POINT TYPOLOGIES, CULTURAL TRANSMISSION, AND THE SPREAD OF BOW-AND-ARROW TECHNOLOGY IN THE PREHISTORIC GREAT BASIN

Robert L. Bettinger and Jelmer Eerkens

Decrease in projectile point size around 1350 B.P. is commonly regarded as marking the replacement of the atlatl by the bow and arrow across the Great Basin. The point typology most widely employed in the Great Basin before about 1980 (the Berkeley typology) uses weight to distinguish larger dart points from smaller, but similarly shaped, arrow points. The typology commonly used today (the Monitor typology) uses basal width to distinguish wide-based dart points from narrow-based arrow points. The two typologies are in general agreement except in central Nevada, where some dart points are light, hence incorrectly typed by the Berkeley typology, and in eastern California, where some arrow points are wide-based, hence incorrectly typed by the Monitor typology. Scarce raw materials and resharpening may explain why dart points are sometimes light in central Nevada. That arrow point basal width is more variable in eastern California than central Nevada likely reflects differences in the cultural processes attending the spread and subsequent maintenance of bow-and-arrow technology in these two localities.

La disminución en el tamaño de las puntas proyectil hacia 1350 AP se considera generalmente una indicación de la sustitución del atlatl por el arco y flecha en la Gran Cuenca de los Estados Unidos. La tipología común en esta área antes de 1980 (tipología de Berkeley) utilizó el peso para distinguir puntas más grandes de puntas más pequeñas pero de forma parecida. La tipología generalmente empleada hoy (Monitor tipología) utiliza el ancho para distinguir puntas de bases anchas de puntas de bases estrechas. Tipicamente, estos dos sistemas de tipología están de acuerdo con la excepción de Nevada central donde algunas puntas proyectil ligeras están clasificadas equivocamente en la tipología de Berkeley. Además, en California oriental algunas puntas de proyectil tienen bases anchas y están clasificadas equivocamente en la tipología Monitor. Probablemente, las puntas de Nevada central son ligeras debido a la falta de materia prima y al proceso de reafilación. Hay más variabilidad en el ancho de las puntas en California oriental que en Nevada central y probablamente refleja diferencias en los procesos culturales relacionados a la propagación y mantenimiento subsiguiente de la tecnología de arco y flecha en estas dos localidades.

Typologies are basic to archaeology. Well-defined artifact types facilitate communication between archaeologists and permit recognition of regional and temporal patterns that would otherwise pass unnoticed. In that sense, it can be argued that typologies themselves are of no intrinsic interest; they are merely intermediary constructions useful in investigating the "real" behaviors and processes we want to study. In this view, typologies should be evaluated mainly in pragmatic terms: "good" ones work—they reveal the patterns in which we are interested; "bad" ones don't. There is much to be said for this view. Nevertheless, it is occasionally worth asking why our "good" typologies work—and more importantly, why and where they don't. As we demonstrate below, such analyses can unexpectedly reveal novel patterns and behaviors as important and interesting as those for which the typologies were originally designed. In particular, we think such work is likely to be especially revealing of basic evolutionary processes connected with the way individuals acquire, modify, and transmit basic cultural knowledge. This is so because "good" typologies identify consistently recurring combinations of attributes, suggesting the presence of evolutionary forces that caused these combinations to be maintained more or less intact across space and time. Myriad processes can produce such associations, of course, but, as we show here, it is possible to narrow the possibilities by observing the performance level of different typologies within given units of time and space. The first part of our analysis is given to such a comparison, showing how two different projectile point typologies succeed and fail in two regions of the western Great Basin of North America. We demonstrate that these typological successes and failures are due to regional differences in morphology and attribute correlation in generally similar point

Robert L. Bettinger ■ Department of Anthropology, University of California, Davis 95616
Jelmer Eerkens ■ Department of Anthropology, University of California, Santa Barbara 93106

American Antiquity, 64(2), 1999, pp. 231–242

types. In the second part of our analysis, we argue these regional differences in morphology and attribute correlation are due to differences in the degree to which dart points were resharpened and to differences in the cultural mechanisms through which a new technology—the bow and arrow—spread and was maintained in different parts of the western Great Basin. The latter argument is informed by use of a version of evolutionary theory, termed *culture transmission theory* (or dual inheritance theory). We close with a brief discussion regarding the relationship of cultural transmission to Darwinian evolution and of the importance of identifying different modes of cultural transmission in the archaeological record.

Typologies in Conflict

The subject of our discussion is an unexpected conflict between two "good" Great Basin projectile point typologies. One is the Berkeley typology developed by Robert Heizer and others in the 1960s at the University of California-Berkeley (Baumhoff and Byrne 1959; Clewlow 1967, 1968; Heizer and Baumhoff 1961; Heizer et al. 1968; Heizer and Clewlow 1968; Lanning 1963). The other is the Monitor Valley typology developed by Thomas (1981). Both of these typologies were developed to identify time-sensitive projectile points that could be used in dating archaeological sites, especially surface sites that resist dating by other means, which are especially common in the Great Basin. The conflict is unexpected because the Monitor typology is a revision of an earlier typology that Thomas (1970) designed specifically to formalize the Berkeley typology and duplicate its results using explicit quantitative criteria.

The Monitor typology has been immensely successful in bringing coherence to Great Basin projectile point studies, and, overall, it reproduces the Berkeley typology (Bettinger 1975:167–189). As we shall show, however, there is systematic disagreement in some parts of the western Great Basin on the identification of two key forms: *Elko Corner-notched*, a large point form held to date between 3150–1350 B.P. (i.e., in the western Great Basin), and Rosegate, a smaller corner-notched point form held to date between 1350–650 B.P. (Figure 1).[1] This size difference is commonly regarded as marking the replacement of the atlatl by the bow and arrow (Fenenga 1953; Lanning 1963:249). The question immediately at hand, however, is one of telling time,

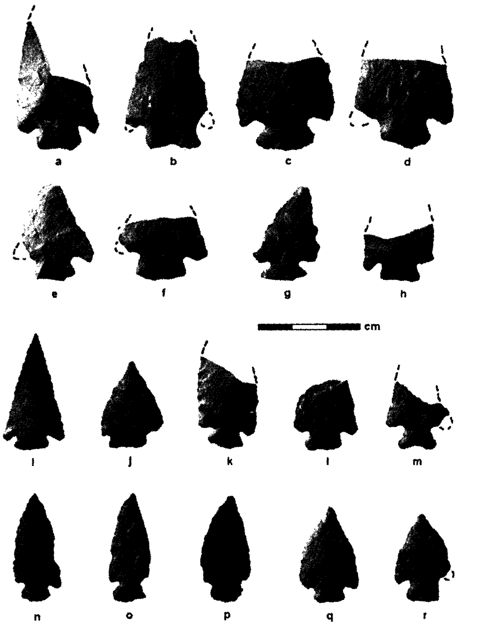

Figure 1. Corner-notched Projectile points from the White Mountains, California. a-h, Elko Corner-notched. i-m, Wide-based Rosegate. n-r, Narrow-based Rosegate.

i.e., distinguishing corner-notched points dating 3150–1350 B.P. (Elko) from corner-notched points dating 1350–650 B.P. (Rosegate). The Berkeley typology uses weight: Rosegate points weigh less than 3 gm; Elko Corner-notched points weigh more

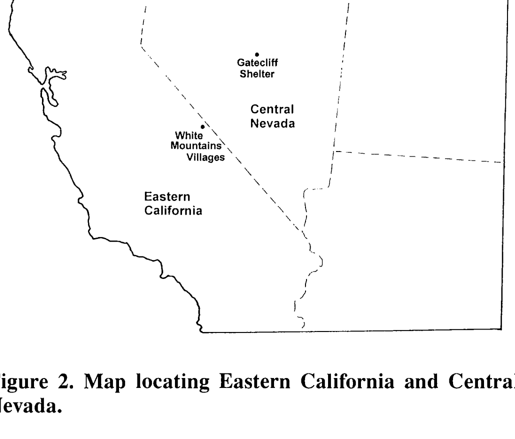

Figure 2. Map locating Eastern California and Central Nevada.

Table 1. Berkeley and Monitor Valley Classification of Rosegate and Elko Corner-notched Points from Eastern California.

		MONITOR Rosegate	MONITOR Elko Corner-notched	MONITOR Total
BERKELEY	Rosegate	113	45	158
	Elko Corner-notched		37	37
	Total	113	82	195

Note: Data from Ainsworth and Skinner 1994; Basgall and McGuire 1988; Bettinger 1989; Bouscaren 1985; Burton 1986; Clarke et al. 1991; Delacorte and McGuire 1993: Appendices 1-3; Delacorte et al. 1995: Appendix; Eerkens 1998; and Gilreath 1995: Appendix.

Table 2. Berkeley and Monitor Valley Classification of Rosegate and Elko Corner-notched Points from Central Nevada.

		MONITOR Rosegate	MONITOR Elko Corner-notched	MONITOR Total
BERKELEY	Rosegate	152	122	274
	Elko Corner-notched	5	248	253
	Total	157	370	527

Note: Data from Thomas 1983:Table 44, 45, 1988:Tables 5, 6, 20, 21, 46,47, 49, 53, 54, 57, 59, 60, 61, 62.

than that (Clewlow 1967; Heizer and Baumhoff 1961; Lanning 1963; O'Connell 1967). Alternatively, on the premise that resharpening makes weight unstable (by changing original weight), the Monitor typology uses basal width, which is less affected by resharpening.[2] In the Monitor typology, Elko points have basal widths greater than 10 mm; Rosegate points have basal widths less than that (Thomas 1981: 14–15, 19–22).

Because the two typologies use different criteria to distinguish the age of corner-notched points, some disagreement is to be expected. In eastern California (Figure 2, Table 1) and central Nevada (Table 2), however, these disagreements are too large and systematic to be ignored. Specifically, of the points that are Rosegate by the Berkeley typology (weight), 28 percent in eastern California and 45 percent in central Nevada are Elko Corner-notched by the Monitor typology (basal width). In both places, the samples in question include many sites and surface isolates, suggesting this is a regional phenomenon. It is pointless to argue whether weight or basal width is inherently better at distinguishing older (Elko) from younger (Rosegate) corner-notched points, because both methods achieve only local success.[3]

In central Nevada, basal width is superior to weight. At Gatecliff Shelter, for example, the 10 mm basal width cutoff correctly predicts the stratigraphic position of about 97 percent of all corner-notched points relative to the boundary between Horizons 3 and 4, which dates to roughly 1350 B.P. (Thomas 1983: 177). By contrast, weight is a poorer predictor of age at this site, the 3 gm cutoff correctly predicting stratigraphic position of only 72 percent of these points.

In eastern California, on the other hand, weight is superior to basal width. For instance, as Lanning (1963: Table 3) showed, the Berkeley typology correctly predicts the stratigraphic position of Elko and Rosegate points above or below 48 in (122 cm) 94 percent of the time at the Rose Spring Site (CA-Iny-372). This near-complete stratigraphic separation by weight was confirmed by Davis (1963), and again by Yohe (1992: Tables 17, 24). Basal width is much less predictive of age in comparison. Yohe (1992: 180,Tables 14a-d) measured 145 Rosegate points recovered from all contexts (i.e., surface and buried) at the Rose Spring site between 1951 and 1989, including those in the collections of Lanning and Davis. Of these, all 53 complete specimens weigh less than 3 gm, as they should according to the Berkeley typology.[4] By contrast, basal widths greater than 10 mm cause the Monitor typology to classify 26 (27 percent) of those 96 specimens measurable on this dimension as Elko Corner-notched. As a result, the Monitor Valley typology correctly predicts the stratigraphic position of the 98 Elko and Rosegate points found in buried contexts and measurable for basal width only about 67 percent of the time (Yohe 1992: Tables 14a-d, 17).

Similarly, the larger eastern California sample demonstrates that weight is superior to basal width

Tables 3a, b. Weight and Basal Width of Obsidian Hydration-Dated Rosegate and Elko Corner-Notched Points from Eastern California.

	Weight		
Date	< 3 gm	≥ 3 gm	Total
< 1350 B.P.	16 (94%)	1 (6%)	17
> 1350 B.P.	5 (28%)	13 (72%)	18
Total	21	14	35

	Basal Width		
Date	≤ 10 mm	>10 mm	Total
< 1350 B.P.	25 (66%)	13 (34%)	38
> 1350 B.P.	9 (31%)	20 (69%)	29
Total	34	33	67

Note: Source specific hydration rates (Hall and Jackson 1989; Basgall and Giambastiani 1995; Delacorte et al. 1995) were used to derive dates B.P. Many more points can be measured for basal width than for weight, hence the unequal total number of observations on the two attributes.

in predicting the age of corner-notched points dated by obsidian hydration relative to the 1350 B.P. Elko/Rosegate boundary (Tables 3a,b). Here, the 3 gm cutoff correctly predicts the age 83 percent of the time, the 10 mm basal width cutoff only 67 percent of the time. These findings concur with a number of reports from all parts of eastern California suggesting that corner-notched points younger than 1350 B.P. are consistently light (3 gm) but frequently wide-based (10mm; e.g. Basgall and Giambastiani 1995: 47, Table B.1; Bettinger 1991a; Delacorte and McGuire 1993: Appendix A). For example, in alpine villages in the White Mountains of eastern California, 180 km north of the Rose Springs site (Bettinger 1991a), 36 percent of the Rosegate points occurring stratigraphically above a tephra layer dating to approximately 1245 B.P. are wide-based and would be classified incorrectly as Elko Corner-notched by the Monitor typology (Table 4; Figure 1 i–m). The larger basal width of eastern California Rosegate

Table 4. Distribution of Narrow- and Wide-based Rosegate Points Relative to Ash Layer in Alpine Villages, White Mountains, California (Bettinger 1991a).

	Narrow-Based ≤ 10 mm	Wide-Based > 10 mm	Total
Above Ash	54 (64%)	31 (36%)	85
In Ash (ca. 1245 B.P.)	19 (70%)	8 (30%)	27
Below Ash	26 (70%)	11 (30%)	37
Total	99 (66%)	50 (34%)	149

points is not a function of their overall size; they are, on average, shorter, narrower, and lighter than Rosegate points from central Nevada (Table 5).

We summarize the situation in Table 6. In eastern California, the Berkeley and Monitor typologies agree on the identification of corner-notched points older than 1350 B.P., which are consistently both heavy and wide-based, but disagree on the identification of points younger than 1350 B.P., which are light (3.0 gm) but often wide-based (10 mm). The Berkeley typology correctly classifies these light, wide-based forms as Rosegate, the Monitor typology misclassifies them as Elko. The situation is just the reverse in central Nevada, where the typologies agree on the identification of corner-notched points younger than 1350 B.P., which are consistently both light and narrow-based, but disagree on the identification of those older than 1350 B.P., which are wide-based but often light. The Monitor typology correctly classifies these light, wide-based forms as Elko; the Berkeley typology misclassifies them as Rosegate.

Explaining Regional Differences in Point Morphology

What do they mean, these regional differences in point morphology? Why do Elko Corner-notched points vary in weight in central Nevada but not eastern California, and why do Rosegate points vary in basal width in eastern California but not central Nevada? One obvious possibility, of course, is that Elko Corner-notched points are not all dart points, as commonly supposed, and that the light Elko Corner-notched points of central Nevada are really arrow points that pre-date 1350 B.P. Similarly, it is possible that not all Rosegate points are arrow points, and that the wide-based Rosegate points of eastern California are really dart points that postdate 1350 B.P. Metrical data provide little support for these suggestions. Shott (1997) examined a sample of 39 hafted, hence relatively unambiguous, dart points and 130 similarly unambiguous hafted arrow points, and used discriminant analysis to derive classification functions to separate darts from arrows. Table 7 summarizes the application of Shott's (1997:94) 2-variable discriminant classification function to the central Nevada Elko Corner-notched point sample and the Rosegate points from the Rose Spring site (CA-Iny-372) in eastern California. These data strongly suggest that the light Elko Corner-notched points in central Nevada are dart points, and that the

Table 5. Summary Metrical Data for Rosegate Points from Monitor Valley (Thomas 1983, 1988), the Rose Spring Site (Ca-iny-372; Yohe 1992), and Eastern California (See Table 1 for References). See Thomas (1981, 1983) for Description of Measurements.

	Maximum Length mm	Axial Length mm	Maximum Width mm	Basal Width mm	Neck Width mm	Thickness mm	Weight gm
Monitor Valley[a]							
mean	29.68	29.47	16.97	8.19	7.11	3.49	1.64
std	7.30	7.33	3.25	1.22	1.21	0.67	0.68
n	33	33	83	120	120	120	20
Eastern California							
mean	25.54	25.05	15.31	8.79	7.78	3.86	1.12
std	5.30	5.57	2.93	2.30	1.67	0.90	0.44
n	55	57	114	157	182	157	39
Rose Spring Site							
mean	27.66	no data	15.08	9.10	7.87	3.77	1.17
std	4.91	no data	2.11	1.88	1.46	0.63	0.46
n	83	no data	129	96	130	144	53

[a] Reference here is to specimens actually measured and omits estimated values routinely given by Thomas (1983, 1988).

wide-based Rosegate points in eastern California are arrow points.[5] Thus, the replacement of Elko Corner-notched points by Rosegate points about 1350 B.P. in central Nevada and eastern California almost certainly reflects the replacement of the atlatl by the bow and arrow, as long suspected.

Unfortunately, this conclusion still leaves us with our original problem of explaining the weight variability observed in central Nevada Elko points and basal width variability observed in eastern California Rosegate points. Following Thomas (1981:14–15,19–20), we think it likely that excessive resharpening makes dart point weight highly variable in central Nevada, producing the light, wide-based Elko Corner-notched points that the Berkeley typology incorrectly types as Rosegate. Support for this idea is provided by the length-width ratio; i.e., maximum length (maximum width) of light Elko Corner-notched points in the central Nevada sample, which is significantly lower than that for the heavy Elko Corner-notched points in that sample ($mean_{light} = 1.62$, $mean_{heavy} = 1.75$, $p < .001$, one-tailed *t*-test, df =345), suggesting the stubbier, lighter forms were more extensively resharpened. That resharpening does not cause similar problems in eastern California, where Elko Corner-notched points are uniformly heavy and long relative to width ($mean_{length:width} = 2.02$, n =10 complete specimens), may be explained by the abundance of high-quality obsidian sources there, perhaps causing Elko points to be discarded without substantial resharpening (cf. Bettinger 1991b; Delacorte 1994). Resharpening, of course, cannot explain why Rosegate points are more variable in basal width in eastern California than central Nevada. We think this variance can be attributed to differences in how these regions' inhabitants obtained and subsequently modified bow-and-arrow technology.

Cultural Transmission and the Spread of the Bow and Arrow

As noted above, it has long been accepted that the appearance of Rosegate points marks the advent of the bow and arrow (Jennings 1986: 116) as reflected

Table 6. Summary of Formal Variation in Elko Corner-notched and Rosegate Points and Success of Berkeley and Monitor Typologies in Identifying Them in Eastern California and Central Nevada.

	Eastern California Forms	Typology Success	Central Nevada Forms	Typology Success
Elko Corner-notched	Heavy, Wide-based	Both Correct	Heavy, Wide-based Light, Wide-based	Both Correct Berkeley Incorrect
Rosegate	Light, Narrow-based Light, Wide-based	Both Correct Monitor Incorrect	Light, Narrow-Based	Both Correct

Table 7. Classification of Central Nevada Elko Corner-notched and Eastern California Rosegate Points from the Rose Spring Site (Ca-iny-372) Using the 2 Variable Function of Shott (1997).

	Dart	Arrow	Total
Central Nevada			
Heavy Elko Corner-notched	97%	3%	229
Light Elko Corner-notched	76%	24%	120
All Elko Corner Notched	90%	10%	349
Shott (1997) Sample Darts	85%	15%	39
Eastern California (CA-INY-372)			
Narrow-based Rosegate	5%	95%	66
Wide-based Rosegate	9%	91%	23
All Rosegate	6%	94%	89
Shott (1997) Sample Arrows	11%	89%	130

Table 8: Pearson's R Correlation Coefficients for Basal Width and Weight in Central Nevada and Eastern California Rosegate Points.

	Monitor Typology	Berkeley Typology
Central Nevada	.80	.65
	$p_{r=0} < .0001$	$p_{r=0} = .0005$
Eastern California	.06	.14
	$p_{r=0} = .36$	$p_{r=0} = .20$

Note: Correlations are on actual measurements because basal width and weight estimates for broken points given in Thomas (1983, 1988) are unavailable for eastern California.

by a reduction in point size (Fenenga 1953; Lanning 1963). This size reduction has been recognized across all of the Great Basin, consistently around 1650–1350 B.P. Appearance of the Rosegate series at essentially the same time throughout the Great Basin is usually taken to support the companion assumption (generally unstated) that the spread of bow-and-arrow technology was a unitary phenomenon— that is, it was accomplished by the same mode of cultural transmission across the entire Great Basin, probably from a common source. Under this assumption, the changes in projectile point morphology from Elko to Rosegate that accompanied the introduction of the bow and arrow should be essentially the same throughout the Great Basin. This is not the case. As we have shown, the Elko-Rosegate transition in both central Nevada and eastern California almost certainly represents the introduction of the bow and arrow somewhere around 1350 B.P. However, the characteristics that distinguish Elko from Rosegate points in central Nevada, and thus the transition to the bow and arrow, are not the ones that distinguish them, and thus the transition, in eastern California.

In central Nevada, Rosegate points fit the criteria of both Berkeley and Monitor typologies: a corner-notched point with a narrow base is nearly always light. This suggests that in central Nevada the two variables these typologies use to distinguish Rosegate from Elko—weight and basal width—were linked together in the transmission of bow-and-arrow technology. Weight and basal width, however, are not linked in this way in eastern California. This is clearly illustrated in Table 8, which shows correlation coefficients between weight and basal width in Rosegate age corner-notched points from multiple sites in eastern California and central Nevada. Using the Monitor typology, basal width and weight are highly correlated in Rosegate points from central Nevada. Because these points nearly always simultaneously fit the criteria of both typologies, the same high correlation is achieved when they are classified according to the Berkeley typology. On the other hand, no matter which way one classifies them, Rosegate points from eastern California are uncorrelated on these two attributes.[6] This suggests that the circumstances surrounding the spread and maintenance of bow-and-arrow technology during Rosegate times in eastern California were different than those in central Nevada.

Boyd and Richerson (1985: 94–95, 243) have identified two contrasting modes of cultural transmission, *guided variation* and *indirect bias*, that are useful in interpreting these differences in trait correlation and their implications for the spread and maintenance of bow-and-arrow technology in the Great Basin. In *guided variation,* individuals acquire new behaviors by directly copying other social models and subsequently modifying these behaviors to suit their own needs by individual trial-and-error experiments. Complex behaviors are frequently compiled in this fashion, using different individuals as social models for various components of the behavior. The result is a composite behavior that is more or less unique to the individual, i.e., as a consequence of experimentation and the particular set of social models that were chosen. In *indirect bias*, on the other hand, individuals acquire complex behaviors by choosing a single social model on the basis of a trait that is deemed to index general proficiency in the activity to which the desired behavior is related. Highly successful hunters, for example, might be chosen as social models by those trying to learn how to make all sorts of hunting gear. In this case, in con-

Table 9. Pearson's r Correlation Coefficients for Various Point Attributes in Central Nevada and Eastern California Rosegate Points.

		Axial Length	Maximum Width	Basal Width	Neck Width	Thickness	Distal Shoulder Angle	Proximal Shoulder Angle	Weight
Max. Length	C. NV	1.00	.58[a]	.48[a]	.51	.51[a]	-.19	-.34	.86
	E. CA	1.00	.24	.07	.21	.15	-.24	-.24	.76
Axial Length	C. NV		.59[a]	.49[a]	.51[a]	.49[a]	-.18	-.33	.86
	E. CA		.22	.04	.16	.14	-.24	-.27	.74
Maximum Width	C. NV			.44	.72	.12	-.48	-.53[a]	.62
	E. CA			.54	.69	.26	-.47	-.08	.71
Basal Width	C. NV				.71	.21	.11	.26	.80[a]
	E. CA				.78	-.05	-.06	.31	.14
Neck Width	C. NV					.23	-.15	-.15	.61
	E. CA					.11	-.06	.15	.40
Thickness	C. NV						.14	-.02	.70
	E. CA						.03	-.02	.57
Distal Shoulder Angle	C. NV							.53[a]	-.12
	E. CA							.16	-.38
Proximal Shoulder Angle	C. NV								-.21
	E. CA								-.01

Note: Correlations are on actual measurements. See Thomas (1981, 1983) for description of measurements.
[a]Significantly stronger correlation ($\alpha = 0.05$).

trast to guided variation, the result is a complex behavior that matches more or less closely in all details of the behavior of just this one social model. Further, since there tends to be general agreement within local groups about the proficiency of potential social models, the individual generally deemed the most proficient will frequently be chosen as a social model by many individuals trying to learn new, complex behaviors. It is impossible to observe these transmission processes directly in the archaeological record, of course, but their statistical signatures should be clear nonetheless. Variables acquired by guided variation will be much less strongly correlated than variables acquired by indirect bias. Following this logic, we contend that in eastern California, where basal width and weight are poorly correlated, bow-and-arrow technology was maintained, and may have spread initially, by guided variation. Conversely, in central Nevada, where the attributes are strongly correlated, we suggest it was maintained, and may have spread initially, by indirect bias.

In many ways, the situation in eastern California, where basal width and weight are not linked, is the one to be expected. This is so because, beyond the minimal effect basal width has on total weight, these two attributes respond to different design constraints that are capable of varying independently, as they clearly do in eastern California Rosegate points. However, basal width and weight do not vary independently, but are instead correlated in central Nevada Rosegate points. This correlation suggests that these elements of design were connected—not as a matter of function, but because central Nevada Rosegate point makers acquired the multiple elements of arrow point design as a package using a mode of transmission akin to indirect bias, copying, as it were, the whole point rather than individual attributes piecemeal and independently. On the other hand, that weight and basal width are uncorrelated in eastern California suggests the bow-and-arrow technology may have spread, and was in any case maintained, by a mode of cultural transmission akin to guided variation, in which craftsmen copied, evaluated, and modified the various elements of point design independently. This hypothesis is strongly supported by observed differences in strength of correlation between other major attributes of Rosegate points, which are consistently larger for central Nevada than eastern California (Table 9). In 22 of these 36 paired correlations, the central Nevada value exceeds the eastern California value, far more than the 18 one would expect under the null hypothesis of no difference in magnitude of attribute correlation in the two samples ($p = .015$). The central Nevada correlation is significantly larger in 10 of these cases ($p = 0.05$).[7] In short, during Rosegate times in central Nevada, individuals seem to have maintained (and may have acquired) this new weapon system—bow, arrow, and point—as a complete package, while individuals in eastern California maintained (and may have acquired) its attributes individually using a great deal of experimentation.

Discussion

Why the peoples of eastern California might have acquired and maintained bow-and-arrow technology through a different mode of transmission than the peoples of central Nevada is unclear. Following a suggestion of the late M. A. Baumhoff, however, we would tentatively propose that eastern California groups may have acquired the bow and arrow from peoples with whom they interacted only minimally, possibly a different linguistic unit occasionally contacted through trade. Owing to this lack of contact, individuals may have had to perfect a workable bow-and-arrow technology largely by trial and error. Bettinger (1989: 64–65,229–232) previously noted that Rose Springs points from eastern California seem unusually prone to breakage (especially across the neck) and suggested this faulty design might reflect early arrow point-makers experimenting with various combinations of point size, basal width and foreshaft diameter. Perhaps some craftsmen attempted to adapt existing dart foreshaft types fitted to wide-based arrow points, while others tried to develop new, narrower foreshafts fitted to narrow-based arrow points. Alternatively, craftsmen may have initially adopted the bow and arrow as a complex, as in central Nevada, but immediately set about modifying it to suit their own individual preferences, so that, as a result, weight, basal width, and other attributes in the points came to be relatively uncorrelated. On the other hand, the spread and perpetuation of bow-and-arrow technology in central Nevada seems to have relied more heavily on social transmission, perhaps facilitated by closer social contacts than characterized the situation in eastern California. Whether the bow and arrow came to central Nevada from the same source as in eastern California, from an entirely different area, or perhaps even from eastern California itself, is unclear. What seems clear, however, is that point makers in central Nevada adopted the projectile point used with the bow and arrow by faithfully copying all its various attributes in detail, which suggests they experimented very little with this new technology, then or subsequently.

Is It Evolution?

The thrust of our paper is about cultural transmission: how cultural behavior is acquired, modified, and subsequently transmitted, and how one might go about identifying different kinds of cultural transmission in the archaeological record. Such mechanisms seem to us to be of great potential importance for humans, because so much of our behavior is acquired socially rather than determined by individual learning or genes. Whether this reliance on social transmission so fundamentally separates humans from other biological organisms as to require that we be regarded as unique, and in some sense beyond the reach of forces that shape the rest of the biological world, has been endlessly debated inside and outside anthropology. Certainly, such a disconnection might be implied if cultural transmission had nothing to do with genetic fitness. We only say "might" because Darwinian theory is really not about genes any more than it is just about the differential reproductive fitness of individuals. Genes are the linchpin in how biological evolution works but genes as we now know them are required neither by Darwinian theory nor for it to operate: Darwin got the story basically right without them; the "modern synthesis" occurred without Watson and Crick. Darwinian evolution requires a mechanism of transmission and genes happen to serve this role in biological evolution. It is possible to imagine all sorts of other transmission mechanisms. Genetic reproduction itself is not a unitary phenomenon. Asexual and sexual reproduction, and in sexual reproduction, the transmission of sex-linked and autosomal traits, for example, are quite different and require comparably different quantitative algorithms. One could not possibly understand the individual fitness of a biological organism without also knowing whether it reproduced asexually or sexually and, in the latter case, which traits were sex-linked and whether it was monogamous or polygamous. The "details" of reproduction and mating count. No one model applies universally. Of course, there is more to biological evolution than just individuals—populations and species matter, for example. The genius of Darwin and especially those after him was in tracing through complex evolutionary recursions: Forces act on specific individuals, play out at the population level, affect individuals in return, and so on. The forces need not be strong. Minor differences often have unexpectedly large evolutionary consequences. Here, again, individual fitness is important in this process, but there are myriad other, sometimes more important, forces. Causal relationships are often complex and evolutionary outcomes are frequently counterintuitive.

It seems clear to us that cultural transmission simply must affect Darwinian fitness—how could it be otherwise? And Darwinian fitness also must bear on cultural transmission. Again, how could that not be true? At minimum, humans must have the biological, hence, genetically transmitted, ability for the cultural transmission of behaviors that certainly affect Darwinian fitness. It is obvious, at the same time, that cultural transmission differs in fundamental ways from any form of genetic transmission. The two are asymmetric. Again, this is what we would expect, since cultural transmission must be doing something that genes cannot do, just as sexual reproduction is doing something that asexual reproduction cannot. It does not follow, however, that this process disconnects cultural transmission from Darwinian fitness. To the contrary, as with sexual reproduction, the human use of cultural transmission is simply the exploiting of an evolutionary opportunity. To deny that would imply that the culturally-mediated evolutionary success of anatomically modern humans is merely serendipitous happenstance.

Do Differences in Cultural Transmission Matter?

There is general tendency for archaeologists to assume that differences in cultural transmission are unimportant (Bettinger et al. 1996). We suppose that reflects a common misperception that Darwinian forces are all obvious, strong, and life-threatening. That, of course, is to misread Darwin, whose uniformitarian gradualism stood in direct opposition to explanations relying on supremely powerful forces and catastrophes capable of instantaneously transforming the world and its species. As we have said, in Darwinian evolution details often matter, and that is the case here.

Our paper contrasts two different modes of cultural transmission, guided variation and indirect bias, that highlight what is perhaps the fundamental contrast in evolutionary potential between genetic and cultural transmission. As Boyd and Richerson (1985:132–171; see also Cavalli-Sforza 1988) observe, where cultural transmission takes the form of guided variation and other modes of transmission involving substantial individual experimentation and learning, human behavior will tend to optimize fitness in accord with the predictions of the genetic model. By contrast, where cultural transmission is by indirect bias and other modes that bypass individual experimentation and learning, there is an opportunity for a much different range of behaviors that are normally precluded when only genes are involved. This situation largely occurs because indirect bias and related forms of social transmission tend to produce behaviorally homogenous local populations. It is precisely under these conditions that the force of selection can fall more heavily on groups than on individuals, i.e., as group selection. That, in turn, makes it easier to understand and explain a host of human characteristics suggesting the presence of selective forces acting at the group level—most notably our ultra-social character and tendency to cooperate despite sometimes extensive personal costs—that have proven difficult to explain with reference to the genetic model.

It has been argued that the hunting behavior of certain hunter-gatherer groups contains built-in restraints that act to prevent resource depletion (e.g., Moore 1965). Such an explanation, however, does not account for individual hunters devising and using alternative behaviors that produce higher short-term returns and thus a benefit from the resource abundance arising from the more restrained practices of their fellow hunters. In that event, restraint quickly gives way to strategies that are more successful in the short term, as in the familiar "tragedy of the commons" (Hardin 1968). In short, individual learning and experimentation prevent the development and maintenance of behaviors that potentially benefit the group. Conversely, because it insulates cultural transmission from both individual learning/experiment and exotic social models, indirect bias produces the conditions under which group-beneficial behaviors can evolve and persist. Accordingly, if, during Rosegate times in eastern California, behaviors connected with hunting (e.g., when, where, and how to hunt, and who to hunt with) were acquired and transmitted by the same means as bow-and-arrow technology, the emphasis on individual learning and experimentation likely would have prevented the development of group-beneficial cooperative behaviors. By contrast, the emphasis on indirectly biased social transmission and imitation suggested by the uniformity of Rosegate projectile point technology in central Nevada implies the presence of the ideal conditions for such group-beneficial, cooperative behaviors to develop and persist. Thus, despite the general similarities in technology, it is quite possible that hunting behaviors and social organization overall differed substantially between the two regions during this interval.

Supporting this argument is evidence which suggests that Numic-speaking groups occupying the Great Basin in ethnographic times spread rapidly out of eastern California sometime after 1000 B.P. (Bettinger and Baumhoff 1982; see also Madsen and Rhode 1994). This rapid occupation, it is argued, succeeded through the competitive advantages of the Numic adaptive strategy over that of pre-Numic peoples, and the latter's failure to readapt to Numic competition through slow culture change partly caused by indirectly biased social transmission (although not specifically labeled as such; Bettinger and Baumhoff 1982: 488–493). The emphasis on indirectly biased social transmission suggested here for central Nevada during Rosegate times is clearly consistent with this hypothesis.

Our hypothesis is just that—an hypothesis. Yet it remains that weight, basal width, and nearly all other attributes are highly correlated in Rosegate points from central Nevada and poorly correlated in Rosegate points from eastern California. The lack of correlation in eastern California establishes that the high correlation in central Nevada is unlikely due to functional constraints. Accordingly, we have chosen to interpret these differences in correlation using the tenets of cultural transmission theory, on the hypothesis that attributes passed on through processes that emphasize social learning over individual learning, such as indirectly biased transmission, should be more highly correlated than those passed on through processes that emphasize individual over social learning, such as guided variation.

It is widely held that evolutionary theory, especially culture transmission theory, has little to offer the archaeologist, partly because evolutionary processes are difficult to detect in the archaeological record. We have shown, with reasonable samples, the possibility for casting standard archaeological data in ways that reveal the basic mechanisms through which cultural evolution operates—in this case, the way in which real individuals acquired and subsequently modified important cultural knowledge. Our main point is that differences in cultural transmission are detectable archaeologically and, in fact, seem to distinguish the maintenance and possibly introduction of bow-and-arrow technology in different parts of the Great Basin. It is about evolutionary theory, then, to the extent that transmission, in this case cultural transmission, is a critical Darwinian process that requires investigation. The approach is straightforward and applicable in a variety of other archaeological contexts. We hope our application will stimulate further research and debate into the study of evolutionary culture change in the Great Basin and elsewhere.

Acknowledgments. We are indebted to Elizabeth Klarich, who provided the Spanish abstract translation; Robert Yohe, who provided data for points from the Rose Spring site; and Susan Harriss, Cynthia Herhahn, Mike Jochim, Lisa Deitz, Frank Deitz, and Brian Ramos who read and commented on various drafts of this paper and helped out here and there with the manipulation of data. We further wish to thank Lynne Goldstein, editor of *American Antiquity,* and three serious reviewers who commented on the previous version of this paper.

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Notes

[1] The Berkeley and Monitor typologies differ somewhat in terminology. The Berkeley typology recognizes separate Rose Spring series and Eastgate series, each with several distinct types. The Monitor lumps all the *corner-notched* forms of Rose Spring and Eastgate into a single Rosegate series. Because our problem concerns corner-notched point forms, we follow the Monitor convention for the sake of clarity, cautioning the reader that many of the references we cite follow the Berkeley terminology.

[2] In the original version of what became the Monitor typology, Thomas (1970) used weight, as in the Berkeley typology.

[3] Note, however, that Thomas (1981) did not argue for the universal applicability of the Monitor typology.

[4] A *fragmentary* surface specimen identified by Yohe as Rosegate weighed 3.2 gm (1992: 288, Table 14a). However, this piece could as easily be classified as Elko. Note also that Yohe (1992) inadvertently ommitted metrics for the 30 Rosegate points he recovered between 1987–1989, but provided these data (labeled Table 16) at our request.

[5] As one would expect, light Elko Corner-notched points are more frequently classified as arrow points than heavy ones. However, the error-rate for the central Nevada Elko Corner-notched sample as a whole (i.e., including light and heavy forms) is lower than for Shott's (1997) dart sample, and the error-rate for light Elko Corner-notched points does not differ significantly from that obtained in Shott's dart sample. Filtering Shott's dart sample to include only specimens weighing (3 gm would almost certainly increase the relative frequency of incorrect classifications in much the same way that filtering the Elko Corner-notched for weight does in the central Nevada sample.

[6] This is not a function of excessive variation in basal width in Rosegate points from eastern California. We have shown elsewhere (Eerkens and Bettinger 1994; Bettinger and Eerkens 1997) that Rosegate basal width is relatively stable in this region, and more stable than Rosegate basal width in central Nevada. Further, those data demonstrate that the variability in basal width of other point types is essentially the same in eastern California and central Nevada (Bettinger and Eerkens 1997: Table 10.5), suggesting that raw material access (i.e., to stone, wood, etc.) is likely not causing the regional difference in Rosegate basal width. The Rosegate series does subsume two formally distinct types, Rose Spring Corner-notched and Eastgate Split-stem, but in eastern California, the two are virtually identical in basal width. In the White Mountains sample (Bettinger 1991a) illustrates this nicely. Eastgate basal width: mean = 1.01 cm, std = 0.19, n = 20; Rose Spring Corner-notched basal width: mean = 0.96, std = 0.18, n = 37).

[7] Note in contrast here, that while eastern California Elko Corner-notched points tend to be somewhat more highly correlated across major attributes than central Nevada Elko Corner-notched points, the difference between the two is not significant ($p = .37$).

Received December 18, 1997; accepted August 25, 1998; revised October 30, 1998