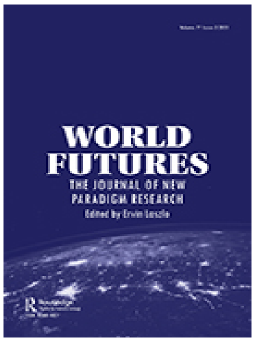

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Martin Stuart-Fox

University of Queensland, Queensland, Australia

ABSTRACT
Eörs Szathmáry and John Maynard Smith famously argued that the evolution of life on earth has been marked by a series of transitions to greater complexity, the last being from primate to human societies. I argue that this last transition, covering all of human evolutionary history, in turn comprises two phases: the first defined by increases in the capacity of the human brain/mind to structurally integrate causal inferences and selectively apply them to construct increasingly sophisticated sociocultural niches; the second defined by manipulation of the universal Darwinian mechanisms driving sociocultural evolution. During the first phase, hominin cognitive structure passed through three key transitions to produce the brain/mind of archaic *Homo sapiens*. The fourth transition, to fully modern *Homo sapiens sapiens* equipped with symbolic cognition and language, marks the fulcrum that leveraged the second phase in which changes in the scope and rate of niche construction were primarily driven by manipulation of sociocultural evolutionary mechanisms. The fifth transition to sedentary living enabled new selection pressures to be exerted through the concentration and application of social power, while the sixth transition multiplied the cognitive variation available to construct more elaborate sociocultural niches. Finally I note that decreasing intervals between transitions creates a pattern of accelerating sociocultural change.

KEYWORDS
Evolutionary transitions; hominin evolution; cognitive evolution; sociocultural evolution; niche construction; worldview; paleolithic revolution; agricultural revolution; scientific revolution; macro-history

In their classic 1995 paper in *Nature*, Eörs Szathmáry and John Maynard Smith identified eight major transitions in the evolutionary history of life on earth, each of which led to increased complexity in the lineages in which they occurred (Szathmáry & Maynard Smith, 1997). All had two

CONTACT Martin Stuart-Fox m.stuartfox@uq.edu.au School of Historical and Philosophical Inquiry, University of Queensland, Brisbane, Australia.

interlocking features in common: the integration of existing entities within larger reproducing units, and their task-specific differentiation. In each transition, certain entities became specialized to transmit information that enabled larger units to replicate. In this way, successively more complex organisms evolved.

The eighth transition, from primate to human societies, does not quite fit this pattern (McShea & Simpson, 2011). Processes of integration and differentiation are not spelled out, leaving the explanatory burden to be borne by language as the novel means by which information is transmitted and heritability assured, through building not more complex organisms, but more complex societies. How this transition came about is unclear, however. All we are told is that language evolved in two stages – proto-language in *Homo erectus* and fully human language in *Homo sapiens* – and that this is what enabled sociocultures to be continuously constructed.

The purpose of this paper is to expand on Szathmáry and Maynard Smith's (Szathmáry & Smith, 1995) eighth transition, with a view to clarifying the stages through which this last evolutionary advance came about.

My argument rests on these claims: that human evolutionary history comprises the entire period from the divergence of the hominin line through to the present; that so defined, human evolutionary history comprises two phases: evolution within the hominin lineage, culminating in *Homo sapiens*; and the subsequent history of humankind thereafter, with the appearance of fully modern *Homo sapiens sapiens* marking the fulcrum between the two; that over the course of this hominin/human evolutionary history, ecological niche construction progressively gave way to sociocultural niche construction as the coevolutionary balance between genetic and sociocultural mechanisms shifted in favor of the latter; that what drove this shift was the evolving capacity of the human brain/mind to infer causal connections; integrate theoretical causal inferences into worldviews; and within the context of these, select behaviors designed to construct larger, more complex and more internally differentiated sociocultural niches. In the process, humans have learned how to manipulate the underlying mechanisms to speed the pace of sociocultural evolution.

Given the doubts that some have expressed that evolutionary theory can add anything to our understanding of social change (e.g. Mann, 2016), the above claims require some defense. To begin with, the phrase 'human evolutionary history' claims continuity between hominin evolution and human history, on the basis that dual evolutionary mechanisms operated across both phases. This is not, however, to suggest that historical change is evolutionary in a narrow Darwinian sense; that is, due to natural selection. Rather, the mechanisms driving sociocultural evolution conform to generalized or universal Darwinism (Cziko, 1995; Nelson, 2007); that is, they differentially select between variant entities that can be communicated, replicated, and acted upon. In any evolving system, it does not matter what varies, how variants are generated, or what selective pressures are applied. What is significant is that change comes about through selection and retention of heritable/replicable variants, whether these are genes that build biological organisms, or concepts and behaviors that construct sociocultural niches.

Evolutionary Transitions

Three things should be noted about evolutionary transitions as understood by Szathmáry and Maynard Smith. The first is that they are contingent: no transition necessarily occurs in any lineage; the second is that they are explicable by reference to evolutionary theory; and the third is that as they take time to manifest, their significance only becomes apparent in retrospect. Given that emergent mechanisms driving sociocultural change are evolutionary in a generalized Darwinian sense, transitions in human evolutionary history can be expected to have similar characteristics.

Attempts to identify transitions in human history go back to Condorcet (1955/1794) and Marx (Cohen, 1978), and have continued in one form or another through to the present (Hall, 1986; Aunger, 2007). In most such theories, transitions relate to necessary sequences of stages, so are not contingent. Neither are they explained by reference to evolutionary theory. Renewed interest in sociocultural evolution in the 1980s and 1990s re-focused attention on historical transitions. While some scholars explained increasing complexity in terms of transitions in the structure of social systems (Pettersson, 1996; Scheffer, 2009), others favored a functional approach focusing on increases in information or cooperation (Coren, 1998; Stewart, 2000). Meanwhile advances in paleoanthropology drew attention to transitions in hominin evolution. While some scholars focused on single transitions (Bar-Yosef, 1998a), others defined sequences in the evolution of mind (Donald, 1991; Mithen, 1996), or in relationships between ecological conditions and social behavior (Foley & Gamble, 2009), or between reduction and differential expansion of populations (Lahr, 2016). Others still have questioned whether transitions or 'revolutions' have happened at all (Foley et al., 2016; McBrearty & Brooks, 2000).

From even this brief survey it is evident that transitions in hominin/human history have been defined in a variety of ways. In part these reflect how evolution writ large is understood – in Spencerian terms (Freeman, 1974), as a cosmic process encompassing physical, biological and social systems (Christian, 2011); or as Darwinian, in which biological and social systems share a common variation-and-selection algorithm (Stuart-Fox, 1999). The ambitions of this study are limited to the latter. It takes as given a set of empirical observations: that human beings constitute a single biological species; that continuity exists between evolution of the human species and subsequent human history; that biological evolution has been augmented by sociocultural evolution in what constitutes a coevolutionary process; that earlier hominins and human beings have materially modified the prevailing environment through both ecological and sociocultural 'niche construction' (Odling-Smee et al., 2003); that this has ratcheted increased complexity of human societies through the selection of novel behaviors; and that the capacity to do this is a faculty of the brain/mind, drawing on epigenetic cognitive structures continuously assembled throughout our lives. None of these observations is contentious; nor is the implication of their sum: that sociocultural change is a function of the interplay between cognition and cooperation. So the obvious conclusion is that as cognitive structures have evolved, the major transitions in human evolutionary history are most likely to be defined by the way these changes have impacted on niche construction; or more specifically, on how the evolution of cognition has impacted on the selection of behavior (van Horik & Emery, 2011).

Hominin evolution is marked by significant anatomical changes, most notably increase in gross cranial capacity reflecting changes in the internal structure of the brain. But while cranial anatomy provides a pointer to cognitive function in a broad sense, how internal cognitive structures evolved, in relation to what environmental circumstances, can only be deduced by factoring in material evidence of niche construction (Warren et al., 2019). Such evidence is scarce at first, though increasingly abundant over time. Even so, interpretation can be problematic. What is not in question is that the human brain/mind is the source of all the creativity and innovation in human history, which is why cognitive structures are central to any understanding of how and why societies and cultures have changed in the way they have through human history.

To anticipate, therefore, the transitions I identify focus on the evolution of cognitive structure, and on how cognition has been applied to create increasingly complex sociocultural constructs (or niches). I shall argue that the first three transitions mark key changes in the means by which species of hominins comprehended and responded to their environments. The product was a brain/mind that functioned as an organ for conscious selection of behavior in relation to defined criteria (goals, intentions) tempered by interests and feelings. Over the course of these transitions, the natural environment was modified in increasingly complex ways to construct 'niches', in the course of which sociocultural selection at first supplemented natural selection in a minimal way, but progressively came to displace it as the primary mode of adaptation of human populations. In the process, the ultimate driver of natural selection (the existential urge to reproduce) came to be displaced by the proximate driver of sociocultural evolution (the evermoreconscious urge to experience satisfaction, in relation to meeting needs, desires and goals of self and significant others). More complex niche construction depended on building new social structural relationships – a process accelerated by the evolution of language as the principal means of communication of the inferences constituting cognitive structure. Later transitions were due to changes in the way sociocultural environments (constructed niches) exerted selective pressures on individual behavior: at first by concentrating social power through the organization of structured social groups; and subsequently by multiplying the variation available for selection through encouraging the production of new knowledge and enabling its application to innovative niche construction. Finally I note that the historical consequence of the central role cognition has played in driving sociocultural evolution has been to accelerate the frequency of transitions.

Phase One: Transitions in Hominin Evolution

Interpreting the human narrative as a sequence of transitions runs the risk of understanding it as linear and necessary. And this is how hominin evolution was once conceived: as sequential changes within a single evolutionary line. But the study of hominin evolution has progressed remarkably over the last few decades as the fossil record has become richer (Tattersall, 2012). We now know that several species of 'bipedal apes' evolved in different parts of Africa; that evolution of hominin features occurred in more than one lineage; and that different species of *Homo* competed with each other until the last remaining Neanderthals, Denisovans and 'Hobbits' (*Homo floresiensis*) died out. At all times hominin populations expanded or contracted in response to environmental conditions. Evolutionary advantage was hard to come by, and advances were more often incremental than dramatic. Indeed the editors of a recent collection of articles devoted to 'major transitions in human evolution' concluded that

> Looking at the totality of hominin evolution, there is no broad division between the earlier and later phases, nor between archaic and modern humans. These transitions are significant, but the richer fossil record now in existence, and the multiple techniques available for studying it, show that the major transitions of human evolution are comprised of multiple smaller ones (Foley et al., 2016).

In other words, hominin evolution should be understood as a 'gradual and cumulative process, best described as mosaic evolution' (Foley, 2016). But if the pattern of hominin evolution does not consist of punctuated advances, nor does it present a smooth curve, whether with respect to anatomical change (notably in cranial capacity) or to cultural production. Increases in brain size have at times been more marked than at others; one, for example, occurred around 1.8 Mya with the evolution of *Homo erectus/ergaster*; another from about 500 to 200 kya coincided with the appearance of later, large-brained *Homo*. Neither, it should be noted, clearly correlates with sudden climate change or greater variability in the natural environment (Shultz et al., 2012). Nor is there any clear association between social structural transformations and changes in human ecology (Foley & Gamble, 2009). One can only conclude, therefore, that the evolution of hominin cognition was in response to combinations of natural and sociocultural environmental conditions that at times exerted greater selection pressures for novel behaviors than at others, perhaps by triggering a 'cascade effect' among a small number of genes (Marcus, 2004).

So the dilemma is this: if we try to correlate the fossil record with cultural advances and changing environment, no well-defined transitions are evident. And yet significant changes in cognition did occur that enabled hominin species to construct ever more sophisticated adaptive ecological niches. Niche construction is the key here (Kendal et al., 2011), for by imposing new cognitive demands, both social (cooperating within groups) and cultural (producing new artifacts, mastering new technologies) (Sterelny, 2011), more complex niche construction exerted new selection pressures. Evolution of cognition was initially in response to the exigencies of the natural environment, but its application to niche construction created ecological changes to which successive generations had perforce to adapt. New causal connections enabled construction of ever more complex sociocultural niches, in a ratchet-like cumulative process that shaped the trajectory of hominin evolutionary history. In the process, the burden of adaptation progressively shifted from natural to sociocultural selection (though never to the exclusion of the former) (Durham, 1991 ; Richerson & Boyd, 2005).

Over the first phase of human evolutionary history, three significant transitions in hominin cognition can be identified. These were: first the ability to interpret natural signs through constructing causal inferences between perceptions and stored category representations; second, extension of causal inference from signs in the natural environment to two additional domains contributing to niche construction: social behavior of conspecifics by assigning motivation (theory of mind), and tool production from crude resources to finished products; and third, cognitive reorganization differentiating functionally distinct yet massively interconnected memory systems, which on the one hand provided an integrated conceptual model of the world (worldview), and on the other underwrote personal identity in the form of self as agent – a combination that factored foresight into selection of behavior.

The product of these three transitions was brain/minds that could be epigenetically programmed through cultural transmission in ways that enabled innovative and adaptive niche construction in response to either newly encountered or rapidly changing environments. Taken in conjunction, assembly of worldview and niche construction functioned as interactive components of an emergent cumulative evolutionary process that was simultaneously cultural (including ritual behavior and material production) and social (comprising cooperative group activity and social structural relationships). For this reason I refer to sociocultural, rather than cultural, evolution.

The First Transition

By common agreement, the principal anatomical changes setting Late Pliocene hominins apart from contemporary apes were associated with the evolution of bipedalism in response to a drying climate and retreating forest cover (Conroy & Pontzer, 2012). While crania show small changes in structure over time, brain capacity in proportion to anatomy hardly increased through the australopithecines; so the cognitive potential available was presumably sufficient to process new behaviors to meet the challenges of terrestrial living. I have previously argued that the key cognitive breakthrough that differentiated the earliest hominins from the ancestral chimpanzee/bonobo line was the ability to construct causal inferences to interpret natural signs, and to store them in relation to preexisting cognitive maps (Stuart-Fox, 2015b). What follows is a summary of the argument.

Causal inference goes beyond the associations of classical Pavlovian or instrumental conditioning, and entails more than an expectation that one event will follow another (Waldmann et al., 2006). A causal inference is an intuited connection between observed effect and putative cause, between an immediate perception and a mental category image stored in memory. It is instantiated through formation of a neural linkage, re-activation of which reiterates the inference and triggers any associated motor response. Inferences are in this way integrated into the physiological structure of the brain (Fugelsang & Dunbar, 2005).

Causal inference is a hard-wired cognitive capacity that we take for granted, but which is present in only rudimentary form in a few other species – and even this has been disputed (Penn & Povinelli, 2007). It is easy to see, however, that for small and vulnerable ground-dwelling hominins in marginal environments, positive selection for the ability to infer the causes of natural signs would have conferred fitness benefits –

because causal inferences could apply not just to the small prey that became part of an omnivorous diet, but more especially to predators of such small and vulnerable ground-dwelling hominins (DeSilva, 2021; Zuberbühler & Jenny, 2002).

The ability to construct causal inferences in relation to natural signs requires not just the instantiation of neural connections between mental representations, but also 'decoupling' of category representations from behavioral responses as a prerequisite for independent association (Sterelny, 2000). Watching a small animal make tracks in the sand may instantiate a connection between the two. But such a cognitive construct counts as a causal inference if and only if, when similar tracks are seen again and no animal is present, the observation re-activates the connection to a category representation of the kind of animal that made them. Once activated, the causal connection initiates appropriate behavior (follow tracks to a burrow and dig). Independent association allows the same category representation to be triggered in response to perception of a natural sign in another sensory mode, such as a sound in the night, or a characteristic smell; and for perceptions of different animals to trigger shared category characteristics (like making tracks or being dangerous).

To be beneficial for survival, causal inferences had to be encoded and stored in memory. But the ability to draw causal inferences did not depend on possessing a large brain: chimpanzees are almost there. Since no substantial increase in brain size accompanies this proposed transition, therefore, initially causal inference would more likely have been stored in relation to an existing cognitive structure, namely the cognitive map that many animals construct of their territories (Portugali, 1996), for in that case return to the location where the inference was instantiated would likely trigger re-activation.[1]

Identification of causal inference as the first significant transition in human cognitive evolution can only be speculative, since we possess only fragmentary skeletal remains and virtually no evidence of niche construction. Support comes, however, from studies of cognitive development in infants. As early as seven months, infants display an innate capacity to construct causal relationships (Newman et al., 2008). So strong is this innate 'drive to explain' (Gopnik, 2000) during the first two years of life that causal understanding has been described as a 'developmental primitive' applying across all cognitive domains (Corrigan & Denton, 1996). This would suggest that hominins became inferential animals at a very early stage in their evolution, perhaps through a single mutation enabling neural connections to form between perceived images and category representations.

Identifying causal interpretation of natural signs as the first cognitive advance for early hominins is in broad agreement with the timing of the first of the 'three separate phases of substantial adaptive change' identified by Robert Foley, which he dates from 5 Mya to 4 Mya and relates to 'locomotion, foraging and habitat adaptations' (Foley, 2016). Over the long period from the earliest bipedal hominins to the later australopithecines, cranial capacity did slowly increase, sufficiently to accommodate the extension of causal thinking to a range of natural signs and activities such as, for example, selection of rocks or sticks for use as crude weapons or tools. Over time the 'causal map' (Gopnik et al., 2004) so assembled exerted selective pressure for greater memory capacity and larger brains.

There are good reasons, therefore, to assert that instantiating causal inferences in relation to natural signs was the key cognitive advance that differentiated the hominin line from the ancestors of chimpanzees and bonobos, and that this constituted the first major transition in human evolutionary history, for in the long term inferring, structurally organizing, and applying causal inferences to select behavior have in combination been the hallmark of what makes us human (Wolpert, 2007). This claim is reinforced by the following three considerations.

The first is that causal connections constitute structural components for the assembly of an integrated understanding of the world, because they can be meta-represented to create hierarchies and allow for recursion to accommodate sub-sequences. Hierarchical organization is a general principle governing information processing in human cognition (Tsien, 2007). Indeed the behavior resulting from cognitive selection is itself hierarchically structured (Botvinick, 2008); and the brain imposes a hierarchical/recursive structure even when processing descriptions of everyday events (Mesoudi & Whiten, 2004).

A second point is that causal inferences are mental constructs that go beyond the information provided by observed covariance (Waldmann et al., 2006). So in this sense inferences about the causes of natural signs are theories (Gopnik & Meltzoff, 1997); they are hypothetical until confirmed through repeated observation, either by the observer or by trusted others. This is why acting on an inference carried a risk for early hominins, which manifested as anxiety, reduction of which depended largely on social confirmation. This was available insofar as early hominins lived in social groups, but required accurate communication in the form of some kind of proto-language of signs and sounds.

A third consequence was that causal inferences engender awareness of time, for not only does inferring cause from effect require working back from present to past, the same inference also invites projection from observed or represented cause to future effect. Causal relationships situate the perceived present in a temporal context, which as far as we know no other organism is capable of doing in anything but a rudimentary way.

The Second Transition

Paleoanthropologists have identified a period of substantial change beginning somewhere between 3 Mya and 2 Mya 'linked to a change in diet, means of acquisition of resources (technology) and life-history strategy' (Foley, 2016). By around 1.8 Mya, the increased brain size of *Homo ergaster* indicates that some significant development had taken place in hominin cognition, conceivably driven by a coevolutionary feedback loop between improved social cooperation and technical innovation (Heyes, 2012). Given the changes that occurred in social behavior over this period, notably the production and use of crude tools to modify the hominin ecological niche, a significant transition around this time does seem likely, even though recent finds extend crude tool production back beyond *Homo habilis* to the late australopithecines (Lewis & Harmand, 2016).

Now throughout hominin evolution it has taken time for the significance of transitions to become apparent, in large part because the potential of evolved cognitive capabilities only becomes evident when they generate new adaptive behaviors in response to subsequent environmental change. So cognitive changes were slow to evolve and take effect. The causal inferences linking natural signs to food and predation that marked the first transition must first have been extended to the use of naturally occurring objects (sticks and stones) as weapons to defend against predators, to attack small prey, and to compete with other scavengers for raw meat, both of which led to dietary change. Conceiving a causal relationship between natural objects and their use led naturally to technological improvement of the former (for example, through breaking a stone to obtain a sharper edge). Improved hunting and competitive scavenging both promoted meat-eating; so causal inference promoted both technological advances and dietary change – which together enabled construction of a new sociocultural niche. The fitness implications of this development exerted selective pressure for increased capacity to conceive and store causal connections.

So what constituted the second major transition in hominin evolution, I maintain, was the extension of causal thinking to those areas of activity with the greatest fitness implications for inferential hominins living in social groups, namely conspecific behavior and the technological use of natural objects to construct a more favorable sociocultural niche. The former, referred to as 'theory of mind', entails inferring mental states (wants, intentions) as causes for observed behavior of social group members. The latter applies causal relationships to the modification of natural objects to improve their efficacy as weapons for defense and tools for material transformation.

The cognitive changes accompanying extension of causal inferences to new areas of activity did not consist simply in increasing brain size to accommodate more neural connections. For kinds of causes most efficiently to trigger appropriate motor responses, neural networks bunched inferences into discrete domains, or 'modules' (Geary & Huffman, 2002). Broadly speaking, causes intuited by early hominins bunched into three broad domains; to folk biology (to do with animal behavior and plant properties) were added folk physics (extending the properties of physical objects to processes applied in tool making) and folk psychology (applied to the motivation and behavior of conspecifics). Inferences in each of these domains had the potential to accrue fitness benefits by triggering new adaptive behaviors. But activation had to be both relevant and rapid, and the most economical way to activate motor responses was for causal connections to be instantiated in parallel, distributed, hierarchically-structured, neural networks linked to appropriate motor responses (Hunt & Hayden, 2017; Rissman & Wagner, 2012). The resultant cognitive architecture, dubbed 'massive modularity', has attracted criticism (Frankenhuis & Ploeger, 2007); but as the existence of several very specific modules, such as face recognition and fear of snakes or heights, is not in doubt, evolutionary psychologists have good reason to maintain that 'theory of mind' and stone working are likely to have comprised two originally distinct domains. What is also not in doubt is that both entailed extensions of causal thinking and differentiated storage.

Like the first, this second major transition had significant flow-on effects. I noted above that all causal inferences are in principle hypothetical. This was especially true when assigning motives to the behaviors of conspecifics where deception is always a possibility. If social inferences are not to cause anxiety, they require confirmation in order to afford a secure basis for action. But to provide confirmation, inferences had to be accurately transmitted to receiving brains. This requirement continued to drive the improvement of collectively endorsed proto-linguistic communication, both to confirm inferences, and to transmit components for 'repeated assembly' Caporael, 2003) of cognitive structures to others – by means of example and teaching, on which cultural accumulation by subsequent generations depends (Sterelny, 2012). Note that exactly replicated causal connections can be instantiated in different ways in cognitive structures, a process functionally similar to genetic assortment through sexual reproduction.

Improved lithic technology (Acheulian axes), planned hunting, meat distribution and use of fire in hearths that acted as social hubs (Foley & Gamble, 2009), all rest on the ability to extend causal thinking in the two ways indicated (social relationships and technology applied to niche construction), and to select behavior on the basis of envisaged outcomes. Such foresight, colorfully referred to as 'mental time travel' (Suddendorf & Corballis, 2007), rests on the ability to string together causal inferences – a competency expressed in the dance and mime sequences that communicate narrative accounts.

Finally what drove early *Homo* to devote time and effort to establishing social relationships and making useful tools was not just the existential need to maximize inclusive fitness: a powerful proximate driver was the satisfaction generated by the brain's complex reward system (Berridge & Kringelbach, 2015). That is to say, anticipation of pleasure associated with such behaviors biased their selection. This made for replication, but not necessarily for innovation: the form of Acheulian hand axes shows little change over almost a million years. In other words, the cognitive advances of the second transition provided only limited impetus for sociocultural evolution.

In summary, the second transition in human evolutionary history was brought about by the extension of causal thinking to motivation explaining social behavior and tool use for niche construction, each organized into its own differentiated modular domain. The satisfaction generated by these activities propelled sociocultural replication in what became an integrated co-evolutionary process, the effects of which, slow to materialize at first, in time prepared the way for a third major transition.

The Third Transition

The last significant increase in hominin cranial capacity was associated with the evolution of late species of *Homo*. Brain size began to increase in late *Homo ergaster* as early as 800 Ka, gained pace with the appearance of *Homo heidelbergensis* some 200,000 years later (Tattersall, 2012), and culminated in the evolution of new species of large-brained hominins from around 500 Ka. Among these, one line led to Neanderthals and Denisovans, while another led to archaic *H sapiens*, from which modern humans had evolved by 200 Ka (Foley et al., 2016). These developments broadly coincide with the third 'phase of substantial adaptive change' identified by Foley (2016), and were in response to changes in both natural and sociocultural environments (Foley & Gamble, 2009), including cyclical glaciations that occurred throughout most of this period.

The behavioral innovations of *H heidelbergensis* included large-animal hunting by coordinated groups using throwing spears, butchering of carcasses, and use of fire in prepared hearths, which together provided the nutritional advances (cooked food) necessary to meet the increased costs of larger brains (Wrangham, 2009). Other cultural advances included building simple shelters and a more varied lithic technology based on striking flakes and blades from prepared cores, a development that may have been reinforced by sexual selection (Miller, 2011). Together these advances equipped large-brained hominins to withstand the rigors of the ice ages in Europe, through behaviors that still only reflected the barest suggestion of symbolic and abstract thought.

From the point of view of evolutionary transitions, therefore, a distinction must be made between the adaptive changes that gave rise over the period 500-200 Ka to substantially larger brains that were common to *H neanderthalensis* and anatomically modern archaic *H sapiens*, and the cognitive advances associated with modern human behavior that became evident some time after 100 Ka. Behavioral modernity reached its apogee in our own species, *Homo sapiens sapiens*, but never fully developed in Neanderthals (Wynn & Coolidge, 2004). We must distinguish, therefore, between Middle Paleolithic changes in cognitive structure that accompanied and drove increased cranial capacity in large-brained hominins, and the Late or Upper Paleolithic developments in cognition that found expression in the form of personal ornaments and composite tools, burial rituals and cave art (Mellars, 2005; Conard, 2014).

Now much of the increase in cranial capacity during the Middle Paleolithic was due to expansion of the prefrontal cortex, which in modern brain/minds is where 'executive control functions' are located (Coolidge & Wynn, 2001). Yet the number of neurons increased more in the cerebellum than in the cerebral cortex (Herculano-Houzel, 2016), which suggests that complex linkages formed between memory storage and the selection and activation of behavior (Strick et al., 2009). Moreover, executive functions presuppose self as agent, able to imagine future scenarios, compute outcomes, and select between alternative courses of action; and it is unlikely that such a developed concept of self as agent evolved any earlier (Leary & Buttermore, 2003). That conjunction is more likely to have occurred in the early Upper Paleolithic, facilitated by extended working memory (Welshon, 2010).

Another suggested explanation is that cognitive evolution was driven by the expansion of general intelligence (Mithen, 1996). The domain-specific modular brain produced by the second transition enabled rapid motor responses to particular kinds of inference; but more complex niche construction depended on behavior that drew on inferences from across domains, which required coordination between them. While specialized reaction modules (to heights, spiders, etc.) were largely unaffected, and much cognition remained domain-specific (Hirschfeld & Gelman, 1994), the demands of more complex and innovative niche construction selected for superordinate integration across domains, which manifested cognitively as increased 'general intelligence' accommodated anatomically by increased brain size.

For superordinate selection of behavior to be rapid and reliable, however, inferences across technical, sociocultural and natural environmental domains had themselves to be hierarchically structured. This suggests that the integration of existing domains entailed more than the addition of connecting neural networks. They required more fundamental structural change in the form of neural reorganization. The cognitive architecture that evolved in the Middle Paleolithic then provided the hardware, as it were, on which Upper Paleolithic programs of symbolic communication and conscious selection of behavior could run. Through this process, the hominin brain evolved to become the human brain/mind, functioning as a nested selective mechanism, which, like the similaly functioning immune system (Hull et al., 2001), enhanced inclusive fitness by increasing individual capacity to survive and reproduce.

So what I propose is that the restructuring of cognition that came about during the Middle Paleolithic consisted of more than integration of modular domains and/or expansion of general intelligence. In addition it entailed differentiation of functionally distinct, but massively interconnected, memory systems, engaging different brain regions and with different processing modes (Henke, 2010). And what drove this development was selection for improved efficiency in selecting behavior in response to more rapidly changing environments, both natural and sociocultural. In the process, the relative influence of the two tipped in favor of the latter, and the pace of change in sociocultural niche construction began to accelerate.

Cognitive psychologists divide memory into four interacting systems: subconscious procedural memory for skills (stone knapping, spear throwing, bicycle riding); working memory, the platform for conscious thought; hierarchically organized semantic memory representing categories and the connections between them (Binder & Desai, 2011); and sequentially ordered episodic memory recording the images and associated emotions of personal experience (Tulving, 2002). While semantic memory assembles socially transmitted causal inferences to create a conceptual model of the world (worldview), episodic or autobiographical memory provides the temporal context for self-identity and agency. These two declarative systems work in conjunction: perceptions remembered as sequential images in episodic memory, while at the same time evoking categories and connections in semantic memory, at the upper abstract level of which self was conceived as a core conceptual component of worldview. Unlike procedural skills, both declarative memory systems are accessible to enhance working memory, which, by providing a platform for the preview of alternative scenarios and their consequences for self and significant others, constitutes 'the final piece in the evolution of modern cognition' (Wynn & Coolidge, 2011).

Now in all animals the ultimate goal of maximizing inclusive fitness is reinforced by the proximate (unconscious) reward system of the brain (Berridge & Kringelbach, 2015); and forming and acting upon confirmed causal inferences were undoubtedly similarly reinforced in early hominins. As the human brain/mind became fully conscious, rewards associated with alternative behaviors could be previewed and compared, and a selection made intended to maximize pleasurable feelings and minimize painful ones – taking into account the vicarious pleasure derived from responses of significant others. Note, however, first that the proximate urge still remains partly unconscious; and second that selection never depends on rational comparison alone: it is always subject to the biases exerted by individual values, interests, moods and desires (Clore & Huntsinger, 2007).

With the evolution of consciousness and agency, the existential urge to survive and reproduce was eventually superseded as the determinant of behavior by the desire, part unconscious, part conscious, to maximize what I have called 'inclusive satisfaction', which is to say the sum of the satisfaction experienced personally through selecting a course of action, plus the expected satisfaction to be derived from it by significant others (Stuart-Fox, 2015a). And as cultural production became more elaborate and the pleasures it offered gained increasing salience, this desire provided the impetus for the self-sustaining sociocultural evolutionary processes associated with niche construction. Note that maximization of inclusive satisfaction never entirely displaces maximization of inclusive fitness, the best example of the two working in tandem being the pursuit of sexual pleasure – at least until the advent of contraception; and nor does sociocultural selection entirely eliminate natural selection (Cochran & Harpending, 2007).

What I am arguing, in summary, is that the third transition marked the ultimate stage in the evolution of the human brain/mind as a system for the conscious selection of behavior, and that this transition was brought about not primarily through integration of cognitive domains (which must have been breaking down for some time in response to the demands of social living and niche construction), but through the differentiation of long-term memory into functionally distinct procedural (unconscious skills) and declarative (consciously accessible) components, and the latter into episodic (self and agency) and semantic (worldview and belief) systems, with their interaction presided over by a much expanded executive prefrontal cortex – the whole requiring a considerable increase in brain size. This composite memory system evolved because it increased inclusive fitness by providing the means to respond more quickly and efficiently to environmental contingencies, natural and sociocultural. The human brain/mind resulting from the third transition functioned, like the immune system, as an independent nested system – not primarily to increase inclusive fitness, however, but to select behaviors that would maximize inclusive satisfaction (Stuart-Fox, 2015a). Once evolved, however, this brain/mind had the potential to construct quite different worldviews in response to natural and sociocultural environments, though to realize that potential required further cognitive advances.

So to recapitulate phase 1: the major transitions that occurred in the course of hominin evolution related not to anatomical form, but to changes in the function and cognitive structure of the brain/mind made possible by increases in brain size. (Edelman, 1998). This is hardly a contentious claim, for cognition more than anything else is what distinguishes us from other primates and accounts for our success as a species. Over the course of hominin evolution the primate brain evolved into the human brain/mind, from an organ whose functional task was to correlate perceptions and reflexively activate behavior to one capable of consciously comparing alternative courses of action, and of selecting one in preference to others. Driven by the need for rapid selection of behavior maximizing survival and reproduction in variable environments, the human brain/mind evolved to become an emergent system for the conscious selection of behavior maximizing inclusive satisfaction within the context of environmental niches constructed and reconstructed by the very behaviors selected.

The Fulcrum: From the Evolution of Cognition to Sociocultural Evolution

The third transition created a brain/mind capable of performing two extraordinary cognitive algorithms. The first was to organize intuited and learned inferences, categories and concepts in semantic memory to form an integrated mental model of the world and the way it works (worldview). The second was to sequence experiences and events in episodic memory to construct the temporal basis for an enduring concept of self as agent. Working memory provided not only access to both systems, but also a platform for the selection of behavior designed to maximize inclusive satisfaction in response to pressures exerted by ongoing construction of the sociocultural niche (Damasio, 2010). This new cognitive structure had the potential, therefore, to transform niche construction from ecological adaptation focusing on food, protection and reproduction to sociocultural adaptation pursued as an end in itself, because continuous production of the sociocultural niche provided opportunities to maximize inclusive satisfaction.

Realization of the potential inherent in the structure and function of this new memory system depended, however, on two associated cognitive developments. One was to meta-represent causal inferences and other conceptual relationships; the other to communicate them. Meta-representations are both abstract and symbolic: they enable inference of higher-level conceptual relationships to figure in the hierarchical construction of worldviews (Binder & Desai, 2011), along with new kinds of abstract associations (metaphorical, allusive, analogical). Both had the effect of directing brain activity from perception to thought, and on to its application, via inferences of meaning, to the selection of behavior. Together they transformed niche construction through expanding the cognitive foundations of social organization and cultural production.

Meta-representations constructed in brain/minds can only influence sociocultural evolution if they are socially communicated – which is to say that worldviews necessarily coevolved along with the means to transmit the abstract relationships that comprise their upper hierarchical levels. The evolution of language as the primary mode of symbolic transmission of inferences and meanings, supplemented by messaging conveyed through visual art, participatory rituals and material products (Lake, 2008; Straffon Mendoza, 2014), accompanied assembly of increasingly complex worldviews. The combination of meta-representation of abstract cognitive relationships and symbolic language as the means of transmitting component connections for the reassembly of worldviews constituted the fourth transition in human evolutionary history, for together these provided the leverage required to accelerate sociocultural evolution, and point it in new directions.

The Fourth Transition

The third transition in hominin evolution did not immediately produce the suite of behaviors we associate with modern humans. Like previous transitions, its implications became evident only over the course of continuing developments played out in parts of Africa in response to environmental exigencies. Challenges posed by the interglacial period beginning around 130,000 years ago were met by exploiting the cognitive potential provided by the third transition. Indications that archaic humans were beginning to understand their world in new ways came with such innovations as personal ornaments (beads), carved geometric designs on bone and ivory, and production of microlithic tools and weapons designed for specific purposes. This period apparently witnessed more than one dispersal of archaic *Homo sapiens* out of Africa into areas of Eurasia already populated by other large-brained hominins

(Neanderthals, Denisovans) (Bae et al., 2017). Not until our own sub-species, *Homo sapiens sapiens*, embarked upon a definitive dispersal around 70,000 years ago, however, did modern humans go on to populate the globe. DNA studies have shown that all human groups participating in this second dispersal were descendants of a single, relatively small ancestral population probably located in East Africa (Marks, 2017).

Homo sapiens sapiens designed new composite tools, buried grave goods with and applied decoration to the bodies of the dead, and produced the first cave art. All provide evidence for the increasing role of abstract cognition and self-reflective agency in collective sociocultural niche construction (Deacon, 1997). Whether or not the cultural developments of the Upper or Late Paleolithic constitute a 'revolution' may be debated (Bar-Yosef, 1998a): what is certain is that the cognitive competences they reveal launched human history on a new trajectory.

Just when and where the components of this fourth transition came together is impossible to determine, for human populations responded differently to environmental challenges in different parts of Africa and Eurasia. What is clear, however, from carved figurines and cave art, is that the behavioral innovations expressed in their creation reflected new kinds of abstract and symbolic relationships and meanings constructed in human brain/minds. Symbolically communicating these relationships and meanings in language and art ensured not only their replication in receiving brain/minds, but also the consistency of worldview necessary to ground group identity, minimize anxiety and promote solidarity.

The extension of causal thinking to abstract categories that offer mythic explanations of such unexpected and uncontrollable events as natural disasters, sickness and death led to construction of ever more sophisticated and complex worldviews. These stand as the most remarkable products of human creativity. Despite the precision of language, however, their selective assembly in receiving brain/minds made exact replication problematic. Hence the importance of reiterating core meanings through ritual and art, and of reducing anxiety by minimizing cognitive dissonance (Harmon-Jones & Harmon-Jones, 2007). Shared worldviews as systems of belief coordinating social action added a reassuring dimension to sociocultural niche construction.

Shared worldviews conferred fitness advantages by reinforcing the social cohesion required to undertake more complex, cumulative, and rewarding niche construction. At the same time shared worldview sharpened inter-group difference, so increasing the role played by group selection in sociocultural evolution (Wilson, 2010). As worldviews are epigenetic constructs, their assembly is highly flexible: children raised in any sociocultural environment will assemble an appropriate worldview. Such cognitive structural flexibility enabled humans rapidly to adapt to new environments encountered through migration driven by population increase and the fission of social groups. So like the biological transitions identified by Szathmáry and Maynard Smith, the fourth transition opened the way for rapid 'speciation', not of organisms, but of sociocultures.

The evolution of language has been the focus of intense study and speculation (Hauser et al., 2014). Its roots go back to gestures and sounds, in mime and song, used to convey and confirm causal inferences. I have argued that what drove improved communication was the need to reduce anxiety through social confirmation of hypothetical inferences, with respect not just to hostile natural environments, but also to the motivations of conspecifics. The proto-language that evolved to meet this need prepared the way for the evolution of a fully symbolic system capable through hierarchical and recursive syntax of communicating the richness and complexity of abstract concepts and cognitive relationships (Fitch, 2010).

There is growing consensus that syntactic language evolved during the early Upper Paleolithic (Fitch, 2017), which I have argued paralleled the construction and communication of abstract components of worldviews. In other words, language evolved in tandem with the higher-level inferences of belief systems; that is, in conjunction with the meanings integral to symbolic thought (Tattersall, 2016). And what drove this coevolution of cognition and communication, apart from reduction of anxiety, was the satisfaction generated by participation in activities that reinforced social cohesion and transmitted common cognitive cultural constructs, through storytelling, ritual and dance, and all that adds significance and pleasure to sociocultural niche construction.

The coevolution of cognition and communication during the Paleolithic accounts for the cognitive cultural advance from archaic to modern *Homo sapiens*. By providing the means by which abstract components of cognitive structure could be transmitted symbolically, language became the principal mode of inheritance in sociocultural evolution. In so doing, language communicated the socially endorsed customs, rules and (eventually) moral principles, all of which acted as selection pressures to limit selfish goals and intentions and promote cooperative participation within social groups. Applied to niche construction, the potential for variation in the high-level inferences incorporated into worldviews unleashed a burst of sociocultural diversity manifested in hunter-gatherer adaptations to new environments (Pagel & Mace, 2004). Note, however, first that cognitive selection between the imagined outcomes of alternative behaviors is seldom determined solely on rational grounds, but rather reflects psychological biases, emotions and personal intentions (Clore & Huntsinger, 2007; Gowlett et al., 2012); and second, that insofar as any worldview fails to reflect actual environmental conditions, selected behavior based on it will inevitably have unintended consequences.

In summary, therefore, the fourth transition provided the cognitive means for more effective selection of behavior. The ability to construct new worldviews conceptualizing new environments encountered through migration enabled sociocultural niche construction to adapt more rapidly, and in new ways. As evolving entities, sociocultures and species share formal similarities. Both are population phenomena; and both evolve through generalized Darwinian mechanisms (replication of selected variation producing descent with modification) (Sober, 1980) – which is why their dual effect can be modeled as a co-evolutionary process (Durham, 1991). The cognitive advances constituting the fourth transition propelled sociocultural niche construction in new directions and provided added impetus to sociocultural evolution.

Phase Two: Transitions in Human History

The second phase of human evolutionary history begins with the fourth transition in the Upper Paleolithic. Over the following 70,000 years modern humans became a global species, thereby demonstrating a remarkable ability to adapt to a wide range of environments. This was achieved not primarily by means of biological evolution (though small variations in skin color and body shape did occur), but overwhelmingly through sociocultural adaptation.

Broad acceptance exists that cultures evolve (Whiten et al., 2011; Mesoudi, 2016) – if less on whether the process is Darwinian (Claidière et al., 2014). I have argued elsewhere that, as population phenomena, sociocultures evolve through selection on three reductively related levels: at the macro-level through the selection of coordinated action by organized groups; at the level of the individual through selection of behavior; and at the cognitive level through selective assembly (and subsequent expression) of causal (and other) inferences to form integrated worldviews. These three levels are broadly analogous to selection of groups, organisms and genes in biological evolution (Stuart-Fox, 2015a).

Hunter-gatherer adaptation focused primarily on the exploitation of new food resources, and ways to hunt, snare, collect, share and cook them. Medicinal properties of plants were noted and remembered, and the ways of animals observed, recounted and explained. Body ornamentation in one form of another became universal, and clothes were made to suit colder climates. But a nomadic lifestyle limited how many cultural artifacts could be transported, and so too the extent to which any natural environment could be beneficially modified. Material niche construction was confined to temporary hearths and shelters and a limited range of transportable goods. Social relationships remained broadly egalitarian

(Boehm, 2009). What did evolve and diversify was hard-won information about new environments, integrated into group-specific worldviews rich in myth and metaphor, history and meaning, which served both to anchor identity, and to select the social activities (story-telling and chanting, ritual and dance, ceremonial initiation and custom) that ensured their replication.

As human groups constructed ever more complex sociocultural niches, the pressures these exerted on the selection of behavior became increasingly significant. This opened up the possibility of modifying these pressures through concerted human action, in a way that was never possible with respect to the natural environment. Niche construction could defend against some natural selective pressures, but it could not alter them – the weather remained unpredictable; predators remained dangerous. Since sociocultural niches were constructed by human activity, the pressures they exerted on those born into them could, however, be modified – once the means to do so became apparent. Effectively this required manipulation of evolutionary process, which could be done on two ways: by intensifying selective pressures on behavior (through concentrating social power); and by maximizing variation (through creating conditions encouraging production and application of new knowledge). The two key transitions that have occurred in human history each exploited one of these means, both of which had the effect of accelerating the rate of sociocultural change, expanding the scope of niche construction, and promoting within-niche differentiation. The next significant transition will combine both.

The Fifth Transition

Anthropologists and pre-historians unanimously agree that a major watershed was crossed when Neolithic hunter-gatherers began to establish permanent settlements, cultivate wild cereal grains and domesticate animals. This radical change in lifestyle took place as early as 12,000 years ago in the Levant, and later elsewhere (Barker, 2009). What drove this 'Neolithic revolution' is disputed, since crops are less nutritious and diverse than wild food, more time-consuming to grow, and more vulnerable to loss through pests or drought (Simmons, 2011). It did not occur when it did for prior want of knowledge: hunter-gatherers knew very well how plants propagate, and may well have helped them do so. Suggested causes for the 'Neolithic revolution' include population growth, climate change, the availability of suitable wild species, and territorial control and defense. All may have contributed at different times and in different places; but in every case, cultural and ideological factors were also in play (Watkins, 2010)[2] – the former derived from the satisfaction inherent in more extensive niche construction; the latter from how these earliest farmers understood their relationship to the world in which they lived.

Subjective feelings and intentions are not the sort of causes hard-headed paleoanthropologists are comfortable with, but they are primary motivations for human behavior. Many Late Paleolithic objects reveal extraordinary care and attention to detail, but apart from their role in sexual selection, there has been little discussion of any psychological satisfaction associated with their manufacture. For hunter-gatherers, however, the number of such objects they could carry was limited. Only in sedentary communities were opportunities available to maximize inclusive satisfaction, not just by accumulation of prized items through trade, but by means of more extensive and rewarding niche construction.

Sedentism, the occupation of a home base for a prolonged time, was not unknown among hunter-gatherers, as large shell middens attest. As only marine resources could provide year-round sustenance, semi-sedentary hunter-gatherers mostly lived near the sea. Modern ethnographic studies show that in such societies, not only did sedentism encourage accumulation of cultural goods as private property (Bowles & Choi, 2013), it also allowed status differences to develop, based on hereditary rights to exploitation of specified resources; for example, to gather shellfish from defined areas of seabed (Ames, 2003).

Sedentism is not an all-or-nothing condition. Most hunter-gatherers had bases associated with seasonal food resources to which they regularly returned. If foods required heavier implements to process (grinders for grains, for example), then once manufactured these were left in place for the following year, as were the foundations of shelters made to last more than a few nights. Pre-conditions already existed, therefore, for Natufian hunter-gatherers in the Levant to make the momentous change to sedentary living (Bar-Yosef, 1998b). So what was attractive about it? Easier care of children and lower infant mortality might have been one; better protection, improved means of food preparation, and storage of more food for longer might have been others. But equally important, I would argue, were the increased opportunities to maximize inclusive satisfaction made possible by sedentary living, which led inexorably to more extensive niche construction.

Sedentism extended niche construction beyond the limit of habitation defined by a settlement, by modifying the immediately surrounding natural environment through productive labor. Hunter-gatherers appear to have done this by assisting propagation of food-producing trees and shrubs and grasses *in situ* (Zeder, 2011), but early horticulturalists deliberately planted them in the vicinity of settlements, and tended them year-round – that is, they constructed their own ecological niche (O'Brien & Laland, 2012). In other words, the transition from hunting and gathering to an agricultural economy was not simply a response to environmental exigencies or increase in population. What encouraged human groups to engage in agriculture was the increased inclusive satisfaction experienced when they settled in one place for longer periods of time and were able to construct more permanent and more comprehensive sociocultural niches.

Archaeological evidence suggests, however, that another factor was involved, that the shift to settled agriculture was propelled by change in how the relationship between social groups and their environment was conceptualized and understood – which is to say, it included a cognitive, or 'ideological', dimension (Cauvin, 2001). As noted above, the hierarchical structure of cognition encouraged conceptualization of increasingly abstract and symbolic categories and relationships between them. Among these categories was the class of supernatural beings (spirits, demons) whose agency was believed to explain all sorts of mysterious phenomena, from extreme weather events, sickness and death to tripping over a tree root and sounds in the night. Belief in unseen beings is characteristic, in one form or another, of all human groups, including modern hunter-gatherers, and plays a significant role in the shared worldview underwriting group identity (for each group conceived its own deities). For small human groups seasonally migrating around defined territories, some unseen beings became identified with natural locations that were remarkable in some way. Over time, the supernatural beliefs of particular groups evolved further in two ways. One was by ascribing greater power to one or more of these beings. The second was in the forms of worship and sacrifice offered in those places where such beings were believed to reside. Both developments were evident in the Khiamian culture that flourished in the Levant between about 12,200 and 10,800 years ago (Cauvin, 2000).

Worship at a sacred site does not necessitate permanent settlement. At Göbekli Tepe in southeast Anatolia, archaeological excavations have revealed no settlement associated with the megalithic temple there (Dietrich et al., 2012). It would appear, therefore, that Göbekli Tepe was constructed as a ceremonial center of worship, attracting people from a wide area at auspicious times to perform rituals that would both have reflected and reinforced their shared worldview and identity (Kyriakidis, 2007). Such locations endowed with special significance sanctified a defined territory, and generated a sense of belonging within a landscape through promoting common practices among a dispersed population (Boyd, 2006).

My argument, in summary, is that the transition to an agricultural economy was not just a response to pressures exerted by the natural environment. Cognitive factors, notably the desire to experience sources of satisfaction associated with niche construction and the group activities associated with the inclusion in worldviews of conceptualized divine beings demanding propitiation, were also significant in bringing about the shift to sedentary living.

But why did sedentism mark a major transition? The answer lies in the potential sedentary niche construction provided for accelerated sociocultural evolution due to deliberate human intervention in the evolutionary process. As noted above, this could be done in two ways: through altering selection pressures, or through increasing the availability of variation. And as also noted, these interventions apply on three levels: the cognitive (what cognitive connections get included in worldview), behavioral (what actions get selected as part of an individual's repertoire) and group levels (what actions coordinated groups decide to undertake). Sedentism, I maintain, opened up new possibilities of increasing selective pressures on all three levels, so altering both the direction and pace of sociocultural evolution.

Now in small, nomadic, multi-family bands of hunter-gatherers, family heads was relatively equal. If one group member temporarily gained power (for example, as leader of a war party) others joined forces to restore relative equality once the crisis was over (Boehm, 2009). Minimal opportunities existed, therefore, for a subgroup to concentrate sufficient social power to determine the behavior of all other group members. Social relationships in subsistence sedentary communities would at first have been similar, but in time status differences developed based on property or descent, allowing within-group social elites to form. The power accruing to such elites could then be applied to maximize their inclusive fitness (by taking more wives) and their inclusive satisfaction (through, for example, luxury consumption). Social structural innovations that did this most effectively changed the dynamics of niche construction in significant ways – and hence the direction of sociocultural change.

The opportunity to concentrate social power and apply it as selective pressure was the crucial new evolutionary ingredient in sedentary societies. Such pressure could be applied coercively, to constrain group action, or through intimidation to control individual behavior, but as Antonio Gramsci (1992) well understood, it was most effectively applied at the cognitive level to shape worldview. Shared worldview legitimized the right of political elites to impose taxation, exact corvée labor, and enforce compliance with top-down regulation. Such legitimizing worldviews were propagated by control over the social transmission of key components (through education, for example), reinforced by public participation (in shrine construction, ritual worship, military parades, and so on).

Replication of legitimating worldviews over successive generations reinforced the social power of ruling elites (of city state, kingdom, or empire) by naturalizing social structural differentiation. Hierarchical organization provided social groups with the structural cohesion necessary to compete with other groups, whether through elite-directed niche construction (of temples and palaces, cities and economies), or in mobilization in the face of threats to group welfare (by raising armies, building defensive ramparts).

The organization of social hierarchies had two interconnected emergent outcomes: one was the appearance of group-level traits associated with different forms of structural organization; the other was more intensive inter-group competition. Groups competed in inter-group arenas on the basis of their group-level traits, selection favoring the better organized (disciplined Roman legions versus undisciplined barbarians) or the more innovative in applying new technology, discovered or borrowed (long bow, stirrups, gunpowder).

In early societies, hierarchical concentration of social power favored authoritarian forms of governance. Behavior that might threaten sociopolitical elites was subjected to strong selective pressure by coercive means. But other kinds of social power were also available, notably economic, through the accumulation of wealth and control over conditions of employment, and political, through social organization and administration (Mann, 1986). In some societies, political structures remained remarkably stable over centuries, even millennia. Others were more ephemeral. Alternative structures distributed social power more or less evenly: the democracy of Greek city states like Athens vis-à-vis the autocracy of Persia. The evolutionary significance of the contrast lies in the extent to which coercive selective pressures limited variation. Nowhere in the ancient world was human thought as free to flower as in the divided and competitive city-states of Greece, and nowhere were social and cultural innovation more evident. What the Greeks lacked were overriding, supra-city, political and legal structures to promote cooperation over competition. That organizational innovation was left to Rome to apply – and Han China and Mauryan India. Where social power was concentrated, whether in the hands of state or church, innovation was restricted – and so too sociocultural change. For as Ernest Gellner (1988, p. 131) noted: ‘The preservation of order is far more important for societies than the achievement of beneficial change.’ So in conclusion, the impetus delivered by the fifth transition to sociocultural evolution derived not from increased economic production, but rather from how sedentism enabled elite sub-roups to concentrate social power and use it to exert selective pressures on the transmission and assembly of worldviews that justified limitations on the behaviors of individuals and groups. These pressures shaped divergent trajectories for different societies (Shennan, 2011), which then competed with and borrowed from each other. In this concentration and application of social power to construct sociocultures specifically benefiting elites lay the significance of the fifth transition.

The Sixth Transition

Most macrohistorians would identify the industrial revolution as a major historical transition, on the grounds that it introduced a new, soon to be dominant, mode of production based on industrialization and capitalism (Galtung & Inayatullah, 1997). From its inception in Britain in the late eighteenth century in the fields of textile production, transportation and metallurgy to its extension throughout Europe and North America in the nineteenth, the industrial revolution was marked by the application of new technologies to facilitate more complex (and rewarding) niche construction. The quickened pace of sociocultural evolution that resulted was due to two factors: increased variation in the form of new knowledge; and changes in selective pressure resulting from redistribution of social power. Together these provided new opportunities for individuals and groups to behave in novel ways that maximized inclusive satisfaction through diversifying niche construction.

In any generalized Darwinian evolutionary system, greater variation opens up more possibilities for change – but only if environmental selective pressures permit transmission and replication. Just as biological species with minimal variation are unable to adapt to rapidly changing natural environments, so societies in which vested interest groups stifle innovation have difficulty adapting to rapidly changing sociocultural environments. And if no variation exists, populations of any kind, whether species or sociocultures, cannot evolve at all, for 'selection depends on the generation of variation' (Sterelny, 2006, p. 139). Where variation is suppressed, the pace of evolutionary change will be slow; where it is promoted change is likely, potentially at least, to be more rapid.

In small social groups shielded from outside influence (like ultra-orthodox Jews, or the Amish), cognitive variation is minimal. In larger, more complex, socially differentiated populations open to new ideas, the potential for variation is greater. But whether new cognitive variants can be expressed in behavior still depends on the strength of selective pressures that can be brought to bear within the sociocultural environments in which they arise. The more concentrated the sources of social power (political, ideological, administrative), the less likely it is that new variants that challenge elite dominance would be allowed expression – let alone that production of variation would be encouraged.

In the mid-sixteenth century, powerful authoritarian regimes held power all across the civilized world – in China the Ming dynasty, in India the Mughals, in the Middle East the Ottoman empire, while in Europe monarchs ruled everywhere but for the Swiss cantons. All were backed by politico-religious organizations providing legitimation in return for patronage – bureaucratic Confucianism, the Islamic Caliphate, and Catholic or Orthodox or state-Protestant churches. The combination of secular authority and religious orthodoxy effectively ensured the replication of dominant worldviews with minimal modification, through the power available to them to exert selective pressure to prevent propagation of novel inferences that might undermine monarchical power or conflict with religious belief, as Galileo Galilei discovered to his cost.

Unlike the other great centers of civilization, however, in Europe social power was sufficiently fragmented to allow innovatory ideas that attracted selective suppression in one jurisdiction to be entertained in another – even as use of a common language of scholarship (Latin) facilitated transmission of new ideas. To rediscovery of first Greek philosophy, then Greek science, during the Renaissance was added renewed interest in 'nature-knowledge' (Cohen, 2015) derived from empirical study of the natural world, a pursuit justified on the grounds that it revealed the glory of God's creation (Gaukroger, 2006). Add to this the changing sociopolitical environment brought about by the wary tolerance of difference that followed the exhausting wars of religion; competition between European courts to attract brilliant minds, which allowed those out of favor to find safety and patronage elsewhere; and the possibility in some places for intellectuals to form independent associations, beginning in 1662 with the Royal Society of London, the institutional independence of which in time was extended to universities (Gaukroger, 2016).

These conditions allowed application of the scientific method to become the principal means by which to generate new knowledge. In part, science triumphed because its methodology incorporated an evolutionary algorithm that ensured that science was not just cumulative, but in addition generated its own momentum (Hull, 2010). New applications of scientific knowledge offered new ways of niche construction – provided countervailing selective pressures permitted. As late as the mid-nineteenth century, Darwin delayed publishing his theory of evolution because he foresaw the religious resistance it would encounter – and still does, despite overwhelming empirical evidence, from those espousing worldviews incompatible with it. And opposition to science continues, not least in the form of doubts propagated by powerful interests as to the causal link shown to hold between climate change and burning of fossil fuels. New science only gives rise to novel behavior if social and political selective pressures permit (McCauley, 2013).

The industrial revolution applied science, through technology, to niche construction. It began in Britain, not because curious inventers suddenly decided to devote their minds to technical problems, and nor because they anticipated windfall profits. A special set of conditions was necessary. In Britain, the selective sociocultural environment comprised institutional structures of law and governance, which, in conjunction with favorable economic opportunities, encouraged rather than suppressed communication of scientific discoveries and application to technology. Both were possible because institutions did not stand in the way of innovation. And this was because in England, more than anywhere else at the time, social power had been redistributed away from the monarchy, the aristocracy and the church to include rural gentry and the mercantile and professional middle class. This made it less likely that any single subgroup could exert sufficient selective pressure to suppress innovation – especially as several promised increased inclusive satisfaction if acted upon. As a result, science and the technologies it spawned were able to transform sociocultural niche construction. In the words of one recent study on the origins of the industrial revolution:

> Britain became the leader of the Industrial Revolution because, more than any other European economy, it was able to take advantage of its endowment of human and physical resources thanks to the great synergy of the Enlightenment: the combination of the Baconian program in useful knowledge and the recognition that better institutions created better incentives (Mokyr, 2009, p. 122).

In other words, the industrial revolution was the result of the fortuitous conjunction of new scientific knowledge with political and social institutions that encouraged rather than impeded its application to sociocultural nice construction. The advantages Britain gained over competing European powers then acted as incentives for other countries to create similar conditions.

Without the scientific revolution, no industrial revolution would have occurred. Only when scientific knowledge (new causal inferences) had been replicated and integrated in brain/minds could it be selectively applied through derivative technologies to niche construction. In this way, the diffusion of scientific knowledge accelerated the pace of sociocultural change. Two factors were at play: along with multiplication of variation went reduction of selective pressures that would otherwise have thwarted both transmission and application. For even the most brilliant inference can have no impact on sociocultural evolution unless expressed in behavior (including, of course, speech acts and writing).

How new inferences are constructed, under what circumstances, in one brain/mind rather than another, remains mysterious, though thinking long and hard about a challenging problem seems to assist the formation of new neural connections. Once formed, new causal connections need to be integrated into existing cognitive structure. So unlike genetic mutations, innovative causal inferences are not entirely random, for in the first place they depend on how environmental challenges are perceived and interpreted within an existing worldview; and in the second, on whether they can be integrated into that worldview without generating dissonance.

The scientific revolution was most effective in accelerating sociocultural change in countries where political power was sufficiently distributed to allow brilliant minds to construct new causal inferences and communicate them to others (Arbilly, 2018). Democratic government permitted independent research and reduced the kind of inhibitory selective pressures authoritarian regimes exert on incompatible innovation. This allowed entrepreneurs to maximize their inclusive satisfaction by producing products that allowed consumers to do the same. In this lay the appeal of capitalism; and was the means by which variation produced through scientific research accelerated the pace of rewarding sociocultural change.

In summary, the scientific revolution brought about a sixth transition in human evolutionary history, because it led to the institutional multiplication of cognitive variation that could generate new behaviors. Like other transitions, it was slow at first to reveal its potential; but as science increasingly found application in technology and industry, the pace of innovative niche construction quickened. By deliberately seeking and communicating new causal relationships, science increased the potential for variation to be expressed in behavior that would accelerate sociocultural evolution. Only when scientific understanding had become embedded within the prevailing Christian worldview, however, could the pursuit of scientific knowledge become institutionalized, and this took time – a process arguably going back to the twelfth century when Peter Abelard successfully claimed a role for rationality in Christian discourse, not long after a similar claim for a role in Islamic discourse had been decisively rejected. By the mid-eighteenth century sociocultural selective pressures were sufficiently relaxed in Britain to permit the trialing of new technologies. Their application to niche construction to build infrastructure and manufacture consumer durables generated its own momentum through increasing inclusive satisfaction.

The Seventh Transition

It is always difficult for those living in a time of transition to comprehend, or even be aware of, the significance of historical processes they are caught up in, but most would agree that the pace of sociocultural change over the last half century has been remarkable. Technological innovation has been the principal driver: in communications, space exploration, weapons, materials, medicine, and the list goes on – all stemming from the scientific revolution. Meanwhile consumerism has continued apace, driven by our insatiable urge to maximize inclusive satisfaction through accumulation and consumption of ever more new goods and services. All these developments can be understood as due to ongoing manipulation of the evolutionary process through increasing variation and altering selection pressures. But neither increased use of technology nor increased consumption, despite their considerable impact on niche construction, amount to a new transition.

Two developments, however, might signify qualitative rather than quantitative change. Both are breakthroughs in technology with unpredictable long-term implications: computers and robotics. Together these have the potential to impact on the mechanisms of sociocultural evolution, with incalculable consequences. Indeed, the first signs are already evident. Storage of information outside the brain/mind has been going on since before the invention of writing. But two things are notable about what is happening now. One is that the mega-data crunched by computers is so voluminous that no human brain/mind could comprehend it; and the second is that knowledge so produced can and is being applied without human intervention (as when computers process feedback to improve design of robots). And because computers can direct robots to perform tasks more quickly and efficiently than humans can, together they have the potential to accelerate evolutionary change.

Robots are already shaping our contemporary world – from production assembly lines to predator drones to driverless cars. Robots mine for minerals, explore the ocean bed, and land on neighboring planets. And we are already beginning to see service robots in homes and hospitals and shops. Nanotechnology promises minute robots capable of cleaning arteries and removing cancers. All require programming. But already a further evolutionary development is becoming possible – that both computers and robots could be controlled by thought alone through brain-computer interfaces (Wolpaw & Wolpaw, 2012). Indeed in the opinion of one robotics engineer: ‘it is merely a matter of time before human-robot couplings greatly outperform purely biological systems’ (Nourbakhsh, 2015, p. 25).

In terms of sociocultural evolutionary processes, a transition to brain-mind-computer control and drive systems is likely to have implication for both niche construction and social structures. Not only would production increasingly be performed by robots, so too would systems management. Niche construction will extend to management of natural systems, and so would increasingly determine the conditions under which all species exist. Through their supervision of the global environment, such systems would determine where wolves should be reintroduced, or panda habitat conserved.

The social implications of robotic niche construction under the control of brain-computer interfaces could be far-reaching. As robots make other robots and computers become ever smaller and faster, running robotic systems would increasingly be the preserve of technocratic elites linked into such interfaces. Alliances between political and financial and technocratic elites would be tempted to exert strong selective pressure to promote their interests (maximize their inclusive satisfaction), and contain mass demands through use of robots to apply coercive force. What new sociopolitical structures might emerge is impossible to predict, but already social mega-data is being used to the benefit of powerful individuals and groups.

My purpose here is not to depict a dystopian future; rather it is to discern the possible contours of a seventh transition, if indeed that is what is underway. The fourth transition provided the means (symbolic representation) for transmission of creative cognitive inferences, their replication and integration into worldviews, and use of these to select adaptive behavior; the fifth opened the way for elites to concentrate social power and use it to exert selective pressure to construct sociocultural niches designed to maximize their own inclusive satisfaction (by prioritizing preservation of existing sociopolitical institutions and the worldviews that legitimized them); while the sixth multiplied variation while reducing selective pressures constraining transmission and expression. So what might be happening in a seventh transition?

The first point to note is that, as also occurred in the biological evolutionary record, each transition has given rise to the relatively rapid proliferation of new structures, of new hominin species following the first three cognitive advances, and of new forms of sociocultural organization and niche construction following the next three. So if, as seems likely, a seventh transition is underway, we can predict with some confidence that it will yet again accelerate the pace of sociocultural evolution, and that it will do so by manipulating evolutionary processes.

One way in which this might happen could be through combining the interventions that brought about the fifth and sixth transitions: that is, to use greater concentrations of social power to promote variation in specified domains (for example, through encouraging innovations in computing and robotics only as applied to military technology); or to select just those innovations that maximize the inclusive satisfaction of power elites – including the satisfaction that comes from exercising power. Since the sixth transition, history and theory combine to make the case that open democratic institutions are more effective than closed political systems in generating and applying variation to accelerate sociocultural change. But authoritarian regimes (like China) can promote scientific innovation applied to specific kinds of technology, such as weapons systems or computing, while suppressing innovation in other areas – all to the benefit of the ruling elite.

More likely is that a seventh transition will be driven by cyborgs, brain/mind/computer interfaces (Mühl et al., 2014) that incorporate technology into cognition in ways that largely free selection of behavior in response to existential challenges from psychological biases. Variations generated by such 'human-robot couplings' would more precisely respond to existential challenges (by, for example, engineering sustainable systems on a planetary level to prevent catastrophic systems failures, or embarking on extra-terrestrial migration). Moreover, they would do so not primarily in response to an urge to maximize inclusive satisfaction within constructed sociocultural niches, but rather to an emergent existential drive to ensure cyborg survival on a planetary scale within our solar system and beyond. This sounds like science fiction. But science has a habit of following up on what science fiction first imagined – precisely because science fiction allows free rein to creativity, and some at least of these new cognitive connections may be selectively expressed in new behaviors. And indeed there is some evidence that such a cyborg seventh transition is already underway.[3] If it is, the seventh transition could represent a second fulcrum in human evolutionary history as momentous as that leveraging hominin cognition to drive sociocultural evolution, and the pace of change in how we construct our globally extended niche will accelerate yet again.

Finally, some indication that we might indeed be approaching a seventh transition is provided by the pattern of previous transitions in human evolutionary history discernable in the sequence as a whole; for such transitions have occurred ever more frequently, with intervals decreasing from millions of years to perhaps mere hundreds. The intervals between the successive transitions outlined above have roughly been as follows: 3 million years, one million years, 100,000 years, 50,000 years, and 10,000 years. We can expect, therefore, that the interval between the sixth and a seventh transition to be shorter still – perhaps no more than 500 years if a seventh transition is already underway.

So to summarize: I have argued that the sequence of major transitions in human evolutionary history began when the earliest hominins evolved the capacity to infer the causes of natural signs, initially stored in relation to cognitive maps, but subsequently as structural hierarchies. Inferential thinking was then extended from the natural environment to new domains, to individual behavior by assigning causal motivation (theory of mind), and to manufacture and use of weapons and tools, each structured in the form of a functionally discreet hierarchical cognitive module. The third transition differentiated declarative memory into semantic world-view and episodic self-as-agent components, while at the same time integrating modules as general intelligence exercising executive control through conscious selection in working memory. The brain/mind that evolved as a result of these three transitions increasingly selected niche-constructing behaviors in response to a new, emergent, existential drive, which was to maximize inclusive satisfaction.

The fourth transition came about through conceptual elaboration of more complex hierarchically structured worldviews along with the means to communicate their upper-level abstract inferences through meta-representation in symbolic language and art. By transmitting the structural components of worldviews, language facilitated their repeated assembly in receiving brain/minds. Sharing more sophisticated worldviews both consolidated group identity and drove cooperative construction of richer and more satisfying sociocultural niches through the nested evolutionary process of cognitive variation and selection. The fifth transition to sedentary living extended niche construction to include an appropriately modified extended environment, but more importantly opened the way for elite subgroups to concentrate social power and apply it to exert selective pressure on the thought and behavior of individuals and groups. Differences in kinds and combinations of social power legitimized by different worldviews produced a diversity of sociopolitical structures that enabled elites both to maintain social cohesion and order, and to channel sociocultural change in directions that maximized their own inclusive satisfaction.

The sixth transition resulted from the proliferation of variation produced by the scientific revolution, which in jurisdictions where coercive sociopolitical selective pressures were relaxed found expression in new technologies. The effect was to accelerate both niche construction and the evolution of forms of sociopolitical organization that would further promote innovation (notably democratic institutions). Elite support for institutions multiplying variation through scientific research and its entrepreneurial application to niche construction hastened the pace of change still more. If our evolutionary history is in the throes of a seventh transition, it is likely to be because brain/mind/computer interfaces provide new means to manipulate evolutionary processes (perhaps through generating and selecting cognitive variation in response to an emergent existential drive to ensure cyborg survival through planetary engineering and space exploration). If such interfaces become reality, the pace of sociocultural evolution will accelerate still more, with momentous implications we can as yet only dimly foresee for future human existence.

Notes

1. Compare the memory maps known as 'songlines' (discussed, from a transactionist perspective, in Heft, 2013).
2. See also Watkins, 2017, in which he argues for a niche construction approach to the Neolithic transition.

3. See Wikipedia. ‘Cyborgology’, at https://en.wikipedia.org/wiki/Cyborg accessed 16/11/2020; and issues of the journal *Brain-Computer Interfaces*

ORCID

Martin Stuart-Fox http://orcid.org/0000-0003-3535-3087

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