical traditions depending on the coordination of individuals (e.g., driving in the left or right lane) can break down when some individuals start acting differently than expected. Instead, larger shifts at the population level may be required for effective change (e.g., governmental decree).

Noting that high-fidelity imitation (copying) is at risk of transmitting maladaptive behaviors in changing environments, Adam Boyette (chapter 7) argues that populations may flexibly adapt to such changes by *culturally* shaping their physical, social, and learning environment. Adopting a cultural niche construction approach—according to which we transform the environment in which we develop and learn from one another through the making of artifacts and the shaping of physical spaces—Boyette argues that humans can guide their children's developmental trajectories and acquisition of complex, vital skills with minimal direct, person-to-person social learning interactions. By flexibly constructing the contexts in which naive learners acquire key technical skills, we ensure the "faithful" reconstruction of technical traditions. This allows children to explore the range of tasks they need to solve freely and safely and to flexibly learn the necessary technical skills. Boyette explores this idea by studying how the BaYaka forest foragers from the Congo Basin encourage their children to autonomously explore blade tools. At the same time, they palliate the costs (such as risks of injuries) of individual exploration by providing their children with reliable and responsive caregiving. While BaYaka cultural niche construction may ensure low variation and a more rigid preservation of skills across generations, it also encourages innovations through this form of flexible and autonomous learning.

Is the prolonged technological stasis marking the Paleolithic really so puzzling? Dietrich Stout (chapter 8) rejects the assumption common in the field of cultural evolution that stability and convergence are anomalous and require special explanation. He characterizes technology as a biocultural reproductive strategy. It is the means for our species to support its distinctive life history and reproductive strategies through the investment of its surplus energy into the production of technical skills, knowledge, and equipment. Technology, therefore, is understood not as the mere production and use of artifacts by individuals or as the result of rigid, high-fidelity transmission of technological information among them. Instead, Stout understands technology as the result of collaborative, life history–oriented activities through which human collectives reconstruct practices and objects. In this perspective, technological stability is not stagnation caused by societies unable to innovate. Rather, achieving stability is the evolutionary challenge addressed by the technological niche in the first place: ensuring the persistence of a population in a changing world. According to Stout, we overcame this challenge by relying on flexible coordination and communication between individuals and the exploitation of cognitive, interactive, and ecological factors in order to reconstruct our technical way of life, from one generation to the next.

Part III, "Exogenous Factors of Technical Rigidity and Flexibility," challenges the view that both stability and change in technical traditions are the effect of endogenous factors inherent to the rigid use and transmission of technical traditions. According to that view, technical stability is best explained by the high-fidelity transmission mechanisms such as imitation while technical changes are best explained as effects of individual innovations resulting from error, serendipity, or insight and selected on the basis of their functional efficiency. While nobody denies that such endogenous factors are important, the contributions in part III highlight the importance of *exogenous* factors. These include cultural factors such as ethnic identity (Ongaro), social influences on use and invention (Cutting), the role of the materials acted on by the technique (which, especially in the case of live materials, can be quite dynamic and reactive) in shaping the technical tradition (Miton), and the impact of a changing environment (Pope-Caldwell). Disentangling the role endogenous and exogenous factors in human and nonhuman technical traditions is a major challenge (Tenpas and colleagues). Contributions in this part make clear the importance of studying exogenous factors to achieve a comprehensive understanding of technical evolution.

While many contributors focus on the capacities and factors that make technical behaviors rigid or flexible, Sarah Pope-Caldwell (chapter 9) takes issue with the human capacity to measure and choose in the face of changing ecological circumstances when it is adaptive to rigidly stick to familiar behaviors, when it is better to switch to different strategies found in the cultural repertoire of the population, and when it is preferable to invent new strategies. Starting from the assumption that humans are capable of being rigid in some circumstances and flexible in others, she examines *in which contexts* rigidity and flexibility are beneficial or detrimental and *by which mechanisms* we make the decision to pursue familiar strategies or move on to new ones. To do so, she proposes the *constrained flexibility framework*, extending existing research on cognitive flexibility in the face of environmental change. She discusses the effects of exogenous variability, predictability, and harshness on adaptive behavior and balances predictive and reactive strategies in the face of fluctuating ecological circumstances.

Central to Giulio Ongaro's ethnographical case study (chapter 10) is the role of exogenous factors in stabilizing technical traditions. He describes two kinds of technical traditions among the Akha of the Laos highlands: esoteric ethnopharmacological knowledge that is flexibly transmitted under secrecy by a few experts, and customs and practices that are widely shared, rigidly transmitted, and stabilized because of their ethnic-defining role. Because ethnopharmacological knowledge is esoteric, restricted, and not seen as constitutive of Akha identity, expertise in this domain is quite flexible and individually variable. Maintaining its secret character takes precedence over ascertaining its instrumental functionality. In the second case, techniques such as house building are transmitted in the open, closely monitored, and stabilized by the community. Yet the Akha, while they individually reject innovations that go against their identity-defining customs, remain flexible as a community and are capable of integrating novel techniques in their repertoire through group decisions.

Echoing a theme developed in the first and second parts of this volume, Nicola Cutting (chapter 11) argues against the standard dichotomy between individual learning and social learning. She reviews the growing experimental literature on children's ability to use tools in innovative ways (to which she has herself made important contributions) and argues that this dichotomy has led experimentalists to deprive children subjects of the social scaffolding necessary to solve tasks that use tools in innovative ways. In the real world, innovations are rarely achieved by individuals in isolation. It therefore remains unclear to what extent standard laboratory experiments paint a proper picture of children's capacity for flexible innovation, of the cognitive mechanisms underlying such capacity, and of their ontogeny. For her part, Cutting approaches the capacity to modify and combine existing solutions into novel ones as a form of innovative flexibility, where innovations are socially embedded and supported by social influences. She argues that experiments on innovative tool use by children remains a promising area of research when social influences are allowed to play a role, with children turning out to be much more flexible than what current research has seemed to demonstrate.

Techniques involving nonhuman animals such as horses face the difficulty of having to deal with living, complex, and changing materials. In her contribution, Helena Miton (chapter 12) asks how technical activities involving two species dynamically interacting with one another can be transmitted as stable, long-lasting traditions. In a tradition such as horse dressage, riders need to adapt expertly and flexibly to the horse's idiosyncrasies, such as its body constraints and temperament, in order to lead the horse in producing rigidly defined figures stabilized in long-standing traditions. Miton combines historical-cultural data, cognitive and veterinary research on horses, and an autoethnography of her own experience as a horse rider and teacher to understand how both riders and horses need to comply to rigidly defined codes and goals of traditional riding practices. For this, teaching traditions guide the riders in flexibly adapting to the idiosyncrasies of the horse's cognition and experience. As a result, she argues, riders and horses come to produce an integrated system where both parties are mutually adapting through the development of an interspecific form of haptic communication channel that is unnatural to both living systems.

Technical traditions are also found in nonhuman species, such as our closest relatives, the chimpanzees. Like humans, chimpanzees must strike a balance between rigidly preserving useful behaviors when beneficial and flexibly changing them when necessary. Sadie Tenpas, Manon Schweinfurth, and Josep Call (chapter 13) underline the fact that most research in comparative psychology has focused on high-fidelity social learning as the main mechanism behind the stability of nonhuman animal traditions. Too little attention has been paid to the means by which these traditions are updated in the face of novel circumstances or remain resilient in the face of disruptions. By excluding ecological and individual factors as noncultural, comparative psychologists are depriving themselves of important explanatory factors that can provide a deeper understanding of the origins and stability of nonhuman technical traditions. The authors propose complementing the social learning view by reintegrating these factors and by adapting cultural attraction theory, initially devised to account for human cultures, in order to enrich the study of chimpanzee technical traditions. In so doing, they develop a multilevel approach to technical rigidity and flexibility, examining how these are expressed at the individual, group, and population levels.

In his concluding discussion, "The Cumulative Culture Mosaic," Kim Sterelny reflects on the contributions in this volume, on the general issues these contributions address, and on the broader theme of the cultural evolution of techniques (the study of which Sterelny himself has made major theoretical contributions, in particular in his 2012 book *The Evolved Apprentice*). The factors favoring rigidity or flexibility, he underscores, have themselves evolved. Early technical skills in hominin evolution were more specific, context-dependent, and rigid. Expertise-based skills emerged progressively, making the preservation of skills more and more compatible with their improvement. Techniques with different goals develop under different ecological and cognitive constraints. Techniques used to act on the physical environment (world-facing traits) are likely to involve a great deal of trial-and-error learning, generating variation that can produce useful innovations when recognized as such and even lead to cumulative change when those techniques are used with technologies depending on maintenance for their reliability. In contrast, practices used as coordination devices within a community (community-facing traits) are less likely to vary once established, given that they act within a complex of norms allowing greater predictability of the behaviors of the members of the group by the members of the group. Because of the entwinement of use, transmission, and innovation in world-facing techniques, differences in learning regimes will affect how innovation is itself practiced. Small-scale pre-state societies favoring a face-to-face interactive form of learning contrast with large-scale state societies securing the reconstruction of expertise mostly through top-down, institutionalized schooling systems.

All in all, Sterelny's concluding discussion brings us back to the initial motivation of this volume: rethinking the use, transmission, and innovation in techniques by examining their contextual, ecological, and temporal variability. We seem to arrive at a more fluid and diversified image of technical evolution, where rigidity and flexibility are not construed as dichotomous opposites but instead define a space of possibility much larger than what is usually envisaged, a space in need of further and deeper interdisciplinary theoretical and empirical investigations.

References

Basalla, G. 1988. *The Evolution of Technology*. Cambridge: Cambridge University Press.

Bleed, P. 2001. "Trees or Chains, Links or Branches: Conceptual Alternatives for Consideration of Stone Tool Production and Other Sequential Activities." *Journal of Archaeological Method and Theory* 8 (1): 101–127.

Boyd, R., and P. J. Richerson. 2005. *The Origin and Evolution of Cultures*. Oxford: Oxford University Press.

Boyd, R., P. J. Richerson, and J. Henrich. 2011. "The Cultural Niche: Why Social Learning Is Essential for Human Adaptation." *Proceedings of the National Academy of Sciences* 108:10918–10925.

Boyd, R., P. J. Richerson, and J. Henrich. 2013. "The Cultural Evolution of Technology: Facts and Theories." In *Cultural Evolution: Society, Technology, Language, and Religion*, edited by P. J. Richerson and M. H. Christiansen, 119–142. Cambridge, MA: MIT Press.

Boyette, A. H. 2016. "Children's Play and the Integration of Social and Individual Learning: A Cultural Niche Construction Perspective." In *Social Learning and Innovation in Contemporary Hunter-Gatherers*, edited by H. Terashima and B. S. Hewlett, 159–169. Dordrecht: Springer.

Charbonneau, M. 2015. "Mapping Complex Social Transmission: Technical Constraints on the Evolution Cultures." *Biology & Philosophy* 30:527–546.

Charbonneau, M. 2016. "Modularity and Recombination in Technological Evolution." *Philosophy & Technology* 29:373–392.

Charbonneau, M. 2018. "Technical Constraints on the Convergent Evolution of Technologies." In *Convergent Evolution in Stone-Tool Technology*, edited by M. J. O'Brien, B. Buchanan, and M. I. Eren, 73–89. Cambridge, MA: MIT Press.

Charbonneau, M. 2020. "Understanding Cultural Fidelity." *British Journal for the Philosophy of Science* 71 (4): 1209–1233.

Charbonneau, M., and P. Bourrat. 2021. "Fidelity and the Grain Problem in Cultural Evolution." *Synthese* 199:5815–5836.

Charbonneau, M., A. Curioni, L. McEllin, and J. W. A. Strachan. "Flexible Cultural Learning Through Action Coordination." *Perspectives on Psychological Science*, July 17, 2023.

Chick, G. 2010. "Work, Play, and Learning." In *The Anthropology of Learning in Childhood*, edited by D. F. Lancy, J. Bock, and S. Gaskins, 119–143. Lanham, MD: AltaMira Press.

Claidière, N., T. C. Scott-Phillips, and D. Sperber. 2014. "How Darwinian Is Cultural Evolution?" *Philosophical Transactions of the Royal Society B: Biological Sciences* 369 (1642), 20130368.

Csibra, G. 2008. "Action Mirroring and Action Understanding: An Alternative Account." *Sensorimotor Foundations of Higher Cognition: Attention and Performance* 22:435–459.

Eerkens, J. 2000. "Practice Makes within 5% of Perfect: The Role of Visual Perception, Motor Skills, and Human Memory in Artifact Variation and Standardization." *Current Anthropology* 41:663–668.

Haidle, M. N. 2009. "How to Think a Simple Spear." In *Cognitive Archaeology and Human Evolution*, edited by S. A. de Beaune, F. L. Coolidge, and T. Wynn, 57–73. Cambridge: Cambridge University Press.

Hamilton, M. J., and B. Buchanan. 2009. "The Accumulation of Stochastic Copying Errors Causes Drift in Culturally Transmitted Technologies: Quantifying Clovis Evolutionary Dynamics." *Journal of Anthropological Archaeology* 28:55–69.

Henrich, J. 2016. *The Secret of Our Success: How Culture is Driving Human Evolution, Domesticating Our Species, and Making Us Smarter*. Princeton, NJ: Princeton University Press.

Lancy, D. F., J. Bock, and S. Gaskins. 2010. *The Anthropology of Learning in Childhood*. Lanham, MD: Rowman Altamira.

Lave, J., and E. Wenger. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.

Lewis, H. M., and K. N. Laland. 2012. "Transmission Fidelity Is the Key to the Build-up of Cumulative Culture." *Philosophical Transactions of the Royal Society B* 367:2171–2180.

Lew-Levy, S., A. N. Crittenden, A. H. Boyette, I. A. Mabulla, B. S. Hewlett, and M. E. Lamb. 2019. "Inter-and Intra-Cultural Variation in Learning-through-Participation among Hadza and BaYaka Forager Children and Adolescents from Tanzania and the Republic of Congo." *Journal of Psychology in Africa* 29 (4): 309–318.

Lipo, C. P., M. J. O'Brien, M. Collard, and S. Shennan. 2006. *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory*. New Brunswick, NJ: Aldine Transaction.

Lombard, M., and M. N. Haidle. 2012. "Thinking a Bow-and-Arrow Set: Cognitive Implications of Middle Stone Age Bow and Stone-Tipped Arrow Technology." *Cambridge Archaeological Journal* 22 (2): 237–264.

Manem, S. 2020. "Modeling the Evolution of Ceramic Traditions through a Phylogenetic Analysis of the *Chaînes Opératoires*: The European Bronze Age as a Case Study." *Journal of Archaeological Method and Theory* 27 (4): 992-1039.

Miton, H. Forthcoming. "Cultural Attraction." In *Oxford Handbook of Cultural Evolution*, edited by R. Kendal, J. Tehrani, and J. Kendal. Oxford: Oxford University Press.

Miton, H., and M. Charbonneau. 2018. "Cumulative Culture in the Laboratory: Methodological and Theoretical Challenges." *Proceedings of the Royal Society B* 285:20180677.

Mokyr, J. 2000. "Evolutionary Phenomena in Technological Change." In *Technological Innovation as an Evolutionary Process*, edited by J. Ziman, 52–65. Cambridge: Cambridge University Press.

Nia, H. T., A. D. Jain, Y. Liu, M.-R. Alam, R. Barnas, and N. C. Makris. 2015. "The Evolution of Air Resonance Power Efficiency in the Violin and Its Ancestors." *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 471 (2175): 20140905.

O'Brien, M. J., and R. L. Lyman. 2000. *Applying Evolutionary Archaeology: A Systematic Approach*. New York: Kluwer Academic Publishers.

O'Brien, M. J., R. L. Lyman, A. Mesoudi, and T. L. VanPool. 2010. "Cultural Traits as Units of Analysis." *Philosophical Transactions of the Royal Society B* 365:3797–3806.

Osiurak, F., and D. Heinke. 2018. "Looking for Intoolligence: A Unified Framework for the Cognitive Study of Human Tool Use and Technology." *American Psychologist* 73 (2): 169-185.

Paradise, R., and B. Rogoff. 2009. "Side by Side: Learning by Observing and Pitching In." *Ethos* 37 (1): 102–138.

Rogoff, B. 2003. *The Cultural Nature of Human Development*. Oxford: Oxford University Press.

Roux, V., and B. Bril. 2005. *Stone Knapping: The Necessary Conditions for a Uniquely Hominin Behaviour*. Cambridge: McDonald Institute for Archaeological Research.

Sperber, D. 1996. *Explaining Culture: A Naturalistic Approach*. Oxford: Blackwell Publishers.

Sternberg, R. J., and E. L. Grigorenko. 2004. "Intelligence and Culture: How Culture Shapes What Intelligence Means, and the Implications for a Science of Well–Being." *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 359 (1449): 1427–1434.

Stout, D. 2002. "Skill and Cognition in Stone Tool Production: An Ethnographic Case Study from Irian Jaya." *Current Anthropology* 43 (5): 693–722.

Stout, D. 2011. "Stone Toolmaking and the Evolution of Human Culture and Cognition." *Philosophical Transactions of the Royal Society B* 366:1050–1059.

Stout, D. 2013. "Neuroscience of Technology." In *Cultural Evolution: Society, Technology, Language, and Religion*, edited by P. J. Richerson and M. H. Christiansen, 157–173. Cambridge, MA: MIT Press.

Strachan, J. W. A., A. Curioni, M. D. Constable, G. Knoblich, and M. Charbonneau. 2021. "Evaluating the Relative Contributions of Copying and Reconstruction Processes in Cultural Transmission Episodes." *PLOS One* 16 (9): e0256901.

Tehrani, J., and M. Collard. 2002. "Investigating Cultural Evolution through Biological Phylogenetic Analyses of Turkmen Textiles." *Journal of Anthropological Archaeology* 21 (4): 443–463.

Tëmkin, I., and N. Eldredge. 2007. "Phylogenetics and Material Cultural Evolution." *Current Anthropology* 48 (1): 146–154.

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