of environmental deterioration and then collapsed because of that environmental deterioration. The ceremonial activities carried out at Cahuachi were probably related to water, fertility, and agriculture. It is possible that during Nasca 3 the drought was severe and therefore rituals were intensified at Cahuachi. After its abandonment, this Nasca center apparently maintained its prestige, and the late establishment of the Wari site of Pacheco near Cahuachi was probably an effort to capture its prestige while replacing it and its Nasca gods with Pacheco and the Wari gods.

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The Origins of Weapon Systems

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As Stiner (1993:70) has recently pointed out, “Upper Palaeolithic and Late Stone Age assemblages of Eurasia and Africa . . . seem to be full of projectile weapons, along with shaft straighteners, wrenches, or throwing boards.” Mousterian weapons included thrusting and throwing spears, the bola, throwing clubs, and perhaps others, but the Upper Palaeolithic produced the dart thrower, using flaked stone and bone points, and eventually the bow-arrow complex. In the Mesolithic the bow and arrow ultimately dominated in Eurasia and Africa, remaining part of a mixed pattern elsewhere. Australia was a dart-thrower area, and the weapon may not have come into use there until about 5,000 years ago. The development of the dart thrower and the bow-arrow complex involved more complex mechanical systems than earlier weapons [although the bola was twirled about the upper body to confer maximum velocity on the missile], and parallels in their mechanical principles suggest a possible relationship between them.

Few anthropologists have ventured consideration of the origin of the bow-arrow complex, and a comment by Birket-Smith (1965:132) is typical: “The way the bow was invented is as puzzling as its age, for it is easy to see that furnishing a wooden stick with a cord in order to utilize the elasticity of the wood is not at all an obvious thing to do.” Archaeological evidence is not present until after the Magdalenian. In the Mesolithic it is found in western Eurasia [Clark 1963, Pericot García 1942, Kehoe 1988, Rust 1943], northwestern Africa [Clark 1970, Wendell 1968], and the Middle East [Belfer-Cohen 1991]. This distribution hints at an early hearth in the Mediterranean Basin and diffusion as part of the Mesolithic, ultimately into northeastern Eurasia [Aikens and Niguchi 1981:177] and Southeast Asia. The bow appears to have been a late entry into North America, although the distribution in South America suggests that an earlier entry must be considered. The bow-arrow complex became dominant in the Neolithic (Rausig 1967), and in interior Eurasia there was innovation of the self-bow, the sinew-backed bow, and later the true composite bow [Hamilton 1970]. A further innovation was the addition of the “ears” to the ends of the bow limbs, creating the fully recurved composite bow [McEwen, Miller, and Bergman 1991].

The “puzzle” of the origins of the bow remained, and no adequate hypothesis was presented in spite of new

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data on the mechanical principles on which the bow depended. In the late 1920s and early 1930s the physicist N. C. Hickman, having taken up archery as a recreational activity and become interested in acquiring a bow that took less physical effort to draw, undertook research to determine the physics of the bow and arrow [Hickman 1929, 1937]. His efforts attracted the attention of another physicist, P. E. Klopfsteg, who initiated parallel research and published a series of papers on the results [1935, 1943]. [Several of these papers and others were reissued by the National Field Archery Association in 1947 [Hickman, Nagler, and Klopfsteg 1947].] All aspects of archery were examined, with special attention to what was termed the “archer’s paradox”—what took place when the bowstring was released and the arrow driven past the left side of the bow grip. With devices to hold the bow stationary and control the release and high-speed photography, a record was made of the behavior of the arrow, and the “archer’s paradox” was explained. With the force of the release of the bowstring, the arrow bent to the left as it went past the grip, and a cycle of oscillation of the shaft was initiated; the arrow recovered as it entered its trajectory toward the target. It was known that an effective arrow had to have the proper “spine,” a range of stiffness of the shaft, and the behavior of the arrow at launch indicated that it was necessary for the arrow to recover from the shock of the launch. The efforts of the physicists also determined the character of the stresses on the bow—the tensile stress on the back of the bow and the compression stress on the belly of the bow, which limited the self-bow, with its all-wood stave, in comparison with the sinew-backed bow and the later composite bow. The aerodynamics of the arrow were also determined. Research showed that “fundamentally, a bow is a two-armed spring spanned and held under tension by a string” [McEwen, Miller, and Bergman 1991:76]. It also showed that the arrow was a related type of spring, bow and arrow thus storing energy to be released at the moment of launch and constituting elements of a mechanical system which produced energy beyond that furnished by the archer.

Anthropologists appear to have shown no interest in this research or its potential contribution to the problem of origins. That the bow-arrow complex was a mechanical system was recognized but not that it might have been an outgrowth of some earlier mechanical system such as the bola or the sling [Korfmann 1973] or the dart-thrower system. By the beginning of the Upper Paleolithic, thus by about 40,000 years ago, there seems to have been an innovation of the throwing spear, the dart thrower—a length of wood with a finger hold at the proximal end and a spur at the distal end to engage the butt end of a missile shaft. There were also improved projectile points. Examples of the dart thrower, recognized on the basis of those of the native peoples of Australia [Davidson 1937], New Guinea and Melanesia [Krause 1905], and Mesoamerica and South America [Métraux 1949], are not found until the Magdalenian. At the ethnographic level the distribution of the dart thrower was extensive and prior to that of the bow and arrow. In most areas the bow and arrow had displaced the dart thrower, although there were periods of transition and periods of overlap such as in the Arctic. Transition was documented in the archaeological horizons.

In spite of observations of and some experiments with the dart thrower, little was known about the mechanical principles involved. The dart thrower was seen as essentially an extension of the arm with added leverage to supplement the human energy of the throw. The technique of the thrower, however, with the release of the missile at the top of the arc, suggested that the dart thrower was more than this. The dart thrower of Basket Maker II times in the northern Southwest had on its underside a small shaped stone whose function was unknown. Several forms of small shaped stones in eastern North America appeared to have served the same function [Kidder and Guernsey 1919, Hester, Miller, and Spencer 1974, Webb and DeJarnette 1942]. There was little speculation on the origin of the dart thrower other than as an innovative use of the spear, although it was seen as possibly related to other sling contrivances [Birket-Smith 1965:330–31; Krause 1905].

As interest in experimental anthropology and in replicative archaeology, in particularly stone flaking techniques, expanded, two Montana State University engineering students initiated a research project in 1984 on the function and design of the dart-thrower weapon system and the mechanical principles involved and after five years issued a detailed report [Perkins and Leiningner n.d.]. The results of the research showed the dart thrower complex to be dependent on much the same principle of physics as had been described for the bow and arrow some 60 years earlier. The dart thrower and the bow were essentially similar types of springs and generated energy which on release of the missile became kinetic energy. The dart-thrower system was somewhat more complex than the bow-arrow system. With regard to the missiles, “the ability to flex and propagate transverse waves is critically important for the dart in the weapon’s design and suggests a close relationship to the arrow of the bow and arrow system” [p. 3]. One of the problems of the dart thrower was the need for precise timing of the release of the energy stored in the dart thrower and the dart for a satisfactory performance of the missile. Whereas the bow was held in a relatively stationary position for launch of the arrow, the dart was launched at a tangent to the arc of the throw, and if the launch was late the dart had a downward motion. There was thus a need for a mechanism to achieve coordination of the dart thrower and the dart.

Through experiments and analysis it was found that the answer to this problem of coordination was a small shaped stone on the underside of the shaft of the dart thrower that functioned as a timing device and also affected the range of the missile. It was found that the range depended on the length of the dart thrower but that “this problem was solved by the weighted atlatl system which has flexibility superimposed onto it in order to influence the launch point” [Perkins and Leiningner n.d.:13]. The ratio of the length of the dart
thrower to the length of the dart was approximately 1:3. Placing the weight at the best point on the underside of the dart-thrower shaft produced maximum energy gain, and with a properly “tuned” dart the energy of both parts was delivered tangent to the arc of the throw. These features resulted in the ideal dart-thrower–dart weapon system.

The arrow was essentially a miniaturization of the dart, with the same features of point, foreshaft, main shaft, and vanes, and the two acted as the same type of spring. It was found that the point attached to the dart shaft set in motion the return of the forward wave action toward the butt end and thus propagated the transverse waves: “The original wavefront will then meet and collide with its own trail of waves travelling away from the atlatl. The superposition of these waves moving in opposite directions creates the phenomenon known as standing waves” (Perkins and Leininger n.d.:5). This action produces a third wave, “gaining more energy” (p. 6). “A flexible dart is a mechanical system capable of undulating potential and kinetic energy” (p. 8). The dart is thus a long spring and as such will compress, store energy, and then release the energy.

The sharing of mechanical principles by the dart-thrower–dart and the bow-arrow weapon system and their early distribution in northwestern Africa, western Europe, and the Middle East (thus the margins of the Mediterranean Basin) suggest that the hearth areas of the two systems were nearly the same and most likely the Maghreb. The bow-arrow complex appears by about 15,000 years ago in the Oranian and the early Capsian cultures (Clark 1970:160). The dart-thrower–dart complex appears about 40,000 years ago in the Aterian culture, also in the Maghreb (Caton-Thompson 1946). The diffusion patterns of the two weapon systems were much the same. The distribution of the dart-thrower–dart complex in Eurasia correlated with the movements of the Upper Palaeolithic and ultimately reached northeastern Eurasia, where it became available for movement into northwestern North America and extensive distribution in the Americas. The rate of movement of the bow-arrow complex in Eurasia appears to have been more rapid than that of the dart thrower, reaching the Japanese archipelago at an early time. A potential hearth area in the Maghreb is also indicated by the early distribution of the tools of arrow manufacture, the shaft smoother and the shaft straightener (Solecki and Solecki 1970).

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