Chapter 12
Toward a Theory of the Point

Michael J. Shott

Abstract Points were the tips of prehistoric weapons like darts and arrows. Bifacially chipped stone points all have sharp tips but vary greatly in the size and form of the bases that secured them to the shafts or foreshafts of larger composite tools. Especially in the Americas prehistoric stone points are superabundant, their near-endless forms most beautiful and wonderful. Archaeologists exploit this diversity to order past time, adapting prehistoric tools as chronometric ones. Traditional analysis emphasized type definition among the variation in points, then toolstone acquisition, function and use-wear, distinctions between darts and arrows, and pattern and degree of resharpening. Yet we still treat points and their types as tools that define segments of past time, and merely describe historical changes from one type to another. We also should treat types as subjects of analysis, prompting questions not ordinarily asked. How and where on points do history and timeless function register, and do they compete? How are valid types identified and distinguished? When and why do types originate and end, and how long does either take? What explains the duration and relative popularity of types, and the number present over the duration of a period? How do new types diversify from existing ones? How are historical continuity or discontinuity identified in point sequences? For their prehistoric users points were tools, trivially. For archaeologists point types are tools, trivially. But point types also are subjects, nontrivially, for and about whom we must develop the theory that can explain their origin, development, and ultimate fate.

Keywords Archaeological theory • Function • Paleobiology • Phylogeny • Reduction

M. J. Shott (✉)
Department of Anthropology, University of Akron, Akron, OH 44325, USA
e-mail: shott@uakron.edu

"*Archaeology is an undisciplined empirical discipline. A discipline lacking a scheme of systematic and ordered study based upon declared and clearly defined models and rules of procedure. It further lacks a body of central theory capable of synthesizing the general regularities within its data in such a way that the unique residuals distinguishing each particular case might be quickly isolated and easily assessed. Archaeologists do not agree upon central theory, although, regardless of place, period, and culture, they employ similar tacit models and procedures based upon similar and distinctive entities—the attributes, artefacts, types, assemblages, cultures and culture groups. Lacking an explicit theory defining these entities and their relationships and transformations in a viable form, archaeology has remained an intuitive skill—an inexplicit manipulative dexterity learned by rote.*" (D. L. Clarke, Analytical Archaeology, 1978: xv).

Pardon the extended quotation that precedes this essay. It concerns a problem identified decades ago but substantially ignored ever since, to archaeology's detriment. Clarke's neglected book assayed a comprehensive reformation of archaeological thought and practice. Even in 500+ pages, the effort was ambitious. This essay is not nearly so ambitious, but attempts to follow Clarke's lead in one small respect.

Projectile points are stone tools made at once to create a sharp tip with expanding margins for penetration of prey targets and to connect with the larger armature, shaft or foreshaft, used to deliver them to the target. Not all points are bifaces and not all bifaces are points (see Douze et al. 2020); my subject is bifacial points, "points" henceforth. Points are common enough worldwide; in North America, they occur in numbers almost beyond belief if not counting. In 1859, long before most points had been found, Henry Thoreau could write "some time or other…it had rained arrowheads, for they lie all over the surface of America" (Bode, ed. 1967: 289–290). Nearly a half-century later, Wilson (1899) provided brief glimpses of that abundance, which over a century more of subsequent collecting has only increased.

To some extent, archaeology's treatment of points traces major advances in its intellectual development. Originally

H. S. Groucutt (ed.), *Culture History and Convergent Evolution: Can We Detect Populations in Prehistory?*, Vertebrate Paleobiology and Paleoanthropology, https://doi.org/10.1007/978-3-030-46126-3_12

points merely were evidence of human presence and undetermined antiquity. Later, as the time-space distribution of particular types emerged, points served as markers of past time and sometimes cultural affinity. Later still, they served as evidence of behavior, usually hunting. More recently, use-wear studies identified a range of specific uses, and degree and pattern of reduction recruited points to emerging theoretical issues like curation rates and their explanation (e.g. Andrefsky 2006; Shott and Ballenger 2007). Separately or together these uses are valid, but do not nearly exhaust points' potential to reveal the cultural past. Yet that fuller potential requires and promotes a reform of archaeological thought along the lines that Clarke sketched, and for which points may be especially suited.

To justify that reform, pardon a necessary digression. Paleobiology circa 1980 forms a crude analogy to archaeology's current dilemma and the prospect that it confronts. Then, paleobiology was a mere adjunct to biology, manufacturing inadequate approximations to the latter's units, imitating its theory and exemplifying its processes. This "passive transference from microevolutionary studies" (Gould 1980: 98) condemned paleobiology to intellectual subservience within the larger field, where it defined the wrong units at the wrong scales that it sought to explain using the wrong theory. The species is a fundamental biological unit, but in synchronic behavior ecology it has only descriptive value; the relevant unit of observation and analysis is the individual, whose anatomy and behavior are governed by microevolutionary adaptation and selection. In diachronic paleobiology, however, species are units of observation and analysis, whose form and behavior but also duration, abundance, origin and fate are governed not by adaptation at the individual level but modes and tempos of change at higher, derived ones. Over long biological time, individuals adapt but only species evolve, and their differential persistence, survival and diversification is explained by inherently paleobiological theory that biology cannot entail. Paleobiology's florescence in the past 40 years amply confirms its "bounded independence" (Gould 1980: 107) as a macroevolutionary field.

Today as then, American archaeology is subsumed beneath anthropology. Its units of observation and especially inference—cultures—and its equally synchronic functional or interpretive theory essentially are anthropological in scale. Contemporary archaeology is characterized by rampant passive transference, and an all-purpose misapprehension of its suitable units, scales and explanations (Perreault 2019). The anthropological model that archaeology adopts treats cultures as integral wholes (yet they are historically contingent types, as Reynolds [2020] notes for broad Paleolithic equivalents), derived from the presence or proportion of artifact and other (e.g. faunal, feature) assemblages. That is, we draw many inferences from many sources of evidence, then bundle together the results as integral "Culture X," which then becomes our unit of analysis. At once, we try to characterize such units by their population size, diet and economy, sociopolitical organization, and systems of meaning. Cultures then change by the appearance or disappearance of artifact types or by dramatic shifts in proportions of artifacts and other materials.

Practically, the way we define archaeological cultures and track their fortunes across time and space denies us a more modular view of our subject—components or units, like point types, which may encompass several cultures at once or persist longer than any single culture—especially when cultures are identified with point or other types assumed not to change over time, merely to come and go in ways and at rates unfathomable. Given the typically coarse time resolution that this practice entails, moreover, we cannot resolve the rate, pattern and direction of culture change as experienced on ethnographic time scales. Over the long periods that we study, this limitation gives our descriptions and explanations of sequences of change a misleading episodic quality noted before (e.g. Frankel 1988; Shott 2003; see Stutz [2020] for a similar view of the Middle-Upper Paleolithic transition).

Like paleobiology compared to biology, archaeology needs methods for the construction and theory for the explanation of the inherently historical (therefore *not* anthropological) units and the phase- and time-pattern regularities (Clarke 1978: 163 and passim) they exhibit. This is a grand task that even Clarke merely foreshadowed and that only recently was taken up again (e.g. Perreault 2019). In Paleolithic contexts, relevant research evaluates rather than assumes the historical behavior of presumed historical units (e.g. Groucutt and Scerri 2014; Monnier and Missal 2014; Reynolds 2020). This essay's far more modest scope concerns points alone. The reorganized thought and practice may require more data, certainly new kinds of data. Chiefly, however, it requires a new way to view points and to derive from them the historical units whose behavior we can describe and must explain. It requires, that is, its own comprehensive theory, some parts of which already exist but key components of which remain undeveloped. Archaeology needs a theory of the point.

A sufficient theory of the point lies far beyond current reach. A first approximation must encompass everything from the dimensions that characterize points and reveal their design, to their use, to the contribution of that use to larger synchronic cultural units and practices, and finally to inherently historical traditions of manufacture and use. Like Clarke in general, therefore, this approach to points progresses by level, from attribute to object to sets of objects in assemblages and finally to types as historical units.

Typology

Point types and their historical properties are among the subjects of an archaeology reformulated along Clarke's lines. A theory of the point requires methods for defining and distinguishing types of points. Most North American point types are defined subjectively by combinations of size, technology but especially outline form, and are distinguished from one another in part by emphasizing modal characteristics thought to differ among them. American archaeology lost its typological innocence by the 1950s Spaulding-Ford debate. At least with respect to points, however, it continued to profess innocence decades later, in the process treating types as revealed kinds rather than constructed units (e.g. Justice 1987). Attempts at typological rigor (e.g. Read 1982) emphasized outline form and neglected the effect of reduction, not original design, upon aspects of that form (Hoffman 1985), as did even more recent typologies constrained by the data requirements of methods like cladistics and innocent of the allometric effects of resharpening. Hoffman (1985) considered what many archaeologists called distinct types as variants of a single original form defined by different degrees and patterns of resharpening (Fig. 12.1). Reduction-sensitive variables are "not appropriate for conducting evolutionary analyses with techniques derived from cladistics" (Goodale et al. 2015: 241; see also Lipo 2006: 106; White 2013: 98; Barrientos 2015: 55; Prentiss et al. 2016: 127). The most systematic approach is a replicable key but it remains descriptive and works best only for where it was designed, the Great Basin (Thomas 1981). We have no general method for defining point types nor distinguishing among them. Instead, we treat points as judges once treated pornography, unable to define them but believing that we know them when we see them.

As described and used, subjectively defined point types are a social fact of archaeological practice, routinely cited in the literature from which in part we must identify the properties of better-defined types. We have no choice but to

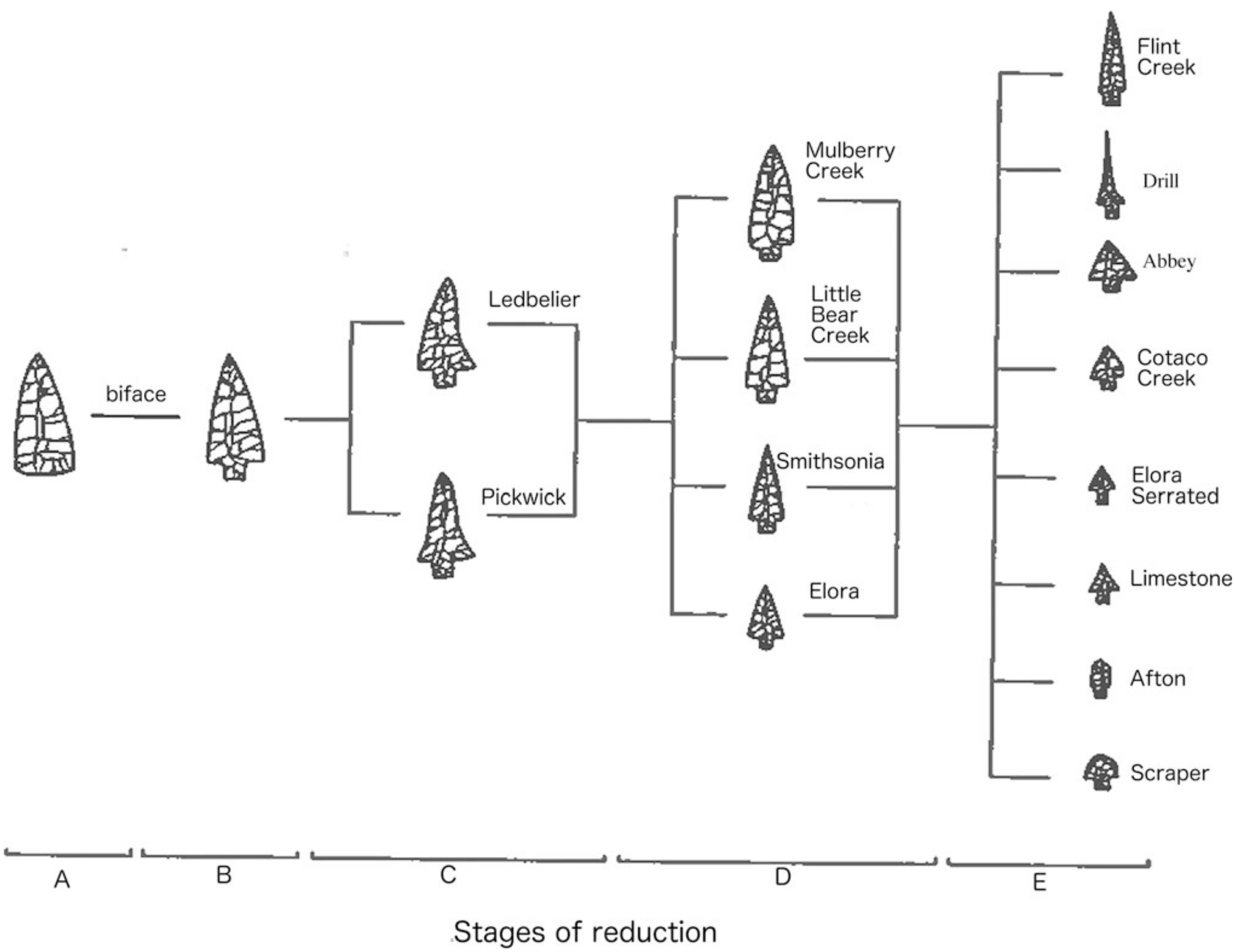

Fig. 12.1 A hypothetical reduction continuum in one point type that links subjectively defined empirical types. *Source* Hoffman (1985: Fig. 18.5)

use them, but only mindful of their serious shortcomings. We need better methods to create types that eventually will replace subjective ones. They must distinguish the most morphologically variable and informative segments of points—their haft elements or stems that articulate with the shaft or foreshaft of the larger weapon of which the point forms a part—from their blades, which are more subject to resharpening effects that compound original design (Hoffman 1985). They must describe in the fullest detail the morphometrics of haft elements. Practically, this requires geometric morphometric (GM) methods applied to two- and three-dimensional (2D and 3D, respectively) models of points (e.g. Thulman 2012), which encode vastly more morphometric information than do orthogonal dimensions; it also enables use of powerful statistical methods not available to conventional dimensional analysis. Better methods also require very large datasets, to fully comprehend types' variation by time, toolstone, curation pattern and rate, and other factors (Barrientos 2015: 56). Whatever types defined will be constructed, not revealed, kinds, units that are constantly arriving but never arrived, "artificial delineations in a continuous evolution of projectile-point morphology over space and time" (Cook and Comstock 2014: 226; see also Bradbury and Carr 2003; Shott 2003), reminiscent of Clarke's (1978: 182) polythetic sets.

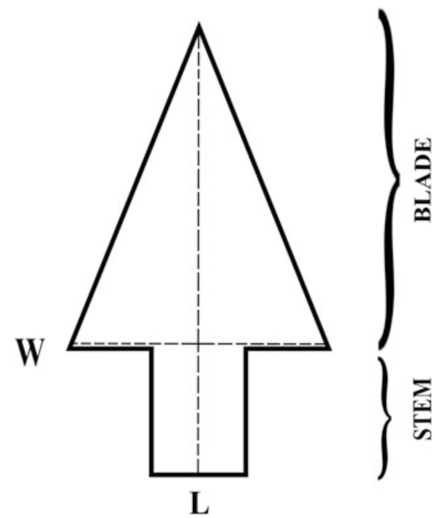

Fig. 12.2 Two-dimensional schematic view of a point, showing separate stem and blade segments and two orthogonal dimensions, length (L) and width (W). Note that values for length, width or other dimensions preserve no information about either their relative positions or overall point shape

Describing Points

Trivially, points are three-dimensional (3D) solids that include at least stem and blade segments (Fig. 12.2). Traditional analysis parses these complex wholes into separate, often orthogonal, dimensions (e.g. length, width, thickness) that measure size and form of the whole or its parts (e.g. blade length, stem width). Dimensions are isolated attributes that lack geometric context within the whole (e.g. a value for width, by itself, says nothing about its value compared to length or thickness, or where along the point's length or thickness profile it was taken), although simple ratios between them or ordination of sets of them can better approximate whole-object form. Still, individual dimensions are as faithful to the fullness of whole-object form as, say, stick-figure drawings are to Leonardo's Vitruvian Man. Other attributes that capture aspects of size (weight, area, perimeter, sectional area [e.g. Hughes 1998: 353]) or form/function [e.g. tip and edge angles]) are less commonly measured, but should be. Besides size and form, points have performance attributes that implicate range, thrust and other ballistic properties but in complex ways not easily derived from individual dimensions (Beck 1998: 24–25; Hughes 1998; Larralde 1990; Ratto 2003: 201–212; Edinborough 2005; Collins 2007; White 2013: 76–77). Points also are durable to varying degree, capable of surviving (or not) more than one firing and impact and large enough to accommodate resharpening (Larralde 1990: 78; Beck 1998; Hughes 1998: 371) experiments suggest much variation in survival depending upon material, targets, weapon systems and other factors (e.g. Odell and Cowan 1986; Cheshier and Kelly 2006; Shott 2016).

Whether used to define types in the first place, size-form variables can track secular trends in sequences of types. For instance, early Holocene midcontinental point sequences can be resolved in part to trends in individual variables that pattern in different directions and rates through time and that implicate complex interactions between weapon technology, hunting methods and environmental structure (White 2013). Viewing subjectively defined normative point types as mere time markers chronicles historical sequences, but detailed attribute studies might identify the underlying causes. Their behavior traced across historical type sequences, attributes also can identify stylistic variation useful for time resolution and functional stasis or change (e.g. Beck 1998; Wilhelmsen and Feathers 2003; Edinborough 2005; Apel and Darmark 2009; White 2013).

Yet recognizing secular trends in types requires controlling for variation by toolstone, and by degree and pattern of use and resharpening. Then, small-scale changes or trends through time within types can be examined, assuming sufficient chronological control. What explains any secular trends identified? Is it toolstone quality or supply? Changing density, body size or behavior of prey species, including people? Social conditions, including high population density and raiding? Changing labor organization of point product or

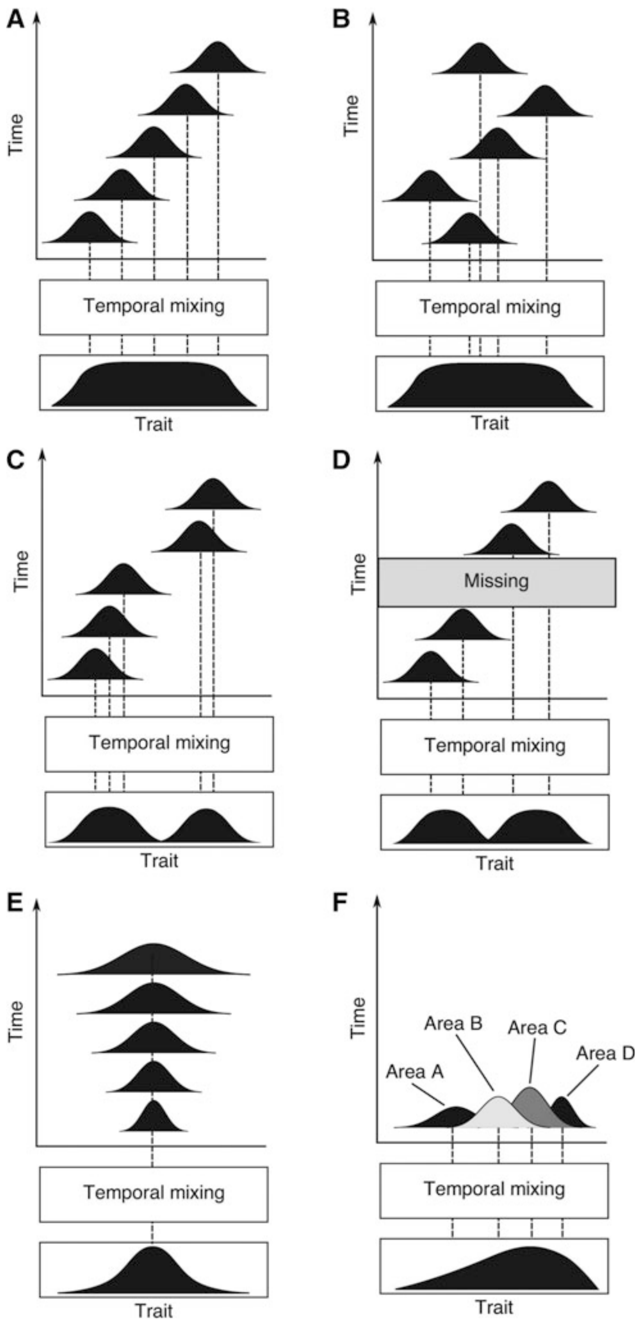

Fig. 12.3 Effects of accumulation ("temporal mixing") upon attribute distributions in time-averaged assemblages. Scenarios **A** and **B** show identical unimodal distributions that result from a steady secular trend (**A**) and fluctuating mean (**B**). Scenarios **C** and **D** show identical bimodal distributions that result from discontinuous trends (**C**) and gaps in accumulation (**D**). *Source* Perreault (2019: Fig. 3.12)

use? Copying error, itself partly a function of population size and number of points produced? Unfortunately, the time scales over which the record accumulates badly compound recognition of secular trends. Trends that vary in rate, magnitude and direction can be swamped or arbitrarily parsed in deposits that themselves vary greatly in scale. The permutations of such pooling effects pose challenges that must be addressed, not ignored (Fig. 12.3).

Moreover, however many individual attributes recorded never will approximate whole-object size and form. What might are GM approaches that characterize 2D and 3D objects by the placement of landmarks (specific functional or morphological coordinate locations like tips, shoulders and base corners) and semi-landmarks. Using landmarks complemented by dense meshes of semi-landmarks, the slope and distance between adjacent locations is reduced to noise, and the configuration of landmarks preserves geometric information and approximates whole-object form. Landmarks can be supplemented with selected attributes (e.g. tip, edge, or notch angles; stem:blade ratio). GM platforms distinguish analyst-defined modules (e.g. stem, blade, tip area) to test for modularity (landmarks in analyst-defined modules covarying significantly more among themselves than with landmarks in other modules), and ordinate morphometric data to characterize ranges of size-shape variation and to measure allometry, none of which is easily accomplished using conventional attribute schemes and manual measurement.

Using GM methods, archaeologists can begin to disentangle complex patterns of variation, for instance in resharpening's allometric effects that alter initial stem-vs.-blade to tip-vs.-rest-of-point modularity (de Azevedo et al. 2014), and measure the complex morphing that describes the transition from one type to another. In this perspective, GM methods and analysis also might explain why individual attributes like base form varied across time both early and late in eastern North American prehistory (e.g. White 2013; Cook and Comstock 2014: 236), perhaps as responses to evolving constraints of shaft width, prey targets or other factors.

Points as Tools

Points are tools, by definition, although what kind of tools they are and whether they are only tools, not also identity-markers, are questions to answer. Use-wear and residues inform on some, certainly last, uses, but treatment here emphasizes function related to morphometrics, mindful of the limits of the approach (Odell 1981). Only extensive experiments, which should be conducted, can identify the ballistic performance requirements of points discussed in the preceding section. Points, especially large ones, may have been designed for use as knives either besides (e.g. Collins 2007: 76–79; Douze et al.

2020) or instead of as one or another type of weapon tip. Discussion here concerns inferring the latter, along with S and L, systemic number and uselife respectively, from Schiffer's (1976: 60) discard equation.

Weapon System

In the limited ethnographic record there are some clear patterns in the use of stone versus other materials for points. Stone is common, but not exclusively so, only for use against larger targets (≥ 40 kg) (Larralde 1990: 7; Ellis 1997: Tables 1–5). Weapons usually were tipped with organic points for use on smaller targets. If the ethnographic record represents prehistoric practice, then our record of stone points pertains to weapons used only on larger, not all, targets. Yet the further argument (Ellis 1997: 45, 63) that stone point size (or form) is not calibrated to prey size rests on a sample that, despite its considerable size and breadth, is not sufficiently detailed to capture subtle adjustments of point size to prey characteristics—size and others—that may have been salient. The ethnographic sample is dominated by groups which used arrows alone or both arrows and darts or thrusting spears. In these cases, arrows are used commonly against smaller game. That is, weapon system but not point size is calibrated to target size.

Before the adoption of arrows, at least in North America, there was no option to calibrate weapon system to prey size; there were only spears and darts. At that time, the sizes of their points and probably foreshafts and shafts as well were adjusted to some combination of prey size, relative value and hunting method, all within single traditions of point design, manufacture, hafting and use. Similarly, Ellis's comparatively narrow boundary conditions of dart-point use—hafting on light shafts and firing over long distances on open ground (Larralde 1990: 75; Ellis 1997: Fig. 12.2)—may reflect the more circumscribed parameters of dart use when arrows also are available. Detailed studies of arrow design and use (admittedly not of stone) document the careful adjustment of point size to hunting method-, range, and possibly game targets (e.g. Watanabe 1975: 68; Estioko-Griffin 1984: 83); when darts were the sole or chief option, it is not unreasonable to expect that hunters would make similar adjustments of point size and form to relevant considerations like prey size. It is simplistic to suppose a close correlation between point size and prey size, yet declining size of deer, for instance, may help explain declining size of late prehistoric arrow points, along with changes in diet breadth and ecosystem structure (Cook and Comstock 2014: 245).

Either we assume that all stone points were spear or dart tips (or knives), or we reason, both from the ethnographic record's inherent limitations and the abundance of both preserved archaeological (e.g. Thomas 1978) and ethnographic specimens (e.g. Fowler and Matley 1979: 64–66), that the archaeological record also contains many stone arrow points. Taking the latter view, the question then is how to distinguish dart, arrow and hand-held spear or other points. Efforts progressed from Wilson's (1899: 69) length threshold of 3 in, to other simple metrics (sources cited in Shott 1997: 98), then to Thomas's (1978; see also Shott 1997) discriminant analysis of sets of attributes of ethnographic or preserved archaeological specimens known, not assumed, to be dart or arrow tip (see also Ratto 2003: 214–219 for methods that distinguish arrow from hand-held spear points). Latterly there has been a reversion to simple measures based on equally simple assumptions, but they do not account for archaeological data as do multivariate methods (Walde 2014). The next logical step is GM analysis of 3D models of stems of *known* arrow, dart and other points that can be distinguished, for instance, by canonical variates analysis.

Discriminant functions were tested on independent data in original studies (e.g. Shott 1997: 95). Recent discoveries of preserved organic weapon parts that establish either dart or arrow status (e.g. Hare et al. 2012) enable further tests. Together, these data and methods largely confirm Blitz's (1988) scenario of the bow-and-arrow's historical diffusion southward in the first millennium CE. Yet across North America, their application also suggests concurrent use of dart and arrow for significant periods (e.g. Erwin et al. 2005; Rasic and Slobodina 2008; Morrissey 2009; Rorabaugh and Fulkerson 2015; see Dev and Riede 2012 for a European example, although not involving bifacial points), and darts persisting to European invasion in places (Walde 2014: 156). Analysis of radiocarbon data from preserved organic segments found recently in wasting glaciers indicates nearly 200 years of dart-arrow overlap in the Subarctic (Grund and Huzurbazar 2018).

Whether as dart or arrow tip, Cardillo et al. (2016: 49–50) sought but did not find correlations between point form and environmental variables, although they did not control for resharpening effects upon the point-shape axis. Any such correlations that may exist should account for lag effects—possibly centuries in length—between environmental trends and human responses (e.g. Kelly et al. 2013). Fiedel (2014: 88), for instance, timed the apparently abrupt spread of bifurcate-base points to a period about 200 years after an early Holocene environmental shift; the hypothesis is worth testing if used with methods to measure degree of historical continuity between types. As interesting as it would be to correlate change in point size or shape with environmental trends, it would be at least as interesting to document type stasis when environments change. In such cases the question becomes, why do types *not* change as environment does?

Systemic Number S and Uselife L

Beyond noting differences in the number of points in arrow versus dart caches or preserved quivers, one admittedly limited way to test for differences in arrow and dart S is to compare their frequencies per unit time in contexts like wasting glaciers, where preserved organic components make identification reliable and direct dating possible. In sources consulted (Dixon et al. 2005: Table 1; VanderHoek et al. 2007: Table 1; Andrews et al. 2012: Table 1; Hare et al. 2012: Table 6; Lee 2012: Table 1; Lee and Puseman 2017), very few specimens preserved stone points in direct association; anyway, most arrows had organic points. Accordingly, only identifiable arrow shafts or dart shafts/foreshafts were counted; atlatls, bows and other miscellaneous objects were excluded. Obviously, resulting counts are of shafts, not points, so do not directly measure the relative frequency of *points* used per unit time; also obviously, results are limited to high-elevation contexts, assume constant population size or at least hunting rate, and dates are uncalibrated. This is a very coarse estimate, but in consulted sources, 53 darts span a range of 9230–1250 rcybp, or 7,980 radiocarbon years, for a mean figure of 6.6 darts per 1000 years. Excluding two possible specimens that exceed all other arrows by nearly two millennia, 33 arrows span a range of 1710 to 60 rcybp, or 1,650 radiocarbon years, for a mean of 20 arrows per 1000 years. Crudely, arrows occur at three times the rate that darts do, suggesting that their systemic frequency S may have been three times as high. Also, arrows often were made and probably carried in substantially higher numbers than darts were; thus, arrow S probably was higher (Larralde 1990: 177). For the Pawnee, 20–40 arrows was the norm per hunter (Weltfish 1977: 138); burial caches of arrow points sometimes fall in this range (e.g. Wright 2003: 86). If arrows less often than darts were tipped in stone (Ellis 1997), then the notable abundance of stone arrow points *underestimates* the true frequency of arrows and also the difference in S between stone dart and arrow points.

L also is a performance attribute of points. It is futile to try to estimate L in units of time because points were used episodically, not constantly. But if their original size can be estimated (e.g. from cache data) then the reduced size and altered form of points as discarded register degree and pattern of reduction. If a point's utility is measured by the amount of reduction it accommodates as it is used, this in turn relates to its curation (e.g. Shott 1996; Shott and Ballenger 2007), a quantity relevant both to the accumulation rate of point assemblages and to theories of technological organization (Shott 2017) and evolution (e.g. Ugan et al. 2003; Surovell 2009). There is little doubt that some types were subject to extensive repair or resharpening, and therefore curation; their allometric effects are documented in points across a wide contextual and time-space range (e.g. Peterson 1978; Hoffman 1985; Iriarte 1995; Archer and Braun 2010; de Azevedo et al. 2014; Goodale et al. 2015; Lerner 2015; Serwatka 2015). Yet some stone points may have been designed to fracture upon impact in order to increase wound size (Ellis 1997: 51; Engelbrecht 2015). Alternatively, any tendency toward impact fracture may have impaired their functionality (Ellis 1997: 57). Thus, breakability can be a design attribute or a design flaw, depending on circumstances.

Assemblages

In assemblages and their analysis, all points are not discarded alike. Traditionally, we interpret a point as evidence of a unit of activity, usually hunting or perhaps use as a knife. Whatever the particular kinds of use, the *amount* of use represented depends greatly upon the size and condition of the point. For any type designed to accommodate two or more resharpening episodes, *ceteris paribus* the more reduced the point the more use it experienced. If we can estimate—by experiment or comparison of used specimens to cached originals—the number of resharpenings that specimens of a type might undergo and then convert degree of reduction in discarded points to number of resharpenings, then we can estimate the latter (e.g. Shott 2017). Resharpening episodes may encompass two or more different uses, but at least the number of resharpenings might correlate with amount of use and degree of curation. In this view, two points of the same type do not represent equal amounts of use if they differ in amount or degree of reduction from resharpening.

Therefore, discarded points may be counted as discrete units, but must be calibrated to ratio-scale rates of use. Two assemblages of, say, 10 Type-X points each do not necessarily register the same amount or rate of point use, depending upon variation in their curation rates (Shott 1996). Besides their effects upon the size and composition of archaeological assemblages, degree and pattern of reduction and the curation rates implicated thereby have additional value. As assemblages of more types across broader time spans, especially within relatively small areas where toolstone supply and distribution can be held roughly constant, are studied for their reduction patterns and curation rates we can identify patterns in curation that then will require explanation.

Besides intact points that differ in size and reduction, tool fragments pose their own challenges. Broken points are common, as above possibly by design. Methods exist for quantification of original wholes represented by assemblages that combine intact and broken specimens (Shott 2000). Beyond quantification, degree of reduction might be possible to estimate for distal or medial fragments, at least sometimes. If so, these fragments inform on degree of point use as much as do intact specimens. Proximal or haft fragments could break at any stage or degree of use, making it difficult to calibrate the amount of tool use that they represent.

S and L obviously affect the size and composition of point assemblages. Besides calibrating archaeological abundance to past time, their formation effects bear upon inferences to other prehistoric trends. For instance, Bettinger (1999: 69–72) inferred prehistoric Great Basin population trends from changing frequencies of time-sensitive point types. This points-to-people equation assumes, obviously, some constant relationship between the numbers of both. Practically, it assumes that all point types had identical systemic frequencies and use lives, Schiffer's S and L. It assumes, that is, that at different times people used the same number of points per capita that lasted for the same period of time. Otherwise, points-to-people breaks down from the complicating effects of S and L independently of population.

Just in the comparison of arrows and darts, the assumption of constant or constantly proportioned S and L seems questionable. As above, arrow S probably was greater than dart S. There are good reasons to suppose that arrow L was shorter than dart L, again considerably. Arrows typically were thinner relative to their width, which made them perhaps more susceptible to breakage (e.g. Cheshier and Kelly 2006; Engelbrecht 2015). Arrows were fired at considerably higher speed than were darts, upon impact thus placing more stress upon the weapon, not least its point. Arrows could be fired from greater distances, making them easier to lose (Larralde 1990: 62). Thus, more abundant arrows that were more fragile were exposed to greater stresses and higher probability of loss.

Types as Historical Units

Attributes and objects are directly observed, and assemblages are defined by joint patterns of use, discard and deposition. The first two undeniably are "primary historical events" or units (Kitts 1992: 136), of a time-space scale commensurate with observation and experience. Most assemblages probably are time-averaged over at least years and often much longer; strictly they are not such primary events although typically we proceed as though they are, assuming that the size and composition of assemblages that include points characterize synchronic moments of the cultural past. An ethnographer could observe points being made and used, and record their number and context among the many more objects and constructions that typify any culture.

Pompeiis are nice to encounter. But the vast majority of the archaeological record accumulated at time scales orders of magnitude longer than the near-momentary Pompeiian one. We must stop using theory and implicit subjects suitable for very short time scales to explain the time-averaged record. Point types as historical units that persist for decades to centuries are beyond the scale of ethnographic observation. Their salient properties—definition, origins, time-space distribution, changing popularity over that distribution, duration, and fate—must be constructed from the many "primary events" that archaeologists document. Types are secondary historical events or units because they "have no counterpart in the present…[and] are composed of primary events related in a spatial and temporal nexus" (Kitts 1992: 137). As historical units, point types possess properties that are emergent at the lower level of primary events—not deducible from the properties of units at that level—and that require "explanatory principles emergent with respect to" (Kitts 1992: 142) it. No ethnographer can observe a point type in the fullness of its time-space range, or trace its origin, its behavior during its floruit, or its fate.

Yet here lies the gravest shortcoming in both contemporary and past archaeological thought. With rare exceptions (e.g. Perreault 2019) archaeology neglects both point types as units of study and efforts to explain their salient properties. No ethnographer can help us; archaeologists are the only ones who can observe, measure and explain the secondary-level or historical behavior of types over time-space scales that exceed ethnography's. Of course we do not ignore types entirely; we use them as markers that coarsely resolve past time, as clues to function and specific behaviors and, more recently, as contexts in which register technological organizational processes (Shott 2017). Here lies our greatest corollary challenge: developing the method and theory to define and analyze the historical behavior of types. Until we meet it, we are reduced to awkward groping toward a satisfactory account. That groping proceeds from time-space distributions and durations to types' changing abundance across those distributions, and finally to origins and fate together, as linked instances of diversification or extinction.

Time-Space Distributions of Types

Point types often serve as markers of cultures, yet their time-space distributions greatly exceed the equivalent scales of ethnographic cultures. Concerning just time scale, Eighmy and LaBelle (1996) documented point-type persistence on a millennial scale (Old World Paleolithic types, or at least facies defined in part by types, can persist even much longer [Monnier and Missal 2014: 67]), although ceramic types typically persisted for shorter spans. Similarly, the uncalibrated time ranges or durations of 49 eastern North American point types reported by Justice (1987) average 1387 years (although the distribution is right-skewed). Confined to types whose antiquity mid-points exceed 3000 BP—roughly, preceramic or pre-Woodland times—the mean span rises to 1762 years; comparable Plains data yield an average of 1696 years (Eighmy and LaBelle 1996: Table 2).

Overall, types' time ranges and antiquity (measured by range mid-point in years BP) are correlated ($r_s = 0.44$ $p < 0.01$) but a cubic, not linear, model provides the best fit (Fig. 12.4). This result suggests greater precision at the margins of eastern North American prehistory, owing to some combination of archaeological interests attracted to early and late prehistoric cultures and the finer contextual control available in later periods. The slope coefficient of linear regression of $\log_{10}$ type span upon age is 0.75 in Perreault's (2019: 175) deposits that include much earlier and therefore longer Paleolithic contexts. A similar regression of eastern North American point data (although, as above, a linear model fits these data poorly) gives a lower but substantial coefficient—a measure of change in the dependent type span with unit change in independent age—of 0.49. Type longevity is age-dependent, mostly later types lasting for shorter intervals.

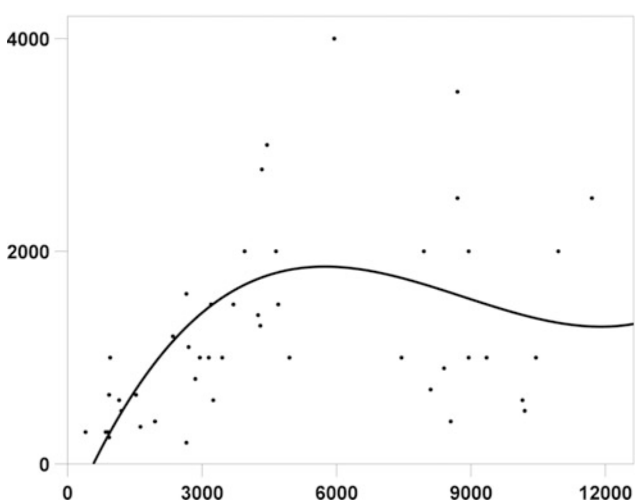

Fig. 12.4 Eastern North American point type duration against antiquity (both in years), measured by mid-point of reported time interval. Curve shows fit to cubic model. *Data source*: Justice (1987)

Properties of Type Floruits

A type's time-space distribution—its floruit—is among its fundamental properties. Fixing time intervals is a matter of adequate sampling, either of stratigraphic sequences, individual closed contexts, or direct dating of points. Considered together, the first two require numerous well dated contexts, for instance in classic alluvial (Coe 1964; Broyles 1971; Dincauze 1976; Stafford and Mocas 2008) or rockshelter (Sherwood et al. 2004) sequences of eastern North America although, as cultures grew progressively more sedentary and depositional regimes stabler through the Holocene, most of these sequences better parse Pleistocene and early Holocene intervals. It also can involve statistical analysis of radiocarbon dates (e.g. Manning et al. 2014; Thulman 2017). Direct dating requires thermoluminescence or other direct methods (Wilhelmsen and Feathers 2003), conceived of but not yet systematically attempted.

A type may exist from t_1 to t_2, but the interval defines only its nominal duration. Its floruit is determined from the interval along with its changing abundance over it. Types that are purely stylistic may exhibit normal distributions, rising gradually from t_1 to reach their maximum abundance at $t_{1.5}$, then declining equally gradually to t_2 (e.g. Manning et al. 2014; Perreault 2019: 237) (Fig. 12.5). Sequences of floruits can overlap only at their tails, forming unbroken sequences over long time periods. But in theory floruits can be skewed, vary in kurtosis, be multi-modal, and overlap in time variably if at all (Fig. 12.5). Over long intervals, some may overlap mostly if not entirely with others, and some intervals of time may be occupied by none.

Unfortunately, summed radiocarbon probabilities (e.g. Thulman 2017: Fig. 12.3) describe samples of radiocarbon dates and points jointly, not the latter alone. They describe the form of floruits over time only by controlling for the manifest biases that reside in radiocarbon samples. In any event, for common types they are derived from vanishingly small fractions of the total point population. Although the contexts are hardly more numerous, types' frequency distributions across dated contexts are somewhat less compounded samples of their changing abundance through time (e.g. Sherwood et al. 2004: Fig. 12.5).

Once the time-space ranges and the forms of floruits are charted, they must be explained. Do time and space ranges correlate with one another, such that more widely distributed types persist longer in time? Do those ranges correlate with their assemblage sizes, such that more common or popular types persist longer or are more widely distributed than others? Do those properties of floruits vary with the length, complexity or failure rates that characterize their production sequences? Do they vary with inferred human population sizes, such that types used by larger populations persist

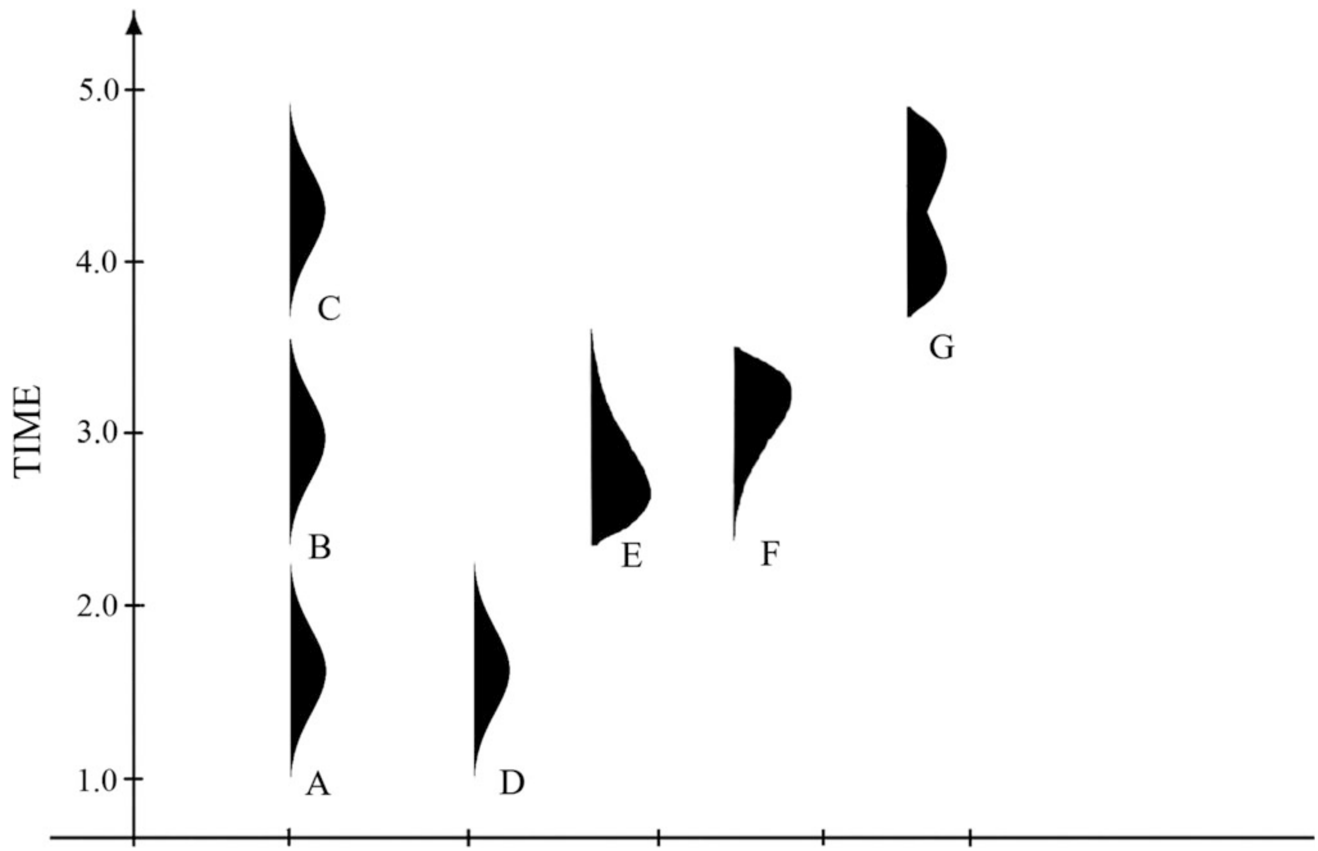

Fig. 12.5 Duration and form of type floruits. Type popularity at any time t_i is proportional to floruit width. **A**–**C** are similar in all properties save time interval, and all describe ideal unimodal, symmetric floruits of equal duration and popularity. They may overlap one another slightly in time, and together form an unbroken continuum or nearly so. **D**–**G** also differ in time interval but also in form, duration, popularity and degree of time overlap

longer and wider than do others? Do they vary with scale or type of sociopolitical organization? Do they vary, as Fiedel (2014) argued, with environmental changes?

Stasis and Sensitivity in Types

Stasis describes the tendency of types to change in forms, gradually or otherwise, during their floruits, sensitivity their somewhat opposing tendency to correlate or not with changes in other cultural units or respects. Why do types change at all? Even today, we cannot answer so fundamental a question about so important and abundant a unit of observation. Is type stasis—lack of change over considerable time—a phenomenon to explain or merely the consequence of the absence of sources of change? In analytical terms, types must possess integrity or they become other types, but what range of variation is permissible and exhibited within them? Across time or space, do specimens of a type drift within its morphometric range? Do types persist longer or shorter depending upon their shape, function, or other properties of the individual points? Are types that require lengthier production sequences prone to greater copying error and therefore higher rates of drift or even tendency to diversification? Explaining stasis is "one of the most interesting and potentially revealing aspects of the history of most species" (Gould 1980: 103), and perhaps of point types as well.

Diversification: Origins and Fate of Types

Diversification encompasses both the origin and demise of points. Types originate either *de novo,* as entirely new and original designs, or by change of pattern and degree of ancestral types and their segments. Obviously, the earliest type arises *de novo,* but descendant ones can arise either way. Why do types stop being made? That is, how and why do types end? Types terminate by extinction or by progressive diversification into one or more descendant types. Archaeologists' descriptions of point-type sequences often assume origin *de novo* and termination by extinction, for instance as we speak of LeCroys replacing Kirks. That may occur, but it is an assumption not a demonstrated inference. Valid inferences to origins and fates require methods that both describe type morphometrics and distinguish variation within from variation between types. They also require theory to explain *de novo* origins and termination by either mode.

Types can end in two ways: simple termination or branching diversification. Termination can occur by population replacement (e.g. "The Invasion of the Side-Notched People") or simple abandonment of the type. Either may be treated idiographically, as unique historical events that cannot be explained by general causes. The point-type sequences that underlie typological cross-dating in North America are well known, and involve many apparent terminations. Thus, termination may be fairly common, yet we have no theory to explain it. What, that is, explains one type's end and the next's origin? We cannot even distinguish between replacement and abandonment, never having established or agreed upon the necessary criteria beyond similarity, broadly conceived (Barrientos 2015: 54).

Branching diversification, a typical pattern in biology, has two modes: cladogenesis, in which one ancestral type gives rise to two descendant ones, or anagenesis, in which the ancestor persists as one type branches from it. In the living world, a single taxon at t_1 can yield many descendent taxa by t_{10}. The root taxon may be gone by then, by extinction or speciation. Many descendant taxa may have originated and terminated in the interval. At any time within it, any number of descendent taxa may exist, for varying durations. Yet in general, within phylogenies taxa diversify with time. At t_0 there is only one but at t_2 there may be two, at t_3 seven, and so on to much greater diversity.

In the made world of objects, branching diversification may be an imperfect model for the history of point sequences or any higher-level archaeological units. Or at least the diversification of cultural units like types is constrained compared to the living world. Clovis, say, may be ancestral to any number of types, but rarely to more than a few at any one time. If Clovis lies at t_0, then at any t_x only one or few descendants are apt to exist. Controlling for time span, for instance, Larralde (1990: 67) detected no significant rise in the diversity of early to late Holocene point types on the northern plains, although Lyman et al. (2009) saw evidence for increased type diversity at the dart-arrow transition. No trend, steady or irregular, toward rising diversity is likely to characterize the interval because prehistoric cultures, unlike prehistoric biomes, had limited capacity to accommodate, and limited need for, point types. At t_0 there is only one; at t_2 there may be two or three, at t_3 also two or three, and so on in sequences of relatively fixed typological, if potentially great morphological, diversity.

Cladistic methods commonly are used to generate point-type cladograms, to chart pattern and degree of relationship between ancestral and descendant types (e.g. O'Brien and Lyman 2003). Cladistics is designed to explain patterns of branching diversification, which suits it well to fossil data. But appropriate traits are not merely what are at hand but instead irreducible units that "must…be the result of a process of descent with modification" and that survive tests of unit-transmission integrity (Pocklington 2006: 25). Constrained typological diversity of point types seems better suited to methods that neither assume nor require progressive diversification (e.g. Lipo 2006; Adams and Collyer 2009), which provide merely detailed morphometric descriptions of transformations between point types, and make no assumptions about diversification mode. Our task then is to explain the transformations, their mode, tempo and path, along with the problem of persistence or stasis. All of this requires "in-depth assessment of character hypotheses" (Barrientos 2015: 55), rarely conducted today.

As in other respects, we have little data to catalog the separate occurrences of cladogenesis and anagenesis, and no theory whatsoever to explain the occurrences. Why do some types become two or more descendant ones? Is it determined by human population size or distribution, or perhaps of changing environmental structure and patchiness? Are types of more complex production sequences and perhaps size and shape more likely than others to undergo cladogenesis or anagenesis? If the former, what explains the number of descendant types that form over time? Among diversifying types, are there patterns when viewed across many types from many time-space contexts? Does morphing occur chiefly on haft elements, on blades, or on both at once?

All else equal, presumably more complex production processes and narrowly specified size and shape might limit the potential for diversification. With the historically unique introduction of arrow technology to North America, were dart points "translated" (Hall 1980; see also Clarke's [1978: 228] "transformation types" and White [2003] on the Jack's Reef to triangle sequence in the Great Lakes) by degree into arrow points until it became clear that radical changes—to small triangular forms—were needed? More broadly, and given the functional constraints to which points were subject, does the range of size-shape types produced by diversification over long spans comprehensively sample point phylogenies' theoretical morphospaces, the full range of possible size-shape permutations that they *may* occupy?

Broader Disciplinary Context

Treating point types as units of observation in their own right, seeking to explain the causes, correlates and properties of their time-space distributions, requires great change in our analytical perspective. Yet the shift is not totalizing. It is something to attend to besides, not entirely in place of, what we do now. It does not preclude continued attention to traditional lines of research (e.g. reduction/production processes, attribute analysis, use-wear, curation). Analytical focus upon types as *units* of analysis complements and extends, not replaces, other approaches to points. At the same time, it allows the study of points to contribute to archaeology's maturation as a discipline with units of observation and analysis that are commensurate with the spatial and especially the time scale at which assemblages accumulated.

Approaching this goal requires changes to and improvements in practice. We must amass much larger samples of points to document the morphological and use-related range of variation within types and the fullest time-space range of types (Barrientos 205: 56); practically, this means that we must engage with the larger communities of collectors, who control by far the majority of the known point population. We must compile larger databases of radiocarbon or other chronometric associations with or directly-dated points, and refine their resolution (e.g. Thulman 2017). We must develop and apply systematic methods to identify and distinguish types. We must conduct a wider range of controlled and actualistic experiments to better gauge the functional properties of points as weapon tips and/or as hand-held spears. We must gauge and explain the full range of the pattern and degree of types' resharpening, and their curation rates. Most important of all, to exploit the potential of such improved units of study, we must develop the second-order theory, not of timeless individual or group behavior, but of the behavior of derived types that will explain the pattern that preceding steps described.

Conclusion

As thick as it is with questions, this essay is remarkably thin in answers; in fact, it has scarcely any. Questions are much easier to ask than to answer, but questions of the nature posed here are, I hope, excusable. They arise from rueful acknowledgment that archaeology's units and their scales of accumulation are not commensurate with the theory that it applies, and the resulting conviction about the need to construct units at suitable scales and to explain them using suitable theory. Points are not the only category in which archaeology might seek solutions to our problems, but they certainly are one, and therefore as good as place as any in which to confront the challenges that Clarke identified 50 years ago. Time enough to start the effort.

It is not difficult to substantiate Clarke's claim that archaeology was and remains an "undisciplined empirical discipline." The history of the field in the 1980s and 1990s practically makes the argument for itself. But even Clarke's own time 20 years earlier, when Beatles roamed the earth, shows both the uncritical borrowing of theory and method from other fields and the waxing and waning of fads. At least in the United States, archaeologists then were in the grip of an epistemological fundamentalism. If exaggerated in that case, legitimate concern for grounding inferences always is salutary, but the philosophical agonizing failed to take root. Later, archaeologists conveniently forgot about the need to document their claims in evidence, thus reducing the earlier epistemological rigor to a passing fad. Similarly, the sincere concern for sampling rigor that began to develop in the 1960s was, at length, conveniently abandoned. Still other fads came and went (e.g. trend-surface analysis from geography, factor analysis from psychology, numerical taxonomy from biology).

Thus, in the 1960s archaeologists talked about logical positivism. In the 1980s they talked of praxis. In the past 20 years, they spoke increasingly of agency and identity. If the field does not change, in 20 years they will speak of whatever is then the prevailing intellectual fancy. Not in particulars of course but in the sense that he meant—a passive consumption of other disciplines' method and theory, and a fondness for ungrounded scholarly fashion—archaeology has changed little since Clarke's time. Unless, like paleobiology, we create the truly distinct theory of diachronic pattern and process of units whose time-space scales greatly exceed those typical of anthropology or behavioral ecology, then in 20 years archaeology will remain, as it was before and is now, a parade of passing intellectual fancies without the slightest cumulative progress. It will remain the undisciplined discipline that Clarke deplored. If that happens, we will continue to repeat the errors that paleobiology corrected, defining the wrong units at the wrong scales that we try to explain with the wrong theory.

This is no brief for a crude identification of point types with biological taxa, or an equally crude reduction of archaeology to biology. On the contrary, we deal with material culture that is vastly less constrained in rate, direction and magnitude of change and much more amenable to horizontal transmission. We deal with hierarchies of units —from attribute through type to tradition and cultural phylogeny—and complex patterns of interaction that exceed biology's. The solution is not to transfer our passive transference from anthropology to paleobiology; our challenge is to fashion our own units and theory for our own scales of culture change.

To realize its potential and its rightful place among the historical sciences, it should be clear that archaeology requires unbounded independence from anthropology. The study of points alone, of course, will not make this change but can be an integral part of it. To that extent a theory of the point, put into practice, will make its own modest contribution to correcting the flaws in archaeological thought and practice that Clarke identified so long ago and that, tragically, continue to burden us today.

Acknowledgments Huw Groucutt kindly invited me to write this essay. I alone am responsible for any errors. I thank the University of Chicago Press and Charles Perreault of Arizona State University for permission to use Fig. 12.3. Thanks also to Eric Olson and Calixto Alvarado, who drafted several figures.

References

Adams, D., & Collyer, M. (2009). A general framework for the analysis of phenotypic trajectories in evolutionary studies. *Evolution, 63,* 1143–1154.

Andrefsky, W. (2006). Experimental and archaeological verification of an index of retouch for hafted bifaces. *American Antiquity, 71,* 743–757.

Andrews, T., MacKay, G., & Andrew, L. (2012). Archaeological investigations of alpine ice patches in the Selwyn Mountains, Northwest Territories, Canada. *Arctic, 65*(Suppl. 1), 1–21.

Apel, J., & Darmark, K. (2009). Evolution and material culture. *Current Swedish Archaeology, 17,* 11–28.

Archer, W., & Braun, D. (2010). Variability in bifacial technology at Elandsfontein, Western Cape, South Africa: A geometric morphometric approach. *Journal of Archaeological Science, 37,* 201–209.

Barrientos, G. (2015). On the problem of identifying homologies in lithic artifacts. In M. Cardillo & H. Muscio (Eds.), *Darwin's legacy: The status of evolutionary archaeology in Argentina* (pp. 49–66). Oxford, UK: Archaeopress.

Beck, C. (1998). Projectile point types as valid chronological units. In A. Ramenofsky & A. Steffen (Eds.), *Unit issues in archaeology: Measuring time, space and material* (pp. 21–40). Salt Lake City, UT, USA: University of Utah.

Bettinger, R. (1999). What happened in the medithermal. In C. Beck (Ed.), *Models for the millennium: Great Basin anthropology today* (pp. 62–74). Salt Lake City, UT, USA: University of Utah.

Blitz, J. (1988). Adoption of the bow in prehistoric North America. *North American Archaeologist, 9,* 123–145.

Bode, C. (Ed.). (1967). *The portable Thoreau*. New York, NY, USA: Viking.

Bradbury, A., & Carr, P. (2003). A method for quantifying size and shape dimensions of North American hafted bifaces. In N. Moloney & M. Shott (Eds.), *Lithic analysis at the millennium* (pp. 173–187). London, UK: Institute of Archaeology, University College.

Broyles, B. (1971). *Second preliminary report: The St. Albans site, Kanawha County, West Virginia.* Report of Archaeological Investigation No. 3. West Virginia Geological and Economic Survey, Charleston, WV, USA.

Cardillo, M., Borrazzo, B., & Charlin, J. (2016). Environment, space, and morphological variation of projectile points in Patagonia (Southern South America). *Quaternary International, 422,* 44–56.

Cheshier, J., & Kelly, R. (2006). Projectile points shape and durability: The effect of thickness-length. *American Antiquity, 71,* 353–363.

Clarke, D. (1978). *Analytical archaeology* (2d ed.). New York, NY, USA: Columbia University.

Coe, J. (1964). Formative cultures of the Carolina Piedmont. *Transactions of the American Philosophical Society, 54*(5). Philadelphia, PA, USA.

Collins, M. (2007). Discerning Clovis subsistence from stone artifacts and site distributions on the Southern Plains periphery. In R. Walker & B. Driskell (Eds.), *Foragers of the terminal Pleistocene in North America* (pp. 59–87). Salt Lake City, UT, USA: University of Utah.

Cook, R., & Comstock, A. (2014). Toward more continuous and practical artifact analyses: Defining and learning from key dimensions of Fort Ancient triangular projectile points in the Miami Valley. *Midcontinental Journal of Archaeology, 39,* 222–250.

de Azevedo, S., Charlin, J., & González-José, R. (2014). Identifying design and reduction effects on lithic projectile point shapes. *Journal of Archaeological Science, 41,* 297–307.

Dev, S., & Riede, F. (2012). Quantitative functional analysis of Late Glacial projectile points from Northern Europe. *Lithics, 33,* 40–55.

Dincauze, D. (1976). *The Neville site: 8,000 years at Amoskeag, Manchester, New Hampshire.* Peabody Museum Monographs No. 4. Harvard University, Cambridge, MA, USA.

Dixon, E., Manley, W., & Lee, C. (2005). The emerging archaeology of glaciers and ice patches: Examples from Alaska's Wrangell-St. Elias National Park and Preserve. *American Antiquity, 70,* 129–147.

Douze, K., Igreja, M., Rots, V., Cnuts, D., & Porraz, G. (2020). Technology and function of Middle Stone Age points. Insights from a combined approach at Bushman Rock Shelter, South Africa. In H. Groucutt (Ed.), *Culture history and convergent evolution: Can we detect populations in prehistory?* (pp. 127–141). Cham, Switzerland: Springer.

Edinborough, K. (2005). Evolution of bow-arrow technology. Ph.D. dissertation, Institute of Archaeology, University College London.

Eighmy, J., & LaBelle, J. (1996). Radiocarbon dating of twenty-seven Plains complexes and phases. *Plains Anthropologist, 41,* 53–69.

Ellis, C. (1997). Factors influencing the use of stone projectile tips: An ethnographic perspective. In H. Knecht (Ed.), *Projectile technology* (pp. 37–74). New York, NY, USA: Plenum.

Engelbrecht, W. (2015). Interpreting broken arrow points. *American Antiquity, 80,* 760–766.

Erwin, J., Holly, D., Hull, S., & Rast, T. (2005). Form and function of projectile points and the trajectory of Newfoundland prehistory. *Canadian Journal of Archaeology, 29,* 46–67.

Estioko-Griffin, A. (1984). The ethnography of Southeastern Cagayan Agta hunting. MA thesis, University of the Philippines, Manila, Philippines.

Fiedel, S. (2014). Abrupt changes of climate and of point styles along the Atlantic seaboard of Eastern North America. *Archaeology of Eastern North America, 42,* 77–100.

Fowler, D., & Matley, J. (1979). *Material culture of the Numa: The John Wesley Powell Collection, 1867–1880.* Smithsonian Contributions to Anthropology No. 26. Smithsonian Institution Press, Washington, DC, USA.

Frankel, D. (1988). Characterising change in prehistoric sequences: A view from Australia. *Archaeology in Oceania, 23,* 41–48.

Goodale, N., Andrefsky, W., Osterhoudt, C., Cueni, L., & Kuijt, I. (2015). Cultural transmission and the production of material goods: Evolutionary pattern through measuring morphology. In N. Goodale & W. Andrefsky (Eds.), *Lithic technological systems and evolutionary theory* (pp. 239–252). New York, NY, USA: Cambridge University.

Gould, S. (1980). The promise of paleobiology as a nomothetic, evolutionary discipline. *Paleobiology, 6,* 96–118.

Groucutt, H., & Scerri, E. (2014). Lithics of the late Middle Palaeolithic: Post MIS 5 technological variability and its implications. *Quaternary International, 350,* 1–6.

Grund, B., & Huzurbazar, S. (2018). Radiocarbon dating of technological transitions: The Late Holocene shift from atlatl to bow in northwestern Subarctic Canada. *American Antiquity, 83,* 148–162.

Hall, R. (1980). An interpretation of the Two-Climax Model of Illinois prehistory. In D. Browman (Ed.), *Early Native Americans: Prehistory, demography, economy and technology* (pp. 401–462). The Hague, Holland: Mouton.

Hare, P., Thomas, C., Topper, T., & Gotthardt, R. (2012). The archaeology of Yukon ice patches: New artifacts, observations, and insights. *Arctic, 65*(Suppl. 1), 118–135.

Hoffman, C. (1985). Projectile point maintenance and typology: Assessment with factor analysis and canonical correlation. In C. Carr (Ed.), *For concordance in archaeological analysis: Bridging* *data structure, quantitative technique, and theory* (pp. 566–612). Kansas City, MO, USA: Westport.

Hughes, S. (1998). Getting to the point: Evolutionary change in prehistoric weaponry. *Journal of Archaeological Method and Theory, 5,* 345–408.

Iriarte, J. (1995). Afinando la puntería: Tamaño, forma y rejuvenecimiento en las puntas de proyectil pedúnculadas del Uruguay. In M. Consens, J. López, & M. del Carmen (Eds.), *Arqueología en Uruguay: 120 años despues* (pp. 142–151). Montevideo, Uruguay: VIII Congreso de Arqueología Nacional Uruguaya.

Justice, N. (1987). *Stone Age spear and arrow points of the midcontinental and eastern United States: A modern survey and reference*. Bloomington, IN, USA: Indiana University Press.

Kelly, R., Surovell, T., Shuman, B., & Smith, G. (2013). A continuous climatic impact on Holocene human population in the Rocky Mountains. *Proceedings of the National Academies of Science, 110,* 443–447.

Kitts, D. (1992). The conditions for a nomothetic paleontology. In M. Nitecki & D. Nitecki (Eds.), *History and evolution* (pp. 131–145). Albany, NY, USA: State University of New York.

Larralde, S. (1990). The design of hunting weapons: Archaeological evidence from Southwestern Wyoming. Ph.D. dissertation, University of New Mexico.

Lee, C. (2012). Withering snow and ice in the mid-latitudes: A new archaeological and paleobiological record for the Rocky Mountain region. *Arctic, 65*(Suppl. 1), 165–177.

Lee, C., & Kathryn Puseman, K. (2017). Ice patch hunting in the greater Yellowstone area, Rocky Mountains, USA: Wood shafts, chipped stone projectile points, and bighorn sheep. *American Antiquity, 82,* 223–243.

Lerner, H. (2015). Dynamic variables and the use-related reduction of Southern Huron projectile points. In M. Shott (Ed.), *Works in stone: Contemporary perspectives on lithic analysis* (pp. 143–161). Salt Lake City, UT, USA: University of Utah.

Lipo, C. (2006). The resolution of cultural phylogenies using graphs. In C. Lipo, M. O'Brien, M. Collard, & S. Shennan (Eds.), *Mapping our ancestors: Phylogenetic approaches in anthropology and prehistory* (pp. 89–107). New Brunswick, NJ, USA: AldineTransaction.

Lyman, R., VanPool, T., & O'Brien, M. (2009). The diversity of North American projectile-point types before and after the bow and arrow. *Journal of Anthropological Archaeology, 28,* 1–13.

Manning, K., Timpson, A., Colledge, S., Crema, E., Edinborough, K., Kerig, T., et al. (2014). The chronology of culture: A comparative assessment of European Neolithic dating approaches. *Antiquity, 88,* 1065–1080.

Monnier, G., & Missal, K. (2014). Another Mousterian Debate? Bordian facies, chaîne opératoire technocomplexes, and patterns of lithic variability in the western European Middle and Upper Pleistocene. *Quaternary International, 350*, 59–83.

Morrissey, G. (2009). Tools and change: The shift from atlatl to bow on the British Columbia Plateau. MA thesis, Simon Fraser University, Burnaby, BC, CAN.

O'Brien, M., & Lyman, R. (2003). *Cladistics and archaeology*. Salt Lake City, UT, USA: University of Utah.

Odell, G. (1981). The morphological express at function junction: Searching for meaning in lithic tool types. *Journal of Anthropological Research, 37,* 319–342.

Odell, G., & Cowan, F. (1986). Experiments with spears and arrows on animal targets. *Journal of Field Archaeology, 13,* 195–212.

Perreault, C. (2019). *The quality of the archaeological record*. Chicago, IL, USA: University of Chicago.

Peterson, R. (1978). Projectile point re-utilization patterns at the Agate Basin site. *Wyoming Contributions to Anthropology, 1,* 139–147.

Pocklington, R. (2006). What is a culturally transmitted unit, and how do we find one? In C. Lipo, M. O'Brien, M. Collard, & S. Shennan (Eds.), *Mapping our ancestors: Phylogenetic approaches in anthropology and prehistory* (pp. 19–31). New Brunswick, NJ, USA: AldineTransaction.

Prentiss, A., Walsh, M., Skelton, R., & Markes, M. (2016). Mosaic evolution in cultural frameworks: Skateboard decks and projectile points. In L. Mendoza Straffen (Ed.), *Cultural phylogenetics: Concepts and applications* (pp. 113–130). Basel, Switzerland: Springer.

Rasic, J., & Slobodina, N. (2008). Weapon systems and assemblage variability during the Northern Archaic Period in Northern Alaska. *Arctic Anthropology, 45,* 71–88.

Ratto, N. (2003). Estrategias de caza y propiedades del registro arqueológico en la Puna de Chascuil (Dpto. de Tinogasta, Catamarca, Argentina). Ph.D. dissertation, Departamento de Ciencias Antropólogicas, University of Buenos Aires.

Read, D. (1982). Toward a theory of archaeological classification. In R. Whallon & J. Brown (Eds.), *Essays in archaeological typology* (pp. 56–92). Evanston, IL, USA: Center for American Archaeology Press.

Reynolds, N. (2020). Threading the weft, testing the warp: Population concepts and the European Upper Palaeolithic chronocultural framework. In H. Groucutt (Ed.), *Culture history and convergent evolution: Can we detect populations in prehistory?* (pp. 187–212). Cham, Switzerland: Springer.

Rorabaugh, A., & Fulkerson, T. (2015). Timing of the introduction of arrow technologies in the Salish Sea, Northwest North America. *Lithic Technology, 40,* 21–39.

Schiffer, M. (1976). *Behavioral archeology*. New York, NY, USA: Academic.

Serwatka, K. (2015). Bifaces in plain sight: Testing elliptical Fourier analysis in identifying reduction effects on Late Middle Palaeolithic bifacial tools. *Litikum, 3,* 13–25.

Sherwood, S., Driskell, B., Randall, A., & Meeks, S. (2004). Chronology and stratigraphy at Dust Cave, Alabama. *American Antiquity, 69,* 533–554.

Shott, M. (1996). An exegesis of the curation concept. *Journal of Anthropological Research, 52,* 259–280.

Shott, M. (1997). Stones and shafts redux: The metric discrimination of prehistoric dart and arrow points. *American Antiquity, 62,* 86–101.

Shott, M. (2000). The quantification problem in stone tool assemblages. *American Antiquity, 65,* 725–738.

Shott, M. (2003). Time as sequence, type as ideal: Whole-object measurement of Woodland biface size and form in Midwestern North America. In M. Soressi (Ed.), *Multiple approaches to the study of bifacial technology* (pp. 251–271). Philadelphia, PA, USA: University of Pennsylvania Museum Press.

Shott, M. (2016). Survivorship distributions in experimental spear points: Implications for tool design and assemblage formation. In R. Ioviţă & K. Sano (Eds.), *Multidisciplinary approaches to the study of Stone Age weaponry*. Vertebrate Paleobiology and Paleoanthropology Series (pp. 245–258). Dordrecht, Holland: Springer.

Shott, M. (2017). The costs and benefits of technological organization: Hunter-gatherer lithic industries and beyond. In E. Robinson & F. Sellet (Eds.), *Lithic technological organization and paleoenvironmental change: Global and diachronic perspectives* (pp. 321–333). Dordrecht, Holland: Springer.

Shott, M., & Ballenger, J. (2007). Biface reduction and the measurement of Dalton curation: A Southeastern case study. *American Antiquity, 72,* 153–175.

Stafford, C., & Mocas, S. (2008). *The Middle, Late, and Terminal Archaic occupations at the Caesars Archaeological Project, Harrison County, Indiana*. Caesars Archaeological Project Report

Volume 3. Archeology and Quaternary Research Laboratory, Technical Report 38. Indiana State University, Terre Haute, IN, USA.

Stutz, A. J. (2020). The Middle-Upper Paleolithic transition: A long-term biocultural effect of anatomically modern human dispersal. In H. Groucutt (Ed.), *Culture history and convergent evolution: Can we detect populations in prehistory?* (pp. 157–186). Cham, Switzerland: Springer.

Surovell, T. (2009). *Toward a behavioral ecology of lithic technology: Cases from Paleoindian archaeology*. Tucson, AZ, USA: University of Arizona.

Thomas, D. (1978). Arrowheads and darts: How the stones got the shaft. *American Antiquity, 43,* 461–472.

Thomas, D. (1981). How to classify the projectile points from Monitor Valley, Nevada. *Journal of California and Great Basin Anthropology, 3,* 7–43.

Thulman, D. (2012). Discriminating Paleoindian point types from Florida using landmark geometric morphometrics. *Journal of Archaeological Science, 39,* 1599–1607.

Thulman, D. (2017). Dust Cave revisited: A Bayesian reanalysis of the radiocarbon record. *American Antiquity, 82,* 168–182.

Ugan, A., Bright, J., & Rogers, A. (2003). When is technology worth the trouble? *Journal of Archaeological Science, 30,* 1315–1329.

VanderHoek, R., Tedor, R., & McMahan, J. (2007). Cultural materials recovered from ice patches in the Denali Highway region, Central Alaska, 2003–2005. *Alaska Journal of Anthropology, 5,* 185–200.

Walde, D. (2014). Concerning the atlatl and the bow: Further observations regarding arrow and dart points in the archaeological record. *American Antiquity, 79,* 156–161.

Watanabe, H. (1975). *Bow and arrow census in a West Papuan lowland community: A new field for functional ecological study.* Occasional Papers in Anthropology No. 5, University of Otago, Dunedin, New Zealand.

Weltfish, G. (1977). *The lost universe: Pawnee life and culture*. Lincoln, NE, USA: University of Nebraska.

White, A. (2003). Mortuary assemblages and the chronology of the Jack's Reef Cluster. *Michigan Archaeologist, 49,* 43–71.

White, A. (2013). Functional and stylistic variability in Paleoindian and Early Archaic projectile points from Midcontinental North America. *North American Archaeologist, 34,* 71–108.

Wilhelmsen, K., & Feathers, J. (2003). Dating the manufacture of projectile points using thermoluminescence. In N. Moloney & M. Shott (Eds.), *Lithic analysis at the millennium* (pp. 189–202). London, UK: Institute of Archaeology.

Wilson, T. (1899). Arrowpoints, spearheads, and knives of prehistoric times. *Report of the United States National Museum for 1897* (pp. 1–267). Government Printing Office, Washington, DC, USA.

Wright, T. (2003). Madison triangles: There must be a point. In B. Redmond & J. Jones (Eds.), *Facing the final millennium: Studies in the late prehistory of Indiana, A.D. 700 to 1700* (pp. 85–94). Indianapolis, IN, USA: Indiana Division of Historic Preservation and Archaeology.