of McKusick (2), who also established a numerical system that is widely used: Hurler, I; Hunter, II; Sanfilippo, III; Morquio, IV; Scheie, V; Maroteaux-Lamy, VI. A plethora of other designations can be found in the literature.
12. Unfortunately, the same terminology is used to designate the proteinpolysaccharide molecules and their carbohydrate branches. The reason for this confusing practice is historical, for the carbohydrate branches were described long before their connection to the protein core had been discovered. For a review of the chemistry of mucopolysaccharides, see, for instance, H. Müir [*Int. Rev. Connective Tissue Res.* **2**, 101 (1964); *Amer. J. Med.* **47**, 673 (1969)].
13. B. P. Toole and D. A. Lowther, *Arch. Biochem. Biophys.* **128**, 567 (1968).
14. L. A. Fransson and L. Rodén, *J. Biol. Chem.* **242**, 4170 (1968); L. A. Fransson, *ibid.* **243**, 1504 (1968).
15. S. Suzuki, H. Saito, T. Yamagato, K. Anno, N. Seno, Y. Kawai, *ibid.* **243**, 1543 (1968).
16. A. Linker and P. Hovingh, *Biochim. Biophys. Acta* **165**, 89 (1968).
17. L. A. Fransson, *ibid.* **156**, 311 (1968); A. Bella, Jr., and L. Danishevsky, *J. Biol. Chem.* **243**, 2660 (1968); U. Lindahl, *Biochim. Biophys. Acta* **130**, 361, 368 (1966).
18. V. Ginsburg and E. F. Neufeld, *Annu. Rev. Biochem.* **38**, 371 (1969).
19. G. de la Haba and H. Holtzer, *Science* **149**, 1263 (1965); A. Telser, H. C. Robinson, A. Dorfman, *Proc. Nat. Acad. Sci. U.S.* **59**, 912 (1965).
20. R. Matalon and A. Dorfman, *Proc. Nat. Acad. Sci. U.S.* **60**, 179 (1968).
21. J. Knecht, J. A. Cifonelli, A. Dorfman, *J. Biol. Chem.* **242**, 4652 (1967).
22. F. van Hoof and H. G. Hers, *Compt. Rend. Acad. Sci. Paris* **259**, 1281 (1964).
23. B. J. Wallace, D. Kaplan, M. Adachi, L. Schneck, B. W. Volk, *Arch. Pathol.* **82**, 462 (1966).
24. B. S. Danes and A. G. Bearn, *Science* **149**, 987 (1965); *J. Exp. Med.* **123**, 1 (1966).
25. R. Matalon and A. Dorfman, *Proc. Nat. Acad. Sci. U.S.* **56**, 1310 (1966).
26. I. A. Schafer, J. C. Sullivan, J. Svejcar, J. Kofoed, W. Van B. Robertson, *Science* **153**, 1008 (1966).
27. J. C. Fratantoni, C. W. Hall, E. F. Neufeld, *Proc. Nat. Acad. Sci. U.S.* **60**, 699 (1968).
28. J. C. Fratantoni, E. F. Neufeld, W. B. Uhlendorf, C. B. Jacobson, *N. Engl. J. Med.* **280**, 686 (1969).
29. J. C. Fratantoni, C. W. Hall, E. F. Neufeld, *Science* **162**, 570 (1969).
30. ———, *Proc. Nat. Acad. Sci. U.S.*, in press.
31. U. Wiesmann, M. Cantz, E. F. Neufeld, unpublished data.
32. K. M. Foley, B. S. Danes, A. G. Bearn, *Science* **164**, 424 (1969).
33. M. F. Lyon, *Amer. J. Hum. Genet.* **14**, 135 (1962).
34. B. S. Danes and A. G. Bearn, *J. Exp. Med.* **126**, 509 (1967).
35. S. Hollmann, *Non-Glycolytic Pathways of Metabolism of Glucose* (Academic Press, New York, 1964), pp. 83–107. The function of the cycle in salvaging uronic acid from mucopolysaccharide breakdown is still hypothesis rather than experimentally established fact. The uronic acid entering the cycle has been said to be derived from (i) the hydrolysis of uridine diphosphate–glucuronic acid, an implausible and now abandoned postulate; (ii) the catabolism of inositol—this occurs only in the kidney, and thus can account for only part of the cycle; or (iii) the turnover of unidentified glucuronides. We propose that these hypothetical glucuronides are none other than the mucopolysaccharides.
36. H. H. Hiatt, in *The Metabolic Basis of Inherited Disease*, J. B. Stanbury *et al.*, Eds. (McGraw-Hill, New York, 1966), pp. 109–123.
37. F. van Hoof and H. G. Hers, *Eur. J. Biochem.* **7**, 34 (1968).
38. M. MacBrinn, S. Okada, M. Woollacott, V. Patel, M. W. Ho, A. L. Tappel, J. S. O'Brien, *N. Engl. J. Med.* **281**, 338 (1969).
39. V. Patel, thesis, University of California, Davis (1969).
40. P. A. Öckerman, *Clin. Chim. Acta* **20**, 1 (1968); P. A. Öckerman and P. Köhlin, *Acta Paediat. Scand.* **57**, 281 (1968); J. E. Gerich, *N. Engl. J. Med.* **280**, 799 (1969).
41. M. W. Ho and J. S. O'Brien, *Science* **165**, 611 (1969).
42. J. S. O'Brien, *J. Pediat.* **75**, 167 (1969).
43. J. C. Fratantoni, unpublished results.

Flaking Stone with Wooden Implements

Flaked stone artifacts from Palliaike, Chile, suggest that wooden flaking tools were used in the New World.

Don E. Crabtree

In recent years the study of prehistoric flaked stone tools has been rejuvenated by the development of modern flintworking. Efforts to replicate the techniques of manufacture and the form of prehistoric stone tools have increased the value of the archeological objects as an instrument for interpreting human history. François Bordes, Jacques Tixier, and I have worked independently and together at the manufacture of flaked stone tools in order to understand the alternate ways by which any tool type might have been made. The use of wooden flaking implements has rarely been considered, because such percussion or pressure-flaking tools do not usually survive in archeological deposits. There must have been times and places in which wooden percussors were used by prehistoric man. This article reports an effort with wooden flaking implements to reproduce stone tools from one of those times and places.

At Palliaike Cave in southern Chile, stemless pressure-flaked points made of basalt and varieties of siliceous stone (Period 3) were found (Fig. 1, a–c), but no bone compressors or percussors were discovered in association with the points. Since well-preserved bone was found in the cave, Junius Bird became curious to determine what implements and techniques were used in their manufacture. He wondered if, like certain Australian aborigines, these people could have used wooden implements; therefore, at his suggestion I decided to try replication with wooden flakers.

Bird generously provided seven examples of the points, as well as a variety of Calafate hardwood (*Berberis buxifolia*) and a small supply of native coarse-grained basalt. The pressure technique used on the points could not be called "classic" or "extremely refined"; nevertheless, planning and control were evident in the flake detachment, and thus I was eager to accept the challenge of replication with wooden implements. Since lithic materials are harder than steel, it may be difficult to visualize shaping and forming them with a wooden tool; but it can be done. The use of a wooden flaker is seldom considered because at New World sites it is common to find compressors of antler, bone, or ivory, and other less perishable tools, which are more resistant to decay than wood. It is entirely possible, however, that wood, because of its perishable nature, has gone unrecorded as material used for flaking stone. Wooden pressure tools are used in the Kimberley region of western Australia (see *1*), and there is a possibility that wood was used as a pressure tip in Mexico for making blades (*2*). As this article will demonstrate, archeologists must on some

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occasions consider pressure flaking with wooden implements as an alternative to flaking with bone or antler pressures.

My experiments involved only the replication of flake character; no attempt was made to duplicate form or size of the artifact. Indeed, the initial attempts with wooden implements were very discouraging and had to be confined to duplication of flake character alone. Replication of flake scars is the real challenge, and duplication of form is no problem. As the experiments progressed, interest became keener, muscle response improved, holding became more comfortable, and the results more gratifying. Certainly, more prolonged experiments would have improved my technique with the wooden flaker.

Experiments in pressure flaking with a replica of the Australian wooden flaker (Fig. 2, left) were limited and resulted in only moderate success, partly because the Australian tool is longer than the bone or antler flaker that I was accustomed to using. The holding method was thus a complete reversal of my normal manner of holding the compressor (Fig. 2). In addition, pressure is applied by thrusting (a sudden application of force) away from the body. Initially, I found the technique awkward and concluded that a longer training period was necessary. The first experiments resulted in imitations of the Australian points, but I did not feel they were duplicates. Further experiments in which I used an actual Kimberley aborigine, hardwood pressure flaker (Fig. 2, left) loaned by the American Museum of Natural History proved more successful, with the results closely similar to the Australian points (see Fig. 3).

One peculiarity of Kimberley points (Fig. 4) is the steep bifacial retouch on the base between both lateral margins (flakes removed on both faces at a steep angle along the edge). This feature was duplicated by pressing straight down to remove a row of flakes, then turning the point over and repeating this process on the other face. All flaking on Kimberley points was done on an anvil of wood or a padded stone by the traditional aboriginal method (*3*).

The Palliaike experiment was not so awkward; it progressed much faster and was successful. It involved pressing toward the worker, a method more parallel to my normal pressure technique. I believe that both the technique and the points were replicated (Fig. 1, d–f).

General Aspects of Flintworking

In the camps of prehistoric man, the most enduring identifiable artifacts are made of stone. The earliest men can be identified as human as much by their associations with stone tools as by their anatomy. For this reason the techniques of making stone tools are of great interest in the study of human origins and dispersals. The stone tools recovered in the earliest as well as in later archeological sites were made by detaching flakes from a block or mass of stone (called a core or nucleus). These rocks or lithic materials are marked by having a negative flake scar (conchoidal fracture) where a blow was struck against a surface. Such a fracture may also be obtained by exerting pressure against a surface or platform, which may be either prepared or natural. The striking of a blow or the exerting of leverage forms a cone, which is used to control the detachment of a flake. That is, a flake may be deliberately shaped by the kind of force applied by the stoneworker. At the same time, the way a flake is shaped and removed affects the character of the core from which the flake is detached. The flake, sometimes called a primary flake, may be further worked in order to make a finished tool.

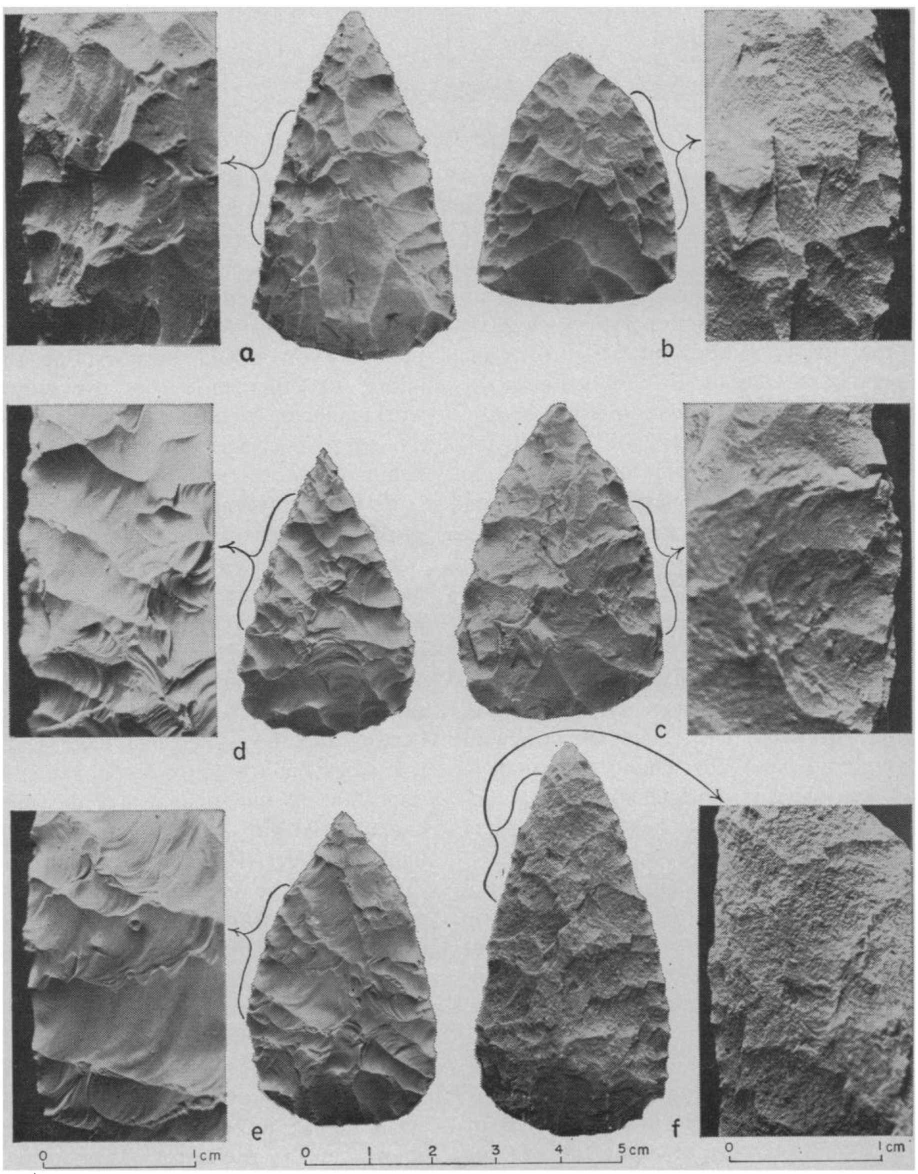
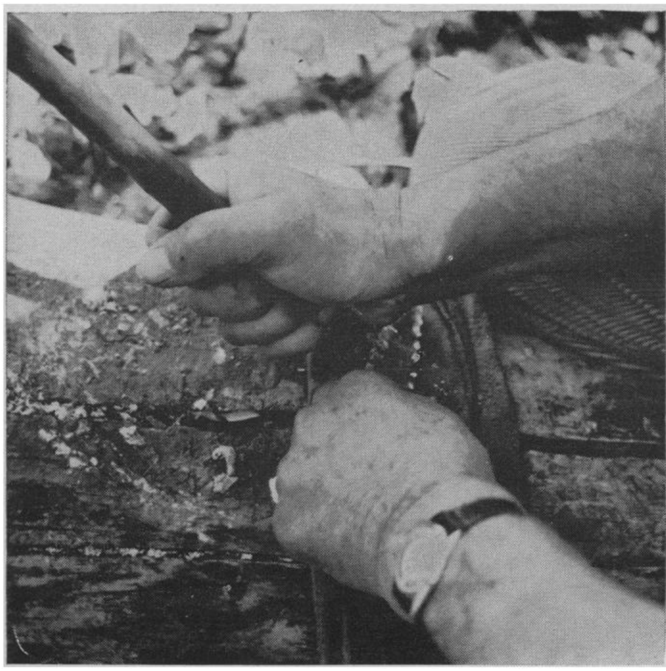


Fig. 1. Knowns and unknowns. (a–c) Points from Period 3, Palliaike Cave, southern Chile. (d–f) Points made by Crabtree with pressure-flaking tools of barberry wood for comparison with points (a–c). The absence of bone flaking tools in Period 3 suggests that wooden ones may have been used. The close identity of fractures on the Crabtree and Chilean examples supports this assumption. Materials (all coated with ammonium chloride): (a) fine-textured green-gray stone (specimen 1755c, American Museum of Natural History); (b, c, and f) basalt; (d and e) obsidian.



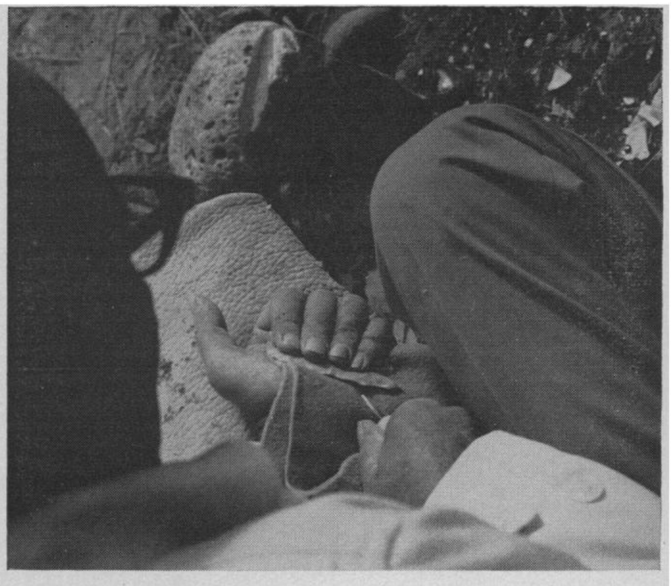


Fig. 2. (Left) Pressure flaking a replica of a Kimberley point (Australia) with a wooden flaker. (Above) Normal holding method when pressure flaking with bone, antler, or metal flaker.

The character of the raw material or lithic material affects the way in which a flintworker performs his flaking. In prehistoric times a wide range of glassy rocks was used, including various chalcedony (that is, flint or jasper), obsidian, ignimbrite, quartz, quartzite, siltstone, and glassy basalt. In each instance the core should be free of internal breaks, for otherwise flakes will detach improperly and the object itself may be shattered. Obsidian lends itself to pressure flaking, but naturally occurring flint or basalt may be easier to work by percussion. At some time in the past men discovered that some glassy rock could be changed by heat treatment (*4*) to make pressure flaking easier. Thus, heat-treated flint, jasper, or quartz can be worked far easier than the untreated material, and the changes that have taken place in material found in archeological sites can be duplicated by laboratory experiments.

Since variations in lithic material affect the outcome of flaking, prehistoric man found it necessary to use different flaking tools (*5*). A percussor or hammer is the tool used for striking a blow, and it can be made of stone, antler, bone, or wood. In each case hardness plays an important part. Stone hammers tend to leave larger negative cones of force on the core or along the edge of a primary flake that is being shaped by percussion flaking. On the other hand, a billet or hammer of elk antler will diffuse the cone, so that the negative scar on the core or along the edge of the flake being worked may be shallower and less well marked. Pressure-flaking tools, called pressers, compressors, or fabricators, were made of antler, bone, ivory, and copper, each being suitable for a particular kind of work. The kind of work done with any one percussor or presser may overlap the effects of other tools, but the skilled workman can execute a wide range of flaking with a variety of implements at hand.

Recent experiments have suggested some of the possibilities for using different tools and different raw materials, but the possibilities have only begun to be realized. In trying to solve a problem presented by the characteristics of a prehistoric stone tool, I find it necessary to use alternating methods in replicating the flakes and the flake scars that mark the artifact to be copied. It is important to understand that the flint knapper is not merely copying the finished object. He is necessarily concerned with the sequence of steps that can be deduced from the succession of flake scars on the prehistoric tool or that can be reconstructed by examination of the flakes found at the archeological site where the object was recovered. The result of experimental work is usually a reduction of the number of ways in which the prehistoric object can be replicated. Most often, two or three solutions remain as suitable explanations of the techniques used by prehistoric man, and a number of other methods have been discarded entirely.

The involved process of preforming is not explained here because it has been adequately described in detail elsewhere (*6*). However, it should be noted that a preform resembles the shape of the finished tool and represents a deliberate intermediate step in constructing. As a result, it has distinctive characteristics in flaking and edge grinding which set the stage for finishing work. The proper use of a wooden percussor is discussed later (see "Hammerstones and Billets").

This article is primarily concerned with the use of wooden pressure flakers. However, it is well to note that when a wooden flaker, rather than one of bone, antler, or metal, is used in pressure flaking, the last stage of preforming must be done with considerable care. The surface of the preform should be left as regular as possible, for it is difficult to remove step or hinge fractures left by careless percussion preforming when the worker is using a wooden flaker.

If the worker employs the core tool technique, he can use a hammerstone, an antler, bone, or wood billet, or a punch and, with direct or indirect percussion, can remove all surplus material from the mass until it is preformed into the proper shape. But for the final forming, thinning, and sharpening, the wooden flaker and the pressure technique are used.

A simpler method, which eliminates the preforming stage, is to obtain blanks by using a hammerstone and percussion to detach simple flakes from the core. A blank has the right characteristics for making a finished tool, but it may or may not have the right shape. Flakes intended for bifacial points should be straight with the distal end pointed and feathered; they must, of necessity, be slightly larger and thicker than the intended artifacts. Since all flakes detached from the core may not have these requisites, the worker selects only the ones that are suitable for pressure work and discards the remainder or uses them for other purposes.

Lithic Materials

Isotropic minerals selected for the experiments of fracturing and shaping stone with wooden flakers and billets ranged in texture from coarse-grained basalt to vitreous obsidian. Materials that were nonhomogeneous or that had apparent planes of weakness and obvious imperfections were discarded (7).

The most granular material used was a basalt from the Magellan Straits and some basalt from southern Idaho. The Palliaike artifacts (Fig. 1, a–c) were made of basalt superior to the experimental material, which was much too granular and tenacious to respond well to the wooden pressure flaker. Therefore, in an effort to duplicate the quality of the Palliaike artifacts, some of the basalt was heat-treated before flaking. One unaltered specimen was retained for control and comparison. The alteration consisted of placing the natural basalt in an oven and, over a period of 12 hours, gradually bringing the temperature to 500°F. Then the oven was turned off, and the stone was allowed to cool undisturbed for approximately 12 hours. This treatment considerably improved the quality of the basalt, but the texture still did not approximate that of the Palliaike artifacts. Possibly a higher temperature and a longer cooling period would have altered the material to a duplicate texture. However, there was not enough of the Chile material to permit further experiments. The alteration was merely an attempt to replicate texture and does not indicate or imply the use of heat treatment at the Palliaike Cave.

Because the basalt supply was limited, porcelain was substituted, for it has a similar texture and it behaves and responds in much the same manner. Both altered and unaltered silica minerals were also used, and it was noted that the heating process greatly improved the flaking quality of the silica. Of course, the more vitreous obsidian from Oregon and Mexico did not require alteration.

Hammerstones and Billets

A hammerstone of medium density weighing approximately 700 grams was used for a twofold purpose: to detach usable flakes from the core and to rough out the preliminary model of the core

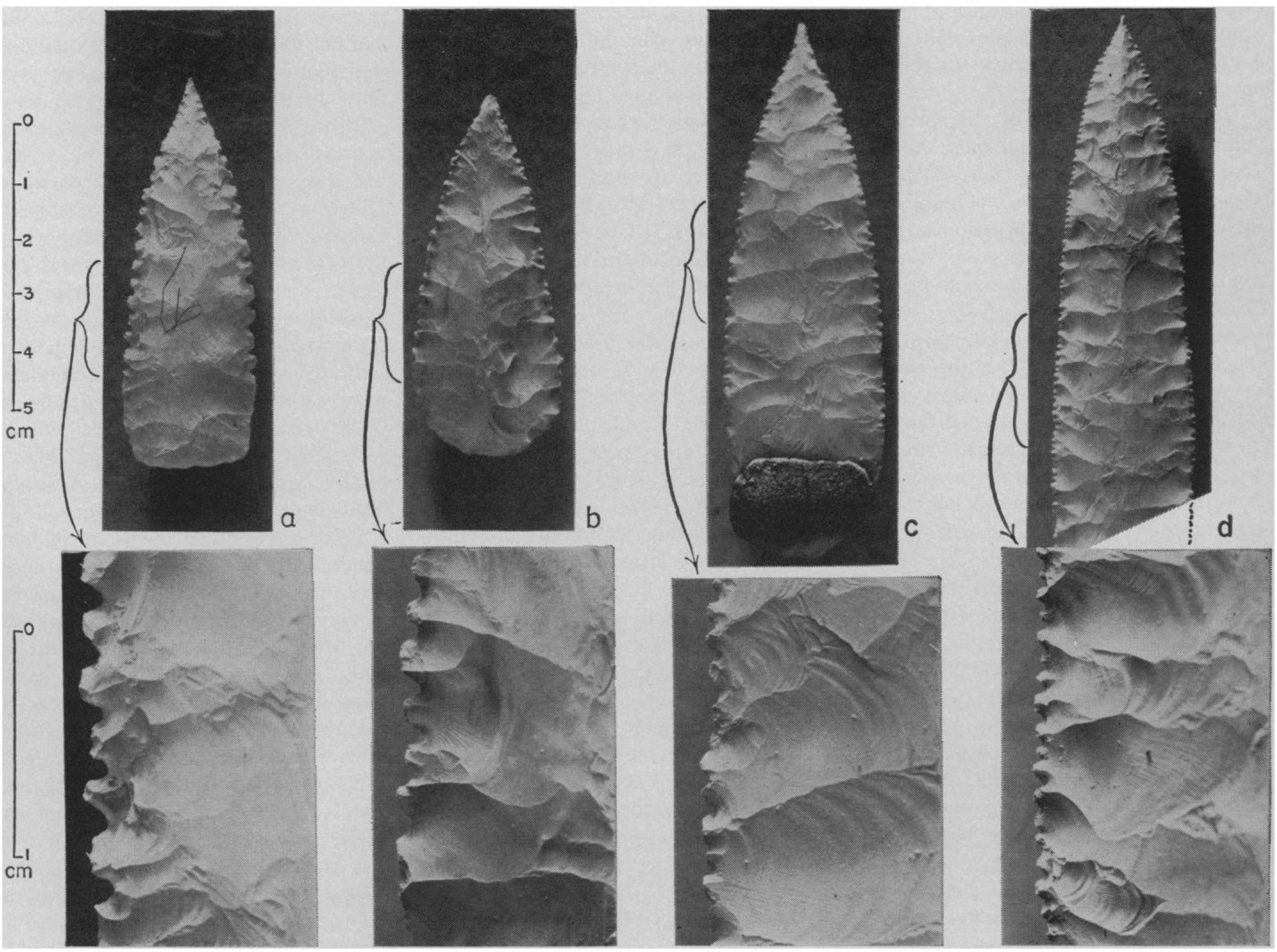


Fig. 3. Glass points made with wooden flaking tools. (a) Point made by Crabtree in Kimberly, Idaho, with the use of an Australian flaking tool. (b–d) Points from the Kimberley division, Western Australia. Point c retains spinifex gum; the base of point d is not shown. All surfaces are coated with ammonium chloride.

tool. An antler or wooden billet was used for the preforming stage.

To expand the experiment with wooden implements, a billet of ironwood from southern Arizona was used for the percussion modification, for, unlike the stone percussor, the hardwood billet will detach flakes without shattering the artifact. When the blow is struck with a wooden billet, the lateral margins of the artifact penetrate the wood, and a flake is detached without the shattering effect. Depth of penetration of the artifact edge into the wooden percussor determines the width of the platform, for it detaches a part of the margin with the flake. Billet-struck flakes often have a lip on the ventral side near the platform and have very little definition of the bulb of force. It should be pointed out, however, that the wooden billet is practically worthless for the preliminary stages of stone flaking—that is, for reducing large natural material to a usable form, for making large usable flakes, for making hand axes and large uniface or biface implements, and for blade making. A hammerstone is much more suitable for these stages.

The working end of the wooden billet is rounded, so that only the arc-like convex end will contact the edge of the artifact. The worker thus has greater striking margin, for the wooden billet with a rounded end does not require the accuracy of the hammerstone. The hammerstone will also shatter unprepared edges, whereas the billet will not. Therefore, the billet allows the worker a greater latitude when delivering blows on the unprepared perimeter of the artifact. Flakes detached from the obscure side of the artifact form ridges on each side of the slightly concave flake scar. These ridges thicken that part of the artifact, and, consequently, the ridge part of the lateral margin (edge) is stronger and will withstand more force than the concave parts of the artifact. When the wooden billet delivers repeated blows on the ridge part of the lateral margin, small flakes will naturally be removed from each side of the ridge, because the concave part of the edge is relatively weak in comparison with the part of the edge bearing the ridge. In turn, the removal of these small flakes forms a projection on the edge, which is in alignment with the ridge. The projection acts as a platform; it receives the major amount of the billet force and detaches a long skimming flake. The novice experimenter may be unaware of creating this projection, become discouraged when the flake does not detach, and increase the velocity of his blows. Ultimately his wooden billet will detach a good flake, owing, however, not to the increased blow velocity but to the created platform. The exterior surface of a core is always an important factor in controlling the form of the flake. When ridges are present on the core surface, they can always be used to advantage to guide and control the flake or blade detachment.

The billet technique does not require the skill and accuracy of the hammerstone; therefore, it makes successful flake detachment easier for the novice experimenter who is unaware of other related factors. As a result, the less seasoned knapper has often misinterpreted his experience and has cited the billet technique as the one used by aboriginal people, although often there is no evidence to substantiate this conclusion. The character of the flakes and their scars must always be described, defined, and evaluated before the manufacturing tool can be determined and the technique interpreted.

Coutier discovered the "wooden hammer" technique: when he struck blows on the side of a piece of flint with a rounded piece of wood, he could detach thin, flat flakes with flat bulbs of applied force (*8*). If Coutier was aware of the penetration of the wooden billet by the stone, of the creation of the platform projection, and of the use of ridges to guide the flakes, he made no reference to this knowledge. Unfortunately, it has therefore been concluded that all thin, flat flakes with diffused bulbs are detached with a wooden billet. This conclusion is erroneous.

The wooden billet can be used successfully for some techniques after preliminary work has been accomplished with percussors of denser materials. The hardwood billet does, however, have a definite and useful place in stone flaking, but, aboriginally, it may not have had the widespread use interpreted by some archeologists. Final conclusions about the knapping instrument used in manufacture can only be determined after an evaluation of a comparatively large population of flakes and artifacts.

Wooden Pressure Flaker

When properly used, wooden pressure tools make fine compressors. Selected hardwoods have sufficient strength to transmit the force necessary to exceed the elastic limit of the lithic material and to induce fracture. When the stone reaches its elastic limit, shear stresses are induced, fracture occurs, and a flake is detached. After much trial and error, it was determined that a wooden flaker with a sharp, pointed working end would not tolerate the pressing strain and would either split or break. But a shaft of selected hardwood (20 to 60 centimeters long and 2 centimeters in diameter) with a blunt working end was strong enough to withstand and transmit sufficient force to fracture the material. But wood must be carefully selected for flakers. It must be sufficiently hard to prevent too deep a penetration of the lithic material into the tip of the wooden flaker, and it must be tough or fibrous enough to prevent splitting. Very hard, highly resinous woods (such as ironwood) were found to be too brittle and would break. Ironwood is good for wood billets but not for compressors. Coarse-grained wood will split before a flake can be removed. The worker should experiment with various types of wood until he finds a satisfactory billet or pressure flaker. At this time, I cannot express a preference because I have not used a sufficient variety of woods. However, experiments reveal that the Calafate wood, a species of barberry that grows in the grasslands near Fells Cave, is a satisfactory tool for pressure work. Junius Bird generously provided four pieces of Calafate, and I gathered some Manzanita from Arizona; both were satisfactory for pressure flakers. Other woods were also tried, but none was equal to the Calafate and Manzanita. I hope to obtain some Australian hardwoods for future experiments.

I was accustomed to flakers of bone, antler, and metal, but I found it necessary to modify the holding method and to vary the application of pressure with the wooden implement. The tips of bone, antler, and metal flakers will withstand more downward pressure than the wooden tool. They also allow greater control and "feel" of flake detachment, and the worker can remove long, narrow, curved parallel flakes from one lateral margin to the other. Although this accomplishment was not realized in this experiment with the wooden flaker, it cannot be rejected, because the experiment may have been too brief to allow it. The coordination and rhythms of muscular motor habits become ingrained in the worker who has used bone, ivory, and metal flakers for years; the new technique and the different "feel" of wooden tools make response difficult. It was necessary to attempt a variety of diverse approaches to overcome some of the difficulties encountered. The wooden pressure tool would slip, the tip would break, the wood was insecure and would yield when pressed against the margin of the artifact, and "feel" was limited. "Feel" has little meaning to the novice, but, when one has pressure-flaked with bone, antler, or metal, which adhere to the platform of the artifact, one is accustomed to feeling the flake part from the piece being worked. Pressure tools must be kept in alignment, and the flake must be pressed off across the face of the artifact to delete small step fractures or irregular areas. The wooden pressure-flaker experiment was limited to a few weeks, whereas years of working with bone and antler compressors have disciplined my muscle responses to adjust to harder flakers. If more time were allowed to become familiar with the wooden flaker, I believe it could be as efficient as the harder tool and its use expanded to include diverse techniques.

If the tip of the wooden pressure flaker is rounded to resemble the end of a broom or mop handle, considerable pressure can be applied without the flaker breaking. As work proceeds, the tip of the compressor is rotated to expose new surfaces, to retain the rounded shape, and to regularize the wear pattern. If the tip becomes fibrous, it can be rubbed on an abrasive stone to expose a new hard surface.

New pressing techniques had to be devised to use the bluntly rounded wooden tip. The blunt end contacts a wider part of the artifact edge and detaches flakes with wider proximal ends than when a harder pressure tool is used. With the wooden flaker, the worker uses a thrusting motion in a straight line toward the edge and then presses away from the artifact to detach a flake. The wooden flaker is firmly seated on a slightly beveled platform and then thrust downward and away in a simultaneous motion, snapping rather than pressing off a flake. If basalt or other coarse-textured materials are being worked, much more force is necessary to detach flakes. If the downward and outward forces are not coordinated, the snapping method may break the flakes off short and terminate the end in a step fracture rather than in the desired feathered edge.

Holding

The method of holding the wooden pressure tool is quite different from the method used with antler or other hard flakers, because the harder tool will tolerate more downward pressure at its tip. When wood is used, the artifact being pressure-flaked must be firmly supported. The support may be a padded anvil stone, or, if hand-held, the artifact may be held in the left hand with its lateral margins horizontal and the back of the hand solidly supported against the inside of the left thigh. The worker sits on a low seat and holds the wooden flaker as close as possible to the tip to increase the leverage. If the pressure tool is longer (about 60 centimeters), one end can be rested against the right ribs and kept in alignment with the forearm of the right hand. This position enables the worker to use the forearm and shoulders to increase the vertical pressing force. The low seat raises the left thigh above the posterior, thus permitting pressure to be applied on the vertical edge of the artifact perpendicular to its longitudinal axis. The position of the Australian aborigine worker differs somewhat since he is accustomed to sitting on the ground.

The wooden flaker is placed on the margin of the artifact, and controlled pressure is applied inward in alignment with the proposed flake. As the pressing force increases, an outward force is imparted which causes the flake to detach from the artifact. Examination of aboriginal flake scars and scars made experimentally reveals that pressure was applied in the same direction. The technique differs from the one used with antler or bone flakers, which are held at an angle to the margin with force directed at right angles to the long axis of the pressure tool.

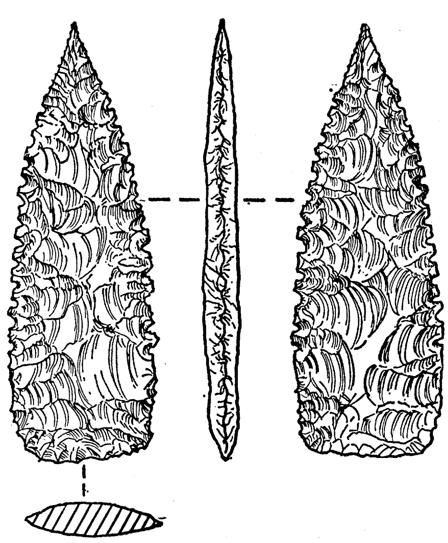


Fig. 4. Kimberley point (Australia), 7 centimeters long.

The wooden flaker technique and the change of applied pressure require the worker to use a different set of muscular motor habits and, in the beginning, will form either blisters or calluses on the right hand. After a few attempts a blister formed at the base between the first and second fingers until I became accustomed to the change in technique. It requires about 3 weeks of intermittent practice before the right hand is really comfortable and tolerates the tool without the bruising. Perhaps the shaft of the pressure tool could be served with fiber or sinew to make it more comfortable and to prevent slippage.

Pressure Flaking

Preforming by direct percussion leaves fairly large, randomly spaced flake scars and creates crests and hollows that must be removed by pressure to make the artifact symmetrical and regular. A platform is established by making a bevel on the edge in alignment with the ridge to be removed. The bevel is made by pressing the wooden flaker at right angles to the margin to detach small flakes and to slant the edge toward the face being flaked. The tip of the pressure tool is then seated firmly on the platform, and the worker, by pressing first inward and then outward, detaches a flake which in turn removes the ridge. When the major ridges are removed, the piece is ready for the next stage of final pressure flaking.

When the artifact is to be pressure-flaked bifacially, the worker has a choice of techniques, but the following are suggested: (i) Pressure-flake one-half of the face from one margin and then one-half of the opposite face from the same margin. After one margin is worked, we have an artifact flaked from one margin and on one-half of both faces. The technique must be repeated from the opposite margin to complete the artifact, but now the detached flakes must meet and terminate at the median line to intersect flakes removed from the opposite margin. (ii) One-half of one face can be pressure-flaked from one margin, then the piece turned and the same face flaked from the opposite margin, with the flakes meeting and terminating at the median line. We now have a unifacially flaked artifact, and the technique must be repeated on the opposite face to complete the artifact.

The edge of one margin is beveled on one face, which removes the overhang left by previous bulbar scars. Then a more pronounced bevel is made on the same margin but on the opposite face, and this bevel is used as a platform area for the pressure retouch. To remove the second series of flakes from the same margin but the opposite face, the edge must again be beveled in the manner previously described. However, now the bevel is on the face to be flaked. After the second bevel is made, the artifact is held in the left hand with the first beveled side resting on the palm and the second beveled side visible to the worker; this bevel serves as a platform to detach flakes on the under side. A series of flakes is removed along the margin beginning at either the base or tip of the artifact, depending on the worker's preference. If work is started at the tip, flakes become increasingly larger as the worker nears the base; if flaking starts at the base, flakes become increasingly smaller as the worker approaches the tip. Flakes progress along the margin toward the base or tip until all of the beveled margin is removed.

When flaking is started on the margin, whether at the base or tip, a short flake with the bevel adhering is removed to establish a ridge. This flake and subsequent flakes become increasingly long, and all flakes terminate at the median line of the long axis. After each flake is detached, the tip of the pressure tool is again seated on the beveled edge, and flaking is spaced to allow the platform part of the second flake to intersect the sharp edge left by removal of the bevel of the preceding flake.

The wooden flaker does not crush the edge. Consequently, it will detach a flake that has a broad and diffused bulb of force rather than one that is deep. Flaking progresses toward either the base or tip (depending on where the worker starts) along the margin until all beveling is removed. The blunt, thick end of the wooden tool makes the spacing interval between flakes broader than it is when an antler pressure tool is used. The worker intentionally spaces the flakes so that each subsequent flake scar will intersect the last scar and form a straight, sharp edge. When pressure flaking is complete, the wooden flaker leaves edges that are uncrushed and quite sharp. Flaking is continued until both faces and both margins are flaked.

The wooden flaker is not suitable for removing long, narrow, curved, parallel flakes and is inadequate as a notching tool, but it could be used for making a shouldered or stemmed point.

Conclusions

Two of the seven Palliaike points show better quality workmanship than the other five. The better workmanship seems to result from use of a material superior to basalt rather than from greater skill. All seven examples show surface smoothing to a varying degree. The bifacial smoothing could be either intentional abrading by the worker or unintentional smoothing by function. Without the aid of considerable magnification and further experiment, it is difficult to pass final judgment. If these points were hafted, it would seem that the bifacial basal smoothing could not be the result of function. Hafting could be accomplished by using resins and adhesives to affix the base of the point to a wooden shaft, as was done by the Kimberley aborigines. Many Clovis points from western North America are smoothed to an even greater degree—for example, those found at the Simon Site in Idaho. Some points show the detachment of short flakes terminating in step fractures. But this may be a result of the Palliaike points being made of basalt, a very difficult material to work, of the worker being less skilled, or of the wooden flaker being inadequate to overcome the coarse-grained material. All the Palliaike points are thick in relation to their width, which makes them resistant to breakage. However, since only one point in the collection (Fig. 1a) shows an attempt at basal thinning, the worker may have been unable to control the coarse-grained basalt, which is difficult to thin with a wooden flaker, or he may simply have wanted the point thick for a particular function.

Palliaike Cave points and replicas that were pressure-flaked with a wooden compressor have flake scars with certain comparable characteristics. The wooden tool distributes the force over a wider area than when bone or antler tools are used, and it produces flake scars with a diffused bulb. It also removes a part of the lateral margin with the flake and thus leaves a distinctive edge. The spacing of the final series of pressure flakes leaves the margin with a serrated appearance, although the serrating technique was not employed.

The wooden compressor can be used by a less skilled worker to produce a sharp edge on a stone tool. The wider, blunter tip of the wooden tool narrowed the margin of the worker's visibility for seating the tool on the edge. For me, the wooden flaker required more foot pounds of pressure than is needed with a harder compressor. I did not find the wooden flaker suitable for detaching long, narrow, curved, parallel flakes, but I do not reject the possibility pending further experiment. The wooden flaker will not withstand the amount of downward pressure that a bone, antler, or metal tip will tolerate. It also limits the worker's muscular reaction, "feel," and control of the lithic material response.

The wooden billet does not shatter the artifact, and a less skilled worker can successfully detach flakes without understanding a more sophisticated technique. However, I believe that this experience has resulted in some erroneous conclusions about billet technique manufacture without a complete analysis and evaluation of the flakes and scars.

There are no horned or antlered mammals among the native fauna of Australia, but, on the other hand, the Australian continent possesses a wide variety of acacia and eucalyptus hardwoods. Thus the Kimberley aborigines, although they perhaps lacked the ideal material for pressure flakers, possessed an alternative that was almost as good. Familiarity by this experimenter with bone pressure flakers suggests that the Australian hardwoods may have been better than bone. Might a similar kind of ecological interpretation apply in the case of the ancient inhabitants of Palliaike Cave and contemporary sites?

Only in Period 3 of this region is there an absence of bone pressure flakers. In the subsequent period, guanaco bone pressure-flaking tools occur in a ratio of 1 to every 15 stone projectile points or knives. In contrast, in Period 3 several hundred stone points occurred but no bone flakers were found. Since there is no evidence for any ecological or faunal changes at this point in the Palliaike sequence, it must be concluded that the probable introduction of wooden pressure flakers in extreme southern South America would be the result of cultural rather than ecological factors.

After working with the wooden flaker and producing some acceptable replicas with characteristics similar to aboriginal flake scars, I believe it is entirely possible that the Period 3 Palliaike points were pressure-flaked with a wooden tool. I would suggest, therefore, that the geographic range of the wooden pressure-flaker technique should not be confined to Australia.

References and Notes

1. A. P. Elkin, *Man* **130**, 110 (1948); N. Tindale and H. A. Kubdsay, *Aboriginal Australian* (Angus & Robertson, Sydney, Australia, 1963), pp. 25–46; personal communication.
2. D. E. Crabtree, *Amer. Antiquity* **33**, No. 4, 446–78 (1968).
3. The collection of 15 ethnographic Kimberley points from Australia was loaned for this project by the American Museum of Natural History, Central Park West at 79th Street, New York 10024.
4. D. E. Crabtree and B. R. Butler, *Tebiwa* **7**, (1964).
5. D. E. Crabtree, *ibid.* **10**, 60 (1967).
6. ———, *ibid.* **9**, 3 (1966).
7. ———, *ibid.* **10**, 8 (1967).
8. L. S. B. Leakey, *Adam's Ancestors* (Harper & Row, New York, 1960).
9. Supported by National Science Foundation grant GS 1659. I thank Dr. H. Swanson, Jr., for his assistance and for the "General Aspects of Flintworking" section; Dr. J. Bird for conceiving and promoting the experiment, for giving personal advice, for loaning the representative collection, and for furnishing lithic material and wooden flakers; Dr. R. A. Gould for contributing the illustrations and photographs, for loaning Australian cultural material, and for his editorial assistance; J. Bopp for typing; my wife Evelyn for her aid and encouragement; and, particularly, Drs. Bird and Gould for spending their valuable time at my workshop observing, advising, and assisting in the actual experiments.

Compensating Persons Injured in Human Experimentation

Ethical precautions do not guarantee the safety of research subjects; financial protection is also needed.

Clark C. Havighurst

Despite all the attention that has been directed to the ethics of experimentation with human subjects, there is one remarkable omission from the various ethical formulations and from most writing on the matter. Emphasis in such discussion is always on two aspects of the investigator's obligation: (i) the preventive aspect—the need to minimize risks—and (ii) the consensual aspect—the research subject's right to be informed of what use is being made of his person. But ethical discussions seem to stop at this point and to disregard the possibility that, in spite of all ethically prescribed precautions and the procurement of adequately informed consent, the research subject will still suffer harm. It would be startling to conclude that ethical considerations do not enter into the question of what should be done for the research subject who is thus injured, yet expressions of this concern have tended to appear more often in legally oriented discussions than in the ethical literature on human experimentation (*1*).

The notable disproportion in the literature is illustrated in the Spring 1969 issue of *Daedalus* (the proceedings of the American Academy of Arts and Sciences), in which only about six of 386 pages devoted to "ethical aspects of experimentation with human subjects" dealt with compensation of the injured participant (*2*). The matter was touched on only by the lawyers present at the symposium, and the only thorough consideration was the provocative discussion by Guido Calabresi of the Yale Law School, who, in concluding his discussion, anticipated the main point of this article: "Examination and refinement of devices like the compensation fund [for injured research subjects] by people who are involved in medical research seem, to me, to offer considerably more promise than further elaborations on the infinite varieties of consent that are currently the mainstay of symposia on human experimentation" (*3*). In defense of the medical literature, it must be noted that Henry K. Beecher, in an excellent recent piece in *Science* (*4*), has looked beyond the care and consent aspects and has squarely advocated compensation arrangements.

The ethical lacuna noted involves no particular moral shortcoming on the part of the medical profession; rather, it reflects the naturally narrow focus of ethics on the personal responsibility of the clinical investigator himself, to the exclusion of the focus on the responsibility of the medical profession as a whole. When the matter is looked at solely in terms of the investigator's responsibility, no real ethical issue can of course be raised in the absence of some kind of demonstrable fault. But, even given exclusive concern with the researcher's standard of conduct, one might still ask whether the investigator does not have an ethical duty to provide research subjects with advance protection against mishaps, by means of insurance or otherwise. Nevertheless, personal responsibility, like the legal duty, has apparently always been deemed discharged by the exercise of care and the obtaining of consent. This course may have produced responsible behavior on the part of most researchers, but it has left the ultimate ethical problem unsolved and undoubtedly some victims uncompensated.

The neglected ethical issue is faced only when one considers the responsibility of the medical profession as a whole (*5*). Indeed, while the ethical impetus has been supplied mainly by the medical profession, ultimate responsibility resides in the entire research "industry," including its educational, corporate, philanthropic, and governmental components. When the situation is viewed in this manner, there can hardly be debate about the basic principle that research costs which take the

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