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Innovation in Cultural Systems: Contributions from Evolutionary Anthropology

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The topic

It would be difficult to find another topic in anthropology that has played as important a role as innovation in structuring arguments concerning why and how human behavior changes. Certainly innovation was implicit in the 19th-century writings of ethnologists such as Edward Burnett Tylor and Lewis Henry Morgan, just as it was in the mid-20th-century work of Julian Steward and Leslie White. For Tylor and Morgan the appearance of cultural innovations was almost a preprogrammed process, which kicked in whenever a cultural group "needed" to ascend the ladder of sociocultural complexity. Adolf Bastian explained it this way: "the psychic unity of mankind constantly impelled societies to duplicate one another's ideas" (Lowie 1937: 29). For Steward and White the process was less orthogenetic, with the source of innovation wrapped up in the kind of mechanisms a group needed to meet the challenges of its physical and social environment.

Archaeological explanations of cultural change, too, have long centered around the introduction and spread of novelties. American culture historians of the 20th century routinely looked to diffusion and trade as a source of innovations, in the process usually adopting without comment the models of their anthropological colleagues as to how and why the innovations arose in the first place. This is the way that James Ford, a leading archaeologist of the mid-20th century, put it: "Archeologists have shown little interest in examining the philosophic bases of their studies. While utilizing the thesis that trait resemblances (in adjacent geographic regions) are evidence for contact, when faced with an unexplainable origin of a trait they have fallen back on independent invention theory" (Ford 1969:194).

With the growing interest in Darwinian evolution that became noticeable in anthropology and archaeology after around 1980, researchers began to reconsider the role of innovation in the evolution of cultural systems. Impor-tantly, modern evolutionary research in the social and behavioral sciences in general is being geared toward identifying innovation not only as a "thing" but also as a "process." In that vein, a recent workshop at the Santa Fe Institute centered on innovation, building on the work of economist Joseph Schum-peter, who made the important distinction between invention—the creation and establishment of something new—and innovation—an invention that becomes economically successful and earns a profit (Erwin and Krakauer 2004: 117). This distinction had been made previously in biology—introduction and fixation of a novelty versus long-term success of a species—but not in the social sciences. There, the long-held belief that humans were somehow exempt from Darwinian processes such as natural selection ensured that the only brand of evolutionism discussed was of the unilinear Tylor-Morgan-White brand.

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Abstracts

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Invention vs. Innovation From a Darwinian Point of View

In regard to the Schumpeter model of invention and innovation, the main question before us is: What does the analogy to natural selection help explain that social scientists cannot already explain in their non-selectionist models? The problem is that the question presupposes that there is a univocal answer to the question, "What does natural selection explain and how does it explain it?" There is not. There are many distinct models of natural selection from Darwin's own to the class of theories called "neo-Darwinian." Even Darwin appears to contradict himself in his discussion of whether natural selection explains new variants ("inventions"). So, the philosopher's answer to our main question is, as philosophers are wont to say, "Well, it depends on what you mean by 'natural selection'"...
To initiate the discussion I will analyze Darwin's two apparently contradictory views on explaining biological inventions (new variants) and innovations (the spread of successful variants). A surprising consequence of Darwin's explanatory scheme emerges from the discussion: while natural selection plays a role in explaining the existence of a new variant ("invention") in a population, it does not explain why any particular individual possesses the invention they do (as opposed to not possessing it).

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Characterizing Innovation Using the Random Copying (Neutral) Model

This paper concerns fashion versus independent thinking in modern science. Ideally, science is the systematic process of testing multiple hypotheses, but as practiced by real people, it is also distinctly social. Academics do their re-search within complex social networks, and are prone to copy ideas from one another. We all have our opinions as to what constitutes trendy ideas versus valid research, yet there is yet little means of evaluating this objectively. Through database research, I will characterize the modern scientific process in terms of a continuum between copying fashionable ideas at one extreme, and independent selective testing of hypotheses at the other.

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Innovation from EvoDevo to Human Culture

Although behavioral innovations and their associated cognitive underpinnings are phylogenetically widespread, with greatest innovation rate associated with "higher" organisms (Lloyd Morgan, Instinct and Experience, 1912), students of animal behavior have only recently begun to conceptualize innovation qua process and product. In their introduction to a recent volume on Animal Innovation, Reader and Laland (2003) list ten "outstanding questions," three of which concern the evolution of

innovation. One of these questions—has the capacity for innovation been directly favored by natural selection, or is it a by-product of selection for other attributes, such as behavioral flexibility or social cognition?—reflects the selectionist bias characteristic of most work in animal behavior. EvoDevo corrects this bias by insisting that evolutionary innovation represents a specific class of phenotypic changes that is different from adaptive modification on the grounds that the origin of novelty may include different mechanisms than the mutations underlying variations and adap-tations, and that certain phenotypic changes may have more important and long-lasting consequences for the dynamics of evolution (Müller and Wagner 2003). Extant approaches to animal innovation do consider developmental issues; yet, we will argue, they are less well equipped to come to grips with the complexities of animal and in particular human cultural evolution than EvoDevo, which allows us to integrate mechanistic accounts of individual development, structured social learning throughout the life cycle, and cultural reproduction on scales appropriate to a variety of social and cultural entities (Wimsatt and Griesemer 2007).
In this paper we will first attempt to conceptually integrate a variety of approaches to innovation—concerning animal behavior, EvoDevo, evolution-ary economics, and science studies—that have been developed largely independently. We will insist that in the cultural realm, a full understanding of innovation requires explaining the origination of innovations in tandem with ex-plaining their recognition by conspecifics and subsequent diffusion (cf. Branni-gan 1981). We will then outline our own view of phenotypic innovation against the background of our Organismic Systems Approach (Callebaut, Müller, and Newman 2007). To round off, we will bring to bear this view on some issues in human cultural evolution, focusing on the tough nut of the emergence of institutions.

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Risk and Hunter-gatherer Technological Innovation

Technological innovation among hunter-gatherers has been linked with the timing and severity of risk. Torrence (1989, 2000) has argued that the diversity and complexity of hunter-gatherer toolkits increase as the risk of resource failure increases, and that this relationship is explained by the fact that the use of more specialized and therefore more elaborate tools reduces the risk of resource failure. Thus, populations that experience high resource failure risk will produce toolkits that are diverse and complex, whereas those that experience lower resource failure risk will settle for more simple toolkits. In this paper, we will outline our recent efforts to test Torrence's hypothesis using quantitative cross-cultural data on hunter-gatherer toolkit structure. The results of these analyses are not consistent. Two global-level analyses we have carried out strongly support the idea that hunter-gatherer toolkit structure is influenced by risk, whereas two region-specific analyses do not. Possible reasons for this discrepancy will be discussed.

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Why Societies Vary in their Rates of Innovation: The Evolution of Innovative-enhancing Institutions

This paper applies an integrated approach to decision-making and cultural evolution to explore some of the characteristics that influence population-level differences in innovativeness and to understand how such differences emerge. In laying the foundation for subsequent arguments I begin by summarizing research showing how evolutionary theory can direct and inform our under-standing of decision making, social learning and cultural evolution. Building on this and extending insights from existing

cultural evolutionary models, I then examine how a population's size and degree of “cultural interconnectedness” can influence rates of both innovation and invention. A simple model illustrates the relative importance of cultural interconnectedness compared to individual invention. Combining ethno-historical and archaeological cases, I further explore the relative importance of "mother necessity" and "heroic genius" vs. recombination, lucky mistakes, and the accretion of small changes in driving invention. This discussion suggests that, at best, "necessity" is neither neces-sary nor sufficient to explain invention and that invention processes are dominated by incremental additions, recombinations, and lucky errors, not revolutionary insights. This means that inventiveness is—at least in part—a product of large populations (that generate more lucky errors) and greater interconnectedness that together with population size favor more recombinant inventions, as well as a greater likelihood of these diffusing widely. Lastly, I examine how increasing the interconnectedness in a population gives rise to an n-person cooperative dilemma. While some partial solutions to this dilemma have emerged across our species, only some societies have evolved the informal (and later formal) institutions—i.e., systems of reputation, signaling, and punishment—that favor the wide sharing of information, ideas, and insights. Theoretical work has revealed three avenues to solving such n-person cooperative dilemmas, but crucially, all three generate multiple stable equilibria, meaning that while they can stabilize cooperative information sharing, they can also stabilize "information hiding" as well as other non-group-beneficial states. In such circumstances, processes of cultural group selection, which operate through various forms of competition among groups, can favor the evolution of those institutional forms that best promote the open dissemination so crucial to innovation. This line of thinking proposes that cultural evolution has favored the emergence of institutions that increase cul-tural interconnectedness, thereby stimulating both greater inventiveness and more innovation.

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The Exploration of Bicycle Design Space

A recurring pattern in biological evolution is that increases in diversity proceed by early diversification at higher taxonomic levels followed by later diversify-cation at lower taxonomic levels. Kauffman (1995, p.205-6) has argued that this pattern results from the increased cost of exploring distant locations in design space as evolution proceeds and that it is the expected outcome of any process of adaptive evolution irrespective of substrate. He cites the develop-ment of the bicycle as a non-biological example of breadth-first search followed by depth-first search. In this paper we build on Lyman and O’Brien’s (2000: 47–53) use of clade diversity statistics to examine the exploration of technological design space. Specifically, we construct an explicit hierarchical taxonomy of bicycle designs in order to investigate changing design diversity across different taxonomic levels.

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The Evolution of Innovation

The capacity for innovation did not spring fully formed in humans but evolved from more limited capabilities in nonhuman primates. In this paper I will provide a brief overview of research into behavioral innovation in animals. Observations of natural populations provides bounteous evidence that animals regularly invent new behavior patterns, or devise new solutions to established problems. In birds and primates reports of innovation have been collated and subjected to statistical analyses. The reported incidence of behavioral innovation co-varies with relative brain size in nonhuman primates, and also with the reported incidence of tool use and social learning. These observations suggest that social learning and innovation may have been a driver of primate brain evolution and intelligence.

Innovation can be studied experimentally in captive animals by presenting them with novel challenges, such as foraging puzzle boxes, and the factors influencing innovation (sex, age, social rank) explored. Such experiments, on various vertebrates (fish, birds, primates), suggest that the adage "necessity is the mother of invention" explains a lot of data. In captive starlings, asocial learning performance measured in isolation predicts which individuals will innovate in a social context. Theoretical analyses help explain the observation that most innovations fail to spread.

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Phenotypic Plasticity and Evolvability:

Conceptual Considerations on Innovation and Novelty
My purpose is to demonstrate how interdisciplinary theory can provide deep insights into novelty and innovation in technology, social structure, language, and human biology. Great advances in genetics, the neurosciences, cognitive research, evolutionary and developmental biology, experimental game theory, network analysis, and linguistics offer us opportunities to apply new evolution-ary principles to anthropological studies in unprecedented ways. These sci-ences demonstrate that evolutionary events are mapped in our DNA, the human brain, and our biological chemistry and behavioral characteristics. In each of these domains, scholars have used, often in a brilliant manner, the explanatory power of novelty and innovation to address the evolvability of our species. Several approaches will be examined and an effort will be made to integrate cross-disciplinary use of novelty and innovation as key concepts. This paper is a modest effort to expand the discussion of phenotypic plasticity and human evolvability.
Understanding the processes behind novelty and innovation is of great relevance to research programs concerning evolving complexity, and in par-ticular for the New Synthesis and recent debates regarding self-organization. From my perspective, the role of evolutionary anthropology is to investigate the interactive effects of gene-culture coevolution from a context of inter-disciplinary evolutionary sciences. Recent advancements in EvoDevo suggest that we have a build a theoretical framework that examines phenotypic plasti-city in gene expression, neurobiological variability, and behavioral expression. Much can be gained from examining the interdisciplinary literature concerning innovation and novelty, particularly from evolution and development, neuro-biology, and biological chemistry. Synthesizing this information will require innovative means of data discovery, standardization, interdisciplinary data inte-gration, and distribution to support a comprehensive assessment of human evolution and behavioral diversity. The paper closes out with a discussion of how we can identify and measure novel and innovative traits in a range of anthropological data mines. New questions are posed and an alternative theoretical perspective is offered to better understand the complexity of human phenotypic plasticity and evolvability.

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Simulating Cultural Innovation in the Psychology Lab

"Innovation" describes the processes by which a novel trait (an invention) emerges and becomes fixed in a population. In my contribution, I suggest that (i) cultural innovation, like cultural evolution in general, can be profitably studied experimentally in the psychology lab (Mesoudi 2007). Rose and Felton (1955), for example, found that invention was more frequent in closed societies with stable group membership than in open societies where participants migrated between groups; and (ii) cultural

innovation can be viewed in terms of adaptive landscapes, where different inventions constitute "peaks" of different heights, and successful innovation occurs when members of a population converge on the same peak. Mesoudi and O'Brien (in press) experimentally simulated the cultural transmission of projectile point designs under the assumption of a multimodal adaptive landscape. While participants used simple reinforcement learning to find a locally adaptive point design, these locally adaptive designs rarely persisted once participants could engage in biased horizontal cultural transmission, when most participants converged on the point design of the most successful player (the highest peak in the adaptive landscape).

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An Introduction to Cultural Innovation

It would be difficult to find another topic in anthropology that has played as important a role as innovation in framing arguments about why and how human behavior changes. Likewise, it would be difficult to find another topic that has so consumed ethnologists and archaeologists as attempting to derive an analytical framework that addresses both the production and spread of innovation. Ethnologists working early in the 20th century paid particular attention to what typically were termed "culture traits," using them as a means of linking related cultures together. Archaeologists did the same. Rarely, how-ever, was there consensus on what a culture trait entailed and at what scale it should be examined. Beginning in the 1980s there occurred an emerging interest in applying Darwinian principles to the study of culture, and one area in which considerable advance was made was the study of cultural in-heritance, especially the pathways by which traits are transmitted. Likewise, there was a more general interest in the social sciences in understanding the nature of the units of cultural inheritance. As interesting and valuable as these collected studies are, there are still areas that need in-depth research, especially with respect to the production of cultural innovation and the scale and tempo at which it is produced. No longer is it sufficient to think of selection "tinkering" with subtle variations, slowly effecting change over long periods of time. Rather, there are times when innovation appears as larger packages, the product of emergent human behaviors at a fairly large scale.

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Cultural Traditions and the Evolutionary Advantages of Non-Innovation

Evolutionary approaches to understanding culture have often focused on the processes that produce cultural change and technological innovation because change is assumed to be the interesting phenomenon that is in need of ex-planation. Such approaches often imply that the absence of change is merely an uninteresting state that occurs when the processes of change are not in action. In contrast, this paper argues that the absence of cultural change is itself often the result of an active process, and that some instances of change and innovation are best seen as the result of failures in the processes preventing change. This alternative perspective is supported with examples where great effort is exerted to prevent changes from taking place during the intergenerational transmission of cultural behaviors. The evolutionary ad-vantages of maintaining traditions by preventing intergenerational changes in cultural behavior are then discussed.

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Technological Innovations, Developmental Trajectories and Techno-Economic Impact: Modes of Social Organization as Evolutionary Forces

Technological innovations can be characterized as continuous or discon-tinuous. An analysis of the "discontinuous" innovations, following the dynamic systems approach–that is, distinguishing between historical scenarios and conditions of actualization–suggests that the actualization and developmental trajectory of these innovations are determined by modes of social organization.
In other words, innovations get fixed and have an impact on techno-economic systems depending on the social conditions prevailing at the time. One example is the wheel-fashioning technique in South Levant. This tech-nique appears in the 5th millennium BC but gets fixed only by the second half of the second millennium BC, given constraints found at the level of the social context of production and transmission. When the technique expands, this is as a specialized activity, to the detriment of the domestic ceramic production, leading therefore to an increasing number of tasks distributed differentially, within the group, between participants of the same biological class.

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Not all Biological Innovations are the Same: Systematics versus Phylogeny

In phylogenetic and especially cladistic analysis, one attempts to delineate a hierarchy of shared derived features with the goal of generating theories of relatedness that yield a pattern of nested clades. Morphological derived-ness is appreciated as either the first appearance of a novel feature or its subsequent modification or loss. Developmentally, however, the appear-ance of a novelty and its subsequent modification represent different phenomena: the emergence of novel signaling pathways (including, e.g., changes in reading frames and intron splicing) in concert with constraints imposed by the physical world, versus change in the intensity, time of expression, or cell-field gradient of molecular and cell-cell interactions. A question that arises is whether, or how, either the methodological principles that lead to theories of derivedness, or an appreciation of the develop-mental underpinnings of features can provide insight into cultural inno-vation.

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Inventing the Wheel?

The origin of the wheel is one of the classic innovation stories not just in archaeology and the history of technology but in western popular culture. It was also one of the first topics to be considered by one of the founders of modern evolutionary approaches to culture, Ted Cloak, in a 1968 presentation at the AAA meetings, where he argued, in effect, that the spoked wooden wheel was not an invention. Just like the eye in the biological realm, despite the fact that it appeared to be a perfectly integrated phenomenon where the lack of a single element would make it useless, it had in fact emerged incre-mentally over time through the action of a cultural analogue. He made his case by looking at what was then known of the archaeological history of the wheel. Since then archaeologists have done an

enormous amount of work on this subject although many of the key issues remain controversial. The object of this paper is to present current understandings of this question and consider to what extent an explicitly evolutionary approach, going beyond Cloak's initial analysis, has anything to contribute to an understanding of the origin, develop-ment and diffusion of the wheel in the Old World, beyond what has been achieved by more conventional approaches and assumptions; and if so what if any new data archaeologists should be collecting to test evolutionary hypo-theses.

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Innovation Diffusion in Time and Space: Social Learning and Threshold Heterogeneity Models

We contrast social learning and threshold heterogeneity models of innovation diffusion, and show how the typical temporal evolution of the distribution of adopters may be consistent with either model. We extend this finding to the case of a spatially structured population, in which diffusion by social learning is modeled spatially as a reaction-diffusion system, and show that the typical spatiotemporal evolution of the distribution is also consistent with both models. Additional contextual information is required to estimate the relative impor-tance of social learning and of economic inequalities in observed adoption lags.

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Demography and the Accumulation of Culturally Inherited Skills

The Upper Palaeolithic Transition occurred around 40-50k years BP in Europe and Western Asia, but somewhat later in North Africa and East Asia, and is associated with a significant increase in human cultural and technological complexity. However, many of its features appear much earlier in the African Middle Stone Age. Many explanations for this cultural shift have been pro-posed, including biological/cognitive change, innovations in social structure, fluctuations in environmental/socio-economic circumstances, and the effects of demography on the transmission of skills. Previous work by Henrich and Boyd (2002) on the inheritance of continuous cultural representations has shown that in a model of directly biased oblique transmission, where the learning mechanism is incomplete and inaccurate, population size is a crucial para-meter in determining the accumulation (or loss) of cultural skills. We have extended this analytical model by using semi-realistic stochastic simulations that reflect plausible human demographic conditions during the Pleistocene. Our simulation model consists of a large number of spatially separated sub-populations connected by migratory activity, which is determined by local sub-population group density. Within each sub-population a naïve offspring generation undergoes a process of enculturation, through both vertical (parental) and directly biased oblique transmission, before replacing the adult generation. We show that (1) the level of cultural skill that can be maintained in sub-populations is related to the density of those sub-populations, and (2) geographic heterogeneity in local sub-population density leads to stable spatial structuring of skill accumulation.

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War, Women, and Religion: The Spread of Salado Polychrome in the US Southwest

During the 13th and 14th centuries, the Salado religion spread across the US Southwest. It was associated with distinctive pottery that was part of an Earth fertility cult developed during massive migration into the area. Many of the migrants were female war refugees and their children fleeing intense violence to the north. The influx of refugees into pre-existing communities created intense female-female competition. Here I argue that the Salado religion re-flects religious innovation by females aimed at mitigating the intense female-female competition. As such, pottery, a significant female economic contri-bution, became the means of expressing the Salado system and symbolizing female integration and unity. The Salado religion reverberated throughout the cultural system, impacting the formation of gender, class, and factions. This case study reflects how innovations can be generated and transmitted over a large area in response to changing selective pressures.