33rd ALTENBERG WORKSHOP IN THEORETICAL BIOLOGY

Convergent Evolution and Stone-Tool Technology

organized by

Briggs Buchanan, Metin I. Eren, and Michael J. O´Brien

June 16–19, 2016

KLI Klosterneuburg, Austria

Welcome

to the 33rd Altenberg Workshop in Theoretical Biology. The Altenberg Workshops are interdisciplinary meetings organized by the KLI Klosterneuburg, Austria. The workshop themes are selected for their potential impact on the advancement of biological theory. Leading experts in their fields are asked to invite a group of internationally recognized scientists for three days of open discussion in a relaxed atmosphere. By this procedure the KLI intends to generate new conceptual advances and research initiatives in the biosciences. We are delighted that you are able to participate in this workshop, and we wish you a productive and enjoyable stay.

Gerd B. Müller
President

The topic

Stone tools and the debris from stone-tool manufacture are found throughout the archaeological record of humans and their ancestors. The first unambiguous hominin-produced tools appeared approximately 2.6 million years ago (de la Torre 2011), although recent studies have shown indirect evidence that hominins began using stone tools nearly 3.4 million years ago (McPherron et al. 2010). Stone has been used to make tools in nearly all of the regions of the globe that have been inhabited. Given the nearly ubiquitous use of stone tools by hominins, their study is an important line of inquiry for shedding light on questions of evolution and behavior. Researchers have been studying stone artifacts for over a century and have investigated a wide range of topics, including the evolution of technology, prehistoric economy, hominin global dispersals, and the ancient engineering of tools, but the topic of evolutionary convergence remains an understudied yet potentially important avenue of research.

Convergence is the phenomenon in which evolutionary processes result in the same, or similar, forms in independent lineages as a result of functional or developmental constraints (McGhee 2011). In studies of stone tools, identifying cases of convergence is of particular importance because similarities in form and function are often used to suggest historical connections among prehistoric groups. Identifying cases of convergence would refute hypotheses that otherwise would suggest some degree of physical or cultural connection among toolmakers. The reason that convergence remains understudied has to do in large part with the unsupported assumption that there are “endless” stone-tool production techniques and forms, and thus “independent innovation in stone tools is incredibly rare” (Bradley, as quoted by Cook 2012).

Considerable reason exists to doubt this widely held belief because the manufacture of stone tools is a reductive process, whereby stone flakes are removed from larger cores to make smaller tool forms. As stone is reduced, the number of possible outcomes in terms of form becomes increasingly constrained. Widespread convergence of lithic technologies is also possible as a result of the fracturing properties of stone, which are governed by a specific set of physical constraints (Dibble and Pelcin 1995; Magnani et al. 2014).

The vast array of stone types that are appropriate for stone-tool manufacture—flint, obsidian, basalt, and quartzite, for example—contain the same basic set of fracture properties, which increases the possibility of convergence (e.g., Braun et al. 2009; Eren et al. 2011, 2014). Moreover, prehistoric people, albeit in different times and places, would have faced similar adaptive challenges that would have ostensibly governed stone-tool forms toward similar optimal designs ("adaptive peaks") (Lycett and Eren 2013). Considering all these factors, it should be no surprise that several recent studies are empirically consistent with the hypothesis that convergence in lithic technology is not rare (Eren et al. 2013, 2014; Lycett 2009, 2011).

The aims

The proposed KLI symposium, and subsequent edited volume of *Vienna Series in Theoretical Biology*, aims to address the lack of research devoted to the principle of evolutionary convergence in stone tools. Through specific empirical case studies, the symposium will address the following questions:

- Why does convergence occur in the stone-tool record?
- Did stone-tool technology originate once, or did prehistoric people converge on this innovation several times independently during the early stone age?
- How often does convergence occur in the stone-tool record, and in what forms?
- Are there particular environmental or behavioral situations in which we can predict convergence in stone tools?
- How is the process of evolutionary convergence in stone tools similar to, or different than, that seen in biological species?

Format

There will be 16 presentations, with 50 minutes allotted for each—roughly 30 minutes for each talk, followed by 20 minutes for questions on that talk and discussion. On Friday we kick off with an introductory statement, addressing the aims and framework of the workshop, by the organizers; on Sunday we end with a general discussion, including publication plans.

To support discussion during the sessions, we encourage all participants to send a rough draft of their presentation and/or some materials that are relevant to their topic to the organizers in advance of the workshop, to be circulated among the participants.

Manuscript preparation and publication

The Altenberg Workshops in Theoretical Biology are fully sponsored by the KLI. In turn, the Institute requires all participants to contribute a paper to a volume edited by the organizers. Altenberg Workshop results are usually published in the *Vienna Series in Theoretical Biology* (MIT Press). The contributors are not necessarily limited to the original participants; they may be complemented by experts on those topics that emerge as important, and may include co-authors invited at the discretion of the participants.

We expect that participants will revise their drafts as a result of our discussions at the workshop and the ensuing review process. We aim for a November 2016 date for receipt of finished manuscripts for publication. The length of the contributions should be approximately 8,000 words. The use of figures and photographs is highly encouraged. All contributions will be edited for style and content, and the figures, tables, and the like will be drafted in a common format. The editor will send specific instructions after the workshop.

Briggs Buchanan, Metin I. Eren, and Michael J. O´Brien

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Convergent Evolution and Stone-Tool Technology

Thursday 16 June	Evening		
6.00 pm		Welcome reception and dinner at the KLI	

Friday 17 June	Morning	A Brief Overview	Chair: Briggs Buchanan
9.30 am – 10.00 am	Organizers	Scope of Workshop, Goals, Final Products	
10.00 am – 10.50 am	Mike O'Brien	Archaeological Perspectives on Convergence	
10.50 am – 11.20 am	Coffee		
11.20 am – 12:10 pm	Alex Bentley	Convergent Evolution and Technological Change	
12:10 pm – 1.40 pm	Lunch	at the KLI	

Friday 17 June	Afternoon	Recognizing Convergence and Constraints	Chair: Mike O'Brien
1.40 pm – 2.30 pm	George McGhee	Limits on the Possible Forms of Stone Tools: A Perspective from Convergent Biological Evolution	
2.30 pm – 3.20 pm	Metin Eren	Why Should Convergence Be a Potential Hypothesis for the Emergence of Stone-Tool Form and Production Processes? An Illustration Using Stone Tool Replication	
3.20 pm – 3:50 pm	Coffee		
3.50 pm – 4.40 pm	Harold Dibble	How Do We Recognize Convergence in Lithics?	
4.40 pm – 5.30 pm	Mathieu Charbonneau	Technical Constraints on Artifact Evolution: From Morphological Models to Theoretical Technospaces	
6.00 pm		Departure for dinner at a local Heurigen	

Saturday 18 June	Morning	Evidence and Other Issues	Chair: Mike O'Brien
9.30 am – 10.20 am	Judith Charlin	Reduction Constraints and Shape Convergence along Tool Ontogenetic Trajectories: An Example from Late Holocene Projectile Points of Southern Patagonia	
10.20 am – 11.10 am	Steven Kuhn	Detecting Homologies without Reliable Phylogenetic Information Is the Challenge for Lithic Studies	
11.10 am – 11.40 am	Coffee		

11.40 am – 12.30 pm	Marcus Hamilton	The Biogeography of Human Cultural Diversity
12.30 pm – 2.00 pm	Lunch	at the KLI

Saturday 18 June	Afternoon	Case Studies I	Chair: Briggs Buchanan
2.00 pm – 2.50 pm	Daniel Lieberman	How Did Early Humans Hunt?	
2.50 pm – 3.40 pm	Jayne Wilkins	The Point Is the Point: Emulative Social Learning and Weapon Manufacture in the Middle Stone Age of South Africa	
3.40 pm – 4:10 pm	Coffee		
4.10 pm – 5.00 pm	Christopher Clarkson	Small, Strong, Sharp and Easy to Make the Same Way Each Time: Experimental and Archaeological Investigations into Convergence in Microlithic Technology	
5.00 pm – 5.50 pm	Ashley Smallwood	The Convergent Evolution of Serrated Points in the Eastern Woodlands, North America	
6.00 pm		Free evening: dinner on one´s own	

Sunday 19 June	Morning	Case Studies II	Chair: Mike O'Brien
9.30 am – 10.20 am	Tom Jennings	Clovis and Toyah: Convergent Blade Technologies in the Southern Plains Periphery of North America	
10.20 am – 11.10 am	Loren Davis	The "Levallois-like" Technological System of the Western Stemmed Tradition: A Case of Convergent Evolution in Early North American Prehistory?	
11.10 am – 11.40 am	Coffee		
11.40 am – 12.30 pm	Briggs Buchanan	On the Probability of Convergence among North American Projectile Points	
12.30 pm – 2.00 pm	Lunch	at the KLI	
2.00 pm		Departure for Danube boat trip & dinner in Dürnstein	

Abstracts

Mike O'BRIEN
University of Missouri, Columbia

Archaeological Perspectives on Convergence

Similarity in nature can occur either from divergence—two or more things are similar because of common descent—or from convergence, which is a process in which two or more distinct lineages independently evolve similar characteristics as a result of similar selective pressures. Often overlooked in evolutionary treatments is the fact that there are two kinds of convergence: analogy, which entails convergent modifications of a nonhomologous feature (e.g., a structure or behavior), and homoiology, which entails convergent modifications of a homologous feature. Both play significant roles in cultural evolution, especially given the ease and speed with which horizontal transmission can occur. Separating instances of cultural convergence from those of divergence can be analytically difficult, but through careful analysis and the use of proper tools, it is possible to do so.

Alex BENTLEY
University of Houston, Texas

Convergent Evolution and Technological Change

Two metaphoric models are useful for considering convergent evolution of technology. One is design space, which represents the multitude of possible designs for the technology, with the space having as many dimensions as the technology has definably discrete characters. The second is a fitness landscape, which also represents the technology as a point in a space, but one in which the dimensions include reproductive fitness and possibly aspects external to the technology, such as its frequency in the population. This raises the larger issue, namely, the success/fitness of a technology often depends on aspects external to it: not only how many people are using it but also the transparency of its intrinsic and social utility and the existence and availability of complementary technologies. How do we consider all these dimensions in design space or on a fitness landscape? My talk will review approaches to this from various disciplines, including ecology, network science, and evolutionary archaeology.

George McGHEE
Rutgers University, New Jersey

Limits on the Possible Forms of Stone Tools: A Perspective from Convergent Biological Evolution

Convergent biological evolution occurs because the potential evolutionary pathways available to life are finite and limited. If there is also a finite number of ways in which stone tools can be made, then convergent, independent discovery of those possible stone tool forms should occur in different human populations. As convergent evolution in stone tool manufacture has been demonstrated empirically, then stone tool evolution, like biological evolution, operates within limits. Limit boundaries in biological evolution are determined by functional constraints, developmental constraints, or both constraints operating in concert. Analogous limit boundaries in stone tool evolution could be produced by constraints on how well possible forms of stone tools function and constraints on how stone tools can be manufactured.

Metin EREN
Kent State University, Ohio

Why Should Convergence Be a Potential Hypothesis for the Emergence of Stone-tool Form and Production Processes? An Illustration Using Stone Tool Replication

There exists an assumption in the study of prehistoric lithic technologies that convergent evolution is rare or unimportant. We suggest that this assumption usually takes one of two forms: a hyper-diffusionist approach in which a stone tool form or production process is invented once and then spreads across vast spatio-temporal distances, or a detail-oriented approach, in which intuitive descriptions, or "readings," emphasize differences, rather than similarities, between lithic forms or production processes. However, in recent years it has become evident that convergent evolution in flaked stone tool technology is actually quite common. Here we explore why this is the case, and by so doing examine why convergent evolution should be a potential hypothesis for the emergence of stone tool forms and production processes. Using experimental stone tool replication, one of us (M.I.E.) flintknapped six distinct stone tool forms: (1) a Lower Paleolithic–style uni-directional core; (2) a bipolar (anvil) core; (3) an Acheulean handaxe; (4) a preferential Levallois core; (5) an Upper Paleolithic–style blade core; and (6) a Clovis point. All production flakes were saved, and a random sample of 30 flakes from each sequence was selected, for a total of 180 flakes. The morphology of each flake was captured using eight interlandmark distances. Multivariate statistical analyses of flakes sampled from each production sequence showed substantial overlap in flake shape. These results suggest that despite the creation of distinct stone tools, production flakes are relatively constrained in shape. Analogous to the "deep homology" of distinct biological forms' shared generative processes and cell-type specification, the limited number of possible stone flake forms can be used both to generate diverse adaptations as well as lead to the parallel evolution of novelties.

Harold DIBBLE
University of Pennsylvania, Philadelphia

How Do We Recognize Convergence in Lithics?

In the relatively short history of lithic research, there has always been a certain tension between cultural-historical and functional-evolutionary models offered to account for observed similarity or variation in lithic objects, whether at the level of morphology or of processes of manufacture. Convergent evolution is an important concept to help explain similarity of features among different biological organism that do not share a common origin, and its application to stone tools offers a promising framework for explaining common characteristics of lithic objects or assemblages. However, technological development is different from biological evolution in important ways. This paper will discuss several factors that influence the morphology of lithic objects, including taphonomy, raw materials, and various lower-level technological processes, all of which contribute to similarities or differences but which are independent of either function or style. These will be illustrated both at the level of individual objects and major industrial variants during the Paleolithic of Europe, the Near East, and Africa. Although it is possible to recognize the potential contributions of various factors and processes that underlie lithic variability, it is much more difficult to isolate or eliminate the effects of any one.

Mathieu CHARBONNEAU
Central European University, Budapest

Technical Constraints on Artifact Evolution: From Morphological Models to Theoretical Technospaces

Formal similarities in artifacts have proven to be powerful proxies for identifying genealogical relationships between technological traditions. However, such similarities are useful genealogical markers only insofar as they are the product of a common technical background. Central to any available metrics of evolutionary change deployed to measure differences in the morphology of artifacts lies the assumption that change in the properties of a type of artifact is congruent with change in the underlying technical behaviors used to produce the artifacts. Yet there has been little discussion of the nature of technical variation, of the metrics required to assess evolutionary change at the level of techniques, or of how variation at the technical level affects variation at the morphological level. In this paper, I examine how technical constraints shape the space of possible and impossible artifact morphologies and discuss implications of different ways that changes at the level of the technique affect changes in the properties of producible artifacts.

Judith CHARLIN
Universidad de Buenos Aires

Reduction Constraints and Shape Convergence along Tool Ontogenetic Trajectories: An Example from Late Holocene Projectile Points of Southern Patagonia

Tool reduction is essentially a continuous process by which the initial form (size and shape) of artifacts is modified generally in a directional way from the first use to discard. Like ontogeny, reduction is a patterned allometric process that changes in extent and degree. It should be considered not only as a confounding factor but also as an integral part of the tool itself. Even though stone tools change during their use-lives, they change in one direction, and the possible changes are limited: A stone tool cannot be larger after reduction, nor can an edge become sharper as it is used.

Fortunately, through different lines of evidence and kind of analyses, many of the allometric changes that result from reduction can be identified. I attempt to show how these changes lead to shape convergence among tools, although they have been used in different ways. In this case, convergence can be seen as a by-product of the ontogenetic trajectory of stone tools along their use-lives. Performance requirements, random errors, and ontogenetic trajectories create the morphospace of lithic tools.

As tool convergence by reduction is in general not controlled, we actually do not know how usual it is within lithic assemblages, but we should be aware that it exists and can bias interassemblage comparisons as well as typological classifications. I present as an example the case of Late Holocene projectile points from southern Patagonia (Argentina and Chile) known as Fell, Magallanes, and Bird IV and V, or simply as “Patagonian” and “Ona” points, respectively. An ethnographic sample of Ona arrow points from Tierra del Fuego is also included in the analysis to test the existence of parallelism, a particular case of convergence.

Steven L. KUHN

University of Arizona, Tucson

Detecting Homologies without Reliable Phylogenetic Information Is the Challenge for Lithic Studies

Most archaeologists recognize the potential for homologous features in lithic technology. Nonetheless, approaches to distinguishing convergence or parallelism from similarity that result from shared ancestry are typically informal. Judgments are based on the plausibility of arguments for historical connections or on the estimated likelihood of shared features arising independently. The issue is further clouded by the persistence of progressivist evolutionary models that do not easily accommodate the concept of a most recent common ancestor. An ongoing attempt to investigate the relationships between widely dispersed early Upper Paleolithic complexes illustrates one more systematic approach to identifying homologies at the assemblage level.

Marcus HAMILTON
Santa Fe Institute

The Biogeography of Human Cultural Diversity

A dominant feature of life on Earth is the latitudinal gradient of biodiversity, where species diversity is highest at the equator and decays exponentially toward the poles. These diversity gradients characterize the distribution of many forms of life, including vascular plants, reptiles, amphibians, birds, mammals, and even human diseases and primate parasites. Recent work shows that human ethnolinguistic diversity follows exactly the same gradient. The universality of latitudinal gradients in biological and cultural diversity suggests a deep biogeographic convergence in the operation of biological and cultural evolutionary processes at a planetary scale. Here I discuss the ecology and evolution of these gradients and their implications for understanding the evolution of human cultural diversity over deep time. I also present some mathematical theory in an attempt to understand the universality of this biocultural convergence.

Daniel E. LIEBERMAN
Harvard University, Cambridge

How Did Early Humans Hunt?

Similarity occurs either from common descent (homology) or convergence (homoplasy), and it is often difficult to distinguish between the two forms of similarity. Although homology is more prevalent than homoplasy, convergence commonly occurs when closely related organisms face similar challenges. Further, while convergence is common in biological evolution, one expects it to be even more common in cultural evolution. In order to examine how this problem applies to hunting weapons, I review how physical and biological challenges of hunting by hominins in different environments affect the technology used to hunt large mammals, focusing on the challenges of locomotion, thermoregulation, throwing, and defense. Because hominins are slow and unsteady, with few natural adaptations for defense, early hunting strategies often required some degree of running combined with throwing projectiles from a distance. In addition, because of unique thermoregulatory capabilities, hominins were better able to hunt from a distance in hot and open environments. As hominins dispersed into different environments, these constraints likely promoted the retention of shared primitive characters and the development of convergently similar technologies.

Jayne WILKINS
University of Cape Town, Rondebosch

The Point Is the Point: Emulative Social Learning and Weapon Manufacture in the Middle Stone Age of South Africa

Emulation is a social-learning mechanism in which the learner develops strategy and technique for accomplishing a copied end goal through trial-and-error learning. Although rarely considered explicitly, emulation can serve as an important source of selectable variation in past human behavior. Through emulation, knappers can converge on lithic endproduct characteristics and reduction sequences. I propose three assemblage characteristics that are consistent with an increased focus on emulative learning over imitative learning: (1) different strategies used to produce similar blanks, (2) different blanks used to produce similar retouched tools, and (3) different endproducts used to accomplish similar tasks. I focus on evidence from the early Middle Stone Age (MSA) in Africa as represented at the archaeological site of Kathu Pan 1, South Africa, where we see intrasite diversity in reduction strategies and diverse processes leading to the same end goal: points used as hafted spear tips. I suggest that lithic assemblage diversity in the early MSA may represent an increased emphasis on emulation compared to earlier and later time periods.

Chris CLARKSON
University of Queensland, Brisbane

Small, Strong, Sharp, and Easy to Make the Same Way Each Time: Experimental and Archaeological Investigations into Convergence in Microlithic Technology

The emergence of backed artifacts (microliths) multiple times at vastly separated points in time and space over the last ~160ky has posed an explanatory challenge for archaeologists. Diffusionist, adaptationist, and symbolic arguments have all been raised to explain this phenomenon. Here I consider backed-tool emergence in light of certain characteristics they possess that make them highly amenable to rediscovery through a process of convergent evolution, or the multiple rediscovery of technological practices without recent shared ancestry. Experimental and archaeological case studies will serve to demonstrate these characteristics of backed artifacts and to illustrate the conditions under which they emerge in different times and places around the globe. Issues of design, efficiency, acquisition of skill, blank production, and technological investment are also considered.

Ashley SMALLWOOD
University of West Georgia, Carrollton

The Convergent Evolution of Serrated Points in the Eastern Woodlands, North America

Here we identify evolutionary convergence in stone tools through an empirical case study of serrated points from the prehistoric record of the Eastern Woodlands of North America. In this region, serrated points were introduced during the Late Paleoindian period, used variably throughout the Archaic, abandoned by the Middle Woodland, and introduced again in the Late Woodland to Early Mississippian/Late Prehistoric. We investigate the relationship between the earliest serrated Dalton points and the Late Prehistoric Scallorn point type to explore how to identify convergent evolution in the stone-tool record and consider the behavioral contexts in which this case of convergence arose. First, we generate phylogenetic trees that show hypotheses of relatedness within and between lineages. Next, we evaluate morphological similarities and differences using geometric morphometric analysis. Finally, we consider these analyses as they relate to adaptive challenges that caused two unrelated populations to converge on the same tool design.

Tom JENNINGS
University of West Georgia, Carrollton

Clovis and Toyah: Convergent Blade Technologies in the Southern Plains Periphery of North America

We explore the chronological occurrence of blades and blade-core reduction in the Southern Plains and periphery of North America as a case study for understanding convergence in the stone-tool record. The first widespread evidence of blade-core reduction is associated with the Clovis record. Evidence of blade production is especially common at Clovis sites in the Southern Plains and Plains periphery. Interestingly, blade technology is not found in the post-Clovis Paleoindian record, and in the Southern Plains, blading does not re-enter the record until the Late Prehistoric Toyah period. We use phylogenetic analyses to demonstrate evolutionary distance between Clovis and Toyah to support a discussion of why these disparate populations converged on the same reduction technology and how these similarities reflect adaptations to comparable environmental conditions.

Loren DAVIS
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The "Levallois-like" Technological System of the Western Stemmed Tradition: A Case of Convergent Evolution in Early North American Prehistory?

Archaeologists in western North America have identified a pattern of lithic reduction similar to the Levallois technique reported from Paleolithic Europe. This pattern, termed "Levallois-like," includes recurrent centripetal preferential flake production elements. Excavations at the Cooper's Ferry site, located in the lower Salmon River canyon of western Idaho, have produced examples of "Levallois-like" cores, preferential flake products, and potential reduction debitage associated with Western Stemmed Tradition cultural components. Although this technology is among the earliest in western North America and bears similarities to Levallois artifacts in western Europe, neither a migration of Paleolithic peoples to the New World nor a direct cultural-historical connection is anticipated. Instead, the presence of the "Levallois-Like" pattern in early western North American sites is hypothesized to reflect the convergent evolution of technological behaviors within a landscape dominated by fine-grained volcanic tool stone. The "Levallois-like" reduction pattern was designed to produce large, linear flake products from spherical, lower-quality tool stones—a pattern that conferred selective advantages.

Briggs BUCHANAN
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On the Probability of Convergence among North American Projectile Points

The archaeological record of North America over the last 13,500 years is rife with various forms of stone weapon tips. These forms are largely bifacial with converging tips, but beyond those attributes the point forms display a range of differences from the way in which they were hafted (for example, stems and channel flakes) to the way in which the blades were configured (serrated or smooth). What is not known about these various forms of North American points is how often certain combinations of attributes arose as a result of convergence versus common ancestry. In an attempt to arrive at an estimate of the rate of convergence, we recorded a set of 10 attributes on 210 North American point types with known spatial and temporal limits. We used paradigmatic classification to then develop a probabilistic estimate of convergence based on how distantly separated point types with shared attributes were in time and space.