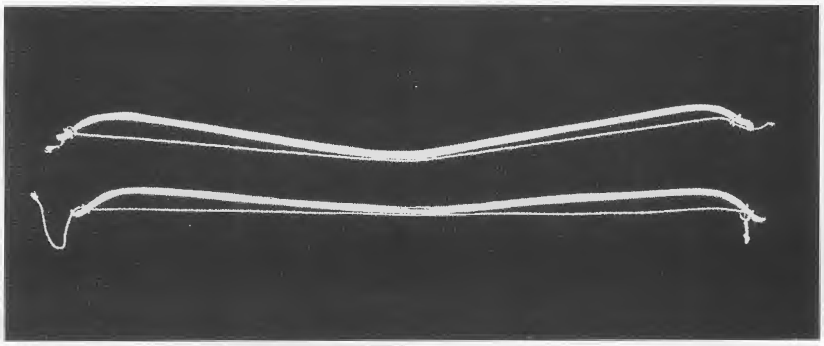

Fig. 10.12. Modern replicas of the Warrior's bow, by E. McEwen.

of value in gaining a clearer impression of the bow. Because of the curvature of the bow the making of the reconstruction had to be spread over a number of weeks, allowing the wood to dry and the curves to 'set'. Primitive peoples took elaborate precautions in the preparation of wood for bows, allowing production to extend over weeks, or even months (Mason 1893:43, 45). On the other hand, African bows which were reflexed were left bound to a strong former of wood for only a few weeks (Clark, Phillips, and Staley 1974). No doubt climatic conditions would largely dictate the length of time required.[2]

A process using steel tools was employed: Firstly, a branch was taken and split lengthwise using wooden wedges. The splitting was done in such a way as to produce as straight a piece of timber as possible. The inside or heart of the wood formed the flat belly and the naturally rounded outside or sapwood, the back. In sidder wood there is no clear differentiation between the heartwood and the sapwood but there is a line of pith running centrally through a branch, which has to be removed. Heartwood resists compression better than sapwood, which is, conversely, more elastic and tolerates tension stresses better than heartwood; therefore, the best use is made of the timber when the bow is formed in this manner.

The wood was cut on the belly side to conform roughly to the thickness of the finished bow. The stave was then cut to its maximum width throughout its length, using a marked straight line down its centre to ensure straightness. The next stage was to soak the wood in cold water for a minimum of two days. The wood was then boiled for two hours to render it flexible. The el-Makkukh bowyer may or may not have used suitably-shaped wooden moulds to form the curves and to hold them while the wood dried. He may have simply bent the wood over a hot stone and held it while it cooled, as some American Indians did (Kroeber 1962:190), or his technique may have been similar to that of the African bowyer noted above. Producing the curves without a mould would have a variable result, with the curvature at each end of the bow being somewhat different (as seems to be the case in the el-Makkukh specimen, although the bow had suffered some distortion over the millennia and we cannot be certain of its exact shape when new). Since we desired the reproduction of the bow to be as accurate as possible, wooden moulds were made using the 1:1 drawing as a guide. After the wood was boiled it was quickly bent over the moulds and bound and clamped into place. It was then left for two weeks in a warm and dry room. After this period of time the bindings were removed and the stave inspected for any deviation from a straight line. At this stage the bow was marked with the various widths at the different parts of the bow and the wood was reduced to almost the exact dimensions. The dimensions of the cross sections of the bow had been taken at intervals of five centimetres along its length. It could be seen from these dimensions that some minor damage other than the breaking of the bow at its centre had occurred. Where there was an abrupt change in thickness, this reduction was ignored. The variations in thickness along the length of the bow were assumed to have occurred gradually and smoothly rather than abruptly, in order to prevent breakage. The wood used for the reproduction naturally did not have its knots in precisely the same positions as the original, and in fact, some of the wood had knots which rendered it totally unuseable. Where a knot occurred it was necessary to leave more wood around it, a factor which affected the dimensions. Since the

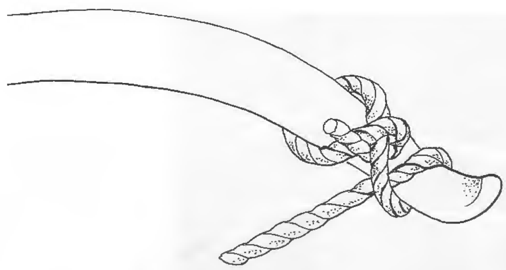

Fig. 10.13. Reconstruction of attachment of bow string to tip of bow.

intention was to construct a shootable bow and take some measurements of its performance, this slight deviation from the actual specimen was felt to be justifiable.

During the forming of the curved tips we noted the tendency of the wood to split despite the soaking and boiling it underwent. The modern answer would be to support the wood with a steel strap. We suggest that the rawhide or skin sheathing applied to one tip was intended to protect the wood against splitting. For this reason we wrapped a few centimetres of the tips at both ends with thin parchment. The extremities in the last few centimetres are recurved abruptly back, away from the archer when holding the bow. This abrupt recurve prevents the bowstring from slipping off when the bow is fully drawn (Fig. 10.9). It also confirms the direction in which the bow was bent during shooting since there would be no purpose for this feature had the bow been bent contrariwise. It is common for bows of this type in ancient Egypt, and more recently in Africa, to have no nocks for the bowstring; the bowstring is simply held in place by multiple turns of the bowstring around the bow stave (Fig. 10.13). For the sake of experiment, one bow was strung with recurved ends, being away from the archer in the act of shooting. When the bow was shot the bowstring had a marked tendency to slip off the tips of the bow, thus rendering it unstable. When the bowstring was pulled the bow almost folded into two halves at its centre. If the bow had originally been bent in this way either string bridges would have had to be attached (as in the Chinese bows of the Ch'ing period) or grooves would have been cut into the outside of the curves to seat the bowstring. As there is no evidence of this we are confident that the bow is of the Hunter's Palette type.

The bow's draw weight – the weight the archer needed to apply to the bowstring to pull it back to the full length of the arrow – was 14.9 kg. In the two bows made of sidder wood this weight only varied by 0.5 kg.

The action of the bow is peculiar. A simple bow usually bends in some form of arc with an emphasis on more bend towards the tips rather than the centre, which is often stiffened. The el-Makkukh bow is reflexed at its centre and this must have some effect of stiffening the bow at this point. However, the inwardly curved tips of the bow, which are virtually rigid, throw the bending stresses onto the centre of the bow; since this section is hardly any thicker than the limbs and is at the same time narrower, the bow works almost entirely by means of this centre bending. Because the bracing height was so low the arrow received impetus from the bowstring for a greater distance than it would if the bracing height was what would nowadays be considered 'normal'. This to some extent mitigates the effect of a lack of tension on the bowstring at the rest position. Since the draw length was short (*c.* 46 cm), the archer could not have aimed with the assistance of a fixed 'anchor point', as a modern archer does. His shooting must have been almost entirely instinctive though accurate, at least at short range. As was stated earlier, if the brace height of our reconstruction is increased the reflex in its centre almost disappears. This may be due to our use in the making of the bow of slender, young branches of the sidder tree rather than more substantial growth. This wood was found to be rather ductile. Although this was helpful in forming the curves, we found that though the boiling of the wood was followed by careful drying to stabilise the shape, when the bowstring was fitted the centre section soon lost its extreme curvature. This renders all the more important the making of a new reconstruction in the wood used for the original bow. Olive wood is harder than sidder and may well hold its curves better under stress.

The Bowstring

The bow's string was missing. Judging from the very few Egyptian finds the bowstring could have been made of gut, rawhide, sinew or even linen. For our experiments we made bowstrings of twisted sinew. The Egyptian specimens are laid as rope, i.e., twisted and counter twisted (McLeod 1982:52–53, Pl. 3). We made sinew strings of six and nine twisted strands; both proved to be good bowstrings of ample strength. The Egyptian strings were not made with permanent loops; thus the bows could easily be unstrung when not in use; indeed, as with the later

African bows of similar profile (but not section, as noted above), they seem not to have been unstrung at all but always kept ready for action. The bow we have of the Hunter's Palette design has very little tension on the bowstring when undrawn. Perhaps this is the reason for its peculiar shape. It is well known that a wooden bow kept braced for any length of time, particularly in a hot climate, will lose its strength and 'take a set'.

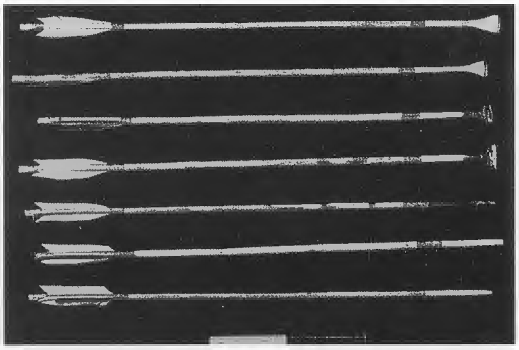

Fig. 10.14. Reconstruction of arrows with various head alternatives.

Reconstruction of the Arrows and the Bow's Draw Length

When the bow was complete, tests were made to assess the length of arrow used with it and the weight necessary to pull the bow to that point.

No complete arrows were found with the bow, merely two foreshafts and pieces of reed (Schick, this volume). From these remains we deduce that the arrows were similar to the Egyptian specimens, i.e., a wooden foreshaft fitted by a tang into a reed. There were no heads or fletchings recovered from the grave but the square cut-off of the foreshaft tips are similar to specimens of arrows fitted with tranchet flint or glass heads set in a mastic or plaster. Clark, Phillips and Staley (1974) give an extensive review of the evidence. We have based our reconstruction of the arrows on this evidence (Fig. 10.14).

The draw length of the bow was found to be approximately 46 cm. In making the arrows we assumed that the foreshaft, which tapers in diameter, was not drawn within the bow; thus the overall length of the arrows would have been approximately 60 cm, including a tranchet arrowhead of flint. It should be noted that many primitive peoples did not use arrows cut exactly to the draw length of the bow and preferred much longer arrows. All that can be said with certainty is, therefore, that the arrows used with the el-Makkukh bow were no shorter than our estimate.

It might be thought that the arrows were blunts for shooting small game and birds; a blunt arrow, however, is usually enlarged at the tip to provide a bruising blow with which to stun the quarry rather than to pierce its flesh. This type of arrowhead was often used to avoid damaging the valuable pelts of fur-bearing animals (see three examples in MacLeod 1982: Pl. 5). The foreshafts found with the bow would have been neither large enough to form effective blunts nor sharp enough for piercing.

The shafts of the arrows were of reed (*Phragmites* sp.; see Shimony, this volume). We were fortunate in having two suitable pieces of reed brought to England from the Euphrates by Dr R. Miller when we collaborated in experiments with incendiary arrows (Miller, McEwen, and Bergman 1986:178–195). The majority of arrows used in testing the bow had a bamboo mainshaft. We found that bamboo was thicker walled than reed and the arrows therefore weighed more.

The arrowheads of flint were made from bladelets kindly supplied by Dr C. Bergman of Cincinnati. The archaeological reports mention the use of 'mastic' for the attachment of tranchet arrowheads made of flint. This 'mastic' is sometimes described as 'gum' and sometimes as resin mixed with beeswax. We have experimented with the latter compound and found it to be adequate for the task. We have also used gypsum plaster, which was reported as being used for an arrowhead found in Syria (Miller 1983:187–190). We found that the gypsum plaster of itself was too brittle but was improved by the addition of animal glue. Miller suggested that archers would have carried a supply of flint heads and gypsum plaster in order to rapidly replace heads lost in battle (Miller 1983:187–190). The plaster we experimented with required some eight hours before it was sufficiently hard. England, however, has a temperate climate with much rain; the drier Middle East climate has much higher average temperatures allowing for some reduction in the setting time.

When one of these tranchet-headed arrows hit a hard target the arrowhead almost always became detached. When the arrow hit flesh it penetrated without damage provided it did not hit solid bone. This type of arrow must have generally been a one-shot missile. Tranchet heads have been thoroughly tested against a deer carcass in modern times (Miller, Bergman, and Azoury 1982).

Performance

To obtain some idea of the efficiency of the bow seven arrows of varying weights were made and shot. There was no appreciable difference in performance between the two bows reconstructed; therefore only the maximum results are presented in the table below. We could have constructed special 'flight' arrows to obtain the maximum distance but there seemed little point in thus testing a bow which must have been a practical weapon for war or hunting rather than a sporting toy. That bows of this type were effective for war is amply attested by numerous illustrations and archaeological excavations (Winlock 1945).[3]

Table 10.1. Arrow Velocities (Bow with 9-Strand Bowstring and a Draw Weight of 14.9 kg @ 46 cm)

Arrows	Weight (gms)	Velocity (m/sec)	Distance (m)
A	25	24.80	65
B	26	24.38	65
C (reed-shaft)	18	32.91	73
D	30	22.02	65
E (ebony foreshaft)	25	30.07	70
F (reed shaft)	14	33.68	77
G	22	32.09	72

Arrows A-D were fitted with tranchet flint heads. A and B heads were held in place with gypsum plaster, C and D heads with a mastic made of pine resin mixed with beeswax. Since none of these heads were found attached to the foreshafts, the reconstructions are conjectural. Arrow E was made with a sharpened ebony foreshaft. Except where noted the shafts of all arrows were made of bamboo with sidder wood foreshafts. As was expected, the reed shafted arrows, being lighter, were faster than the heavier bamboo arrows. Arrows F and G were made with foreshafts patterned on those found with the bow and without any form of head or sharpening. We found these arrows to have very little penetration; but due to their lighter weight they flew somewhat faster than the arrows with flint arrowheads and the heavy ebony foreshafted arrow.

The fletching of the arrows is again conjectural but follows the known Egyptian examples and artistic representations. The foreshafts were glued into the reed shafts with animal glue and wrapped with sinew. The sinew covering the join of the foreshaft with the reed and the wrappings used to hold the feathers in position were painted to protect them from moisture. Here again we have followed Egyptian practice. Since we can derive very little information from the actual arrows found, our reproductions were not finished with polish nor any other form of decoration (Fig. 10.14).

We have here presented the best possible results. The sharpness of the release of the bowstring affected the distance and speeds achieved. For maximum distance the arrows were shot at an angle of approximately 45° elevation. For measuring the speed, the arrows were shot horizontally through an electronic speed trap with an accuracy of 99.5%.

Conclusion

There can be no doubt that the el-Makkukh bow was an effective weapon and hunting tool. Its design is sophisticated for such an early period and it can safely be assumed that there was a considerable period of development and experimentation before this design of bow became established. As reconstructed in sidder wood the bow has a light draw weight – too light perhaps for the reconstructed arrows. It is expected that a reproduction made in olive wood, which is harder and denser than sidder, will have a draw weight of approximately 20 kg, giving a much improved performance with the same arrows.