THE PREHENSILE MOVEMENTS OF THE HUMAN HAND

J. R. NAPIER, LONDON, ENGLAND

Reader in Anatomy, Royal Free Hospital School of Medicine, London

The function of the human hand in terms of the discrete movement of the joints and the action of individual muscles is well enough understood. Little is known, however, of the movements of the hand as a whole. It is possible to talk loosely of closing, opening or cupping the hand; of selected postures such as the pinch or hook or of prehensile functions such as grasping and gripping. These terms are not only unscientific but have little or no universal connotation.

The need for a system of disability evaluation of the hand in connection with industrial and insurance work has resulted in the development of several methods of analysing the function of the hand as a unit. Griffiths (1943 and personal communications) has for many years divided the functions of the hand into cylinder grip, ball grip, ring grip, pincer grip and pliers grip. These terms, although expressive and useful are somewhat selective in that they represent a series of functional end-results rather than a fundamental analysis of the potential of the hand as a whole. The units of function devised by Slocum and Pratt (1946)—namely, grasp, pinch and hook—are not clearly defined nor are they comprehensive, for no allowance appears to be made, for instance, for the numerous functions of the hand in which the thumb is not in opposition. The classification proposed by McBride (1942) divides the functions of the hand into three types: grasping by the hand as a whole, grasping between the thumb and fingers and grasping by the combined use of the palm and the digits. These three types of movement are somewhat arbitrarily conceived and do not appear to have any particular functional or anatomical basis.

A terminology, if it is to be effective and generally acceptable, must develop out of a fundamental approach to the problem of the function of the hand as a whole and it seems that little has been done in this respect. The purpose of this paper is to present a method of classifying prehensile movements based on such an approach. The two discrete patterns of movement that have emerged through this study are analysed from both the anatomical and functional points of view and are termed *precision grip* and *power grip*.

PREHENSILE AND NON-PREHENSILE MOVEMENTS

The movements of the hand can be divided into two main groups: 1) *Prehensile movements*—or movements in which an object is seized and held partly or wholly within the compass of the hand; and 2) *non-prehensile movements*—or movements in which no grasping or seizing is involved but by which objects can be manipulated by pushing or lifting motions of the hand as a whole or of the digits individually. The present paper is concerned solely with prehensile movements.

At first sight it would seem that the prehensile activities of the hand are so extensive and varied that a simple analysis would not be feasible. On closer examination, however, it becomes clear that this diversity is in fact not so much an expression of a multiplicity of movements but of the vast range of purposive actions involving objects of all shapes and sizes that are handled during everyday activity.

A study of the normal hand suggests that there are, in fact, only two distinct patterns of movement in man and that these, either separately or in combination, provide the anatomical basis for all prehensile activities whether skilled or unskilled.

The fundamental requisite of prehension is that the object, whether it is fixed or freely movable, should be held securely. Stability is a pre-requisite for further activity and without it all refinements of hand function are of little value even in the presence of normal sensory acuity. Stability may be achieved in the normal hand in one of two ways: 1) The object may be held in a clamp formed by the partly flexed fingers and the palm, counter pressure being applied by the thumb lying more or less in the plane of the palm. This is referred to as the *power grip** (Fig. 1). 2) The object may be pinched between the flexor aspects of the fingers and the opposing thumb. This is called the *precision grip** (Fig. 2).

It is clearly important to establish that these two operations are distinct both in the anatomical and in the functional sense.

The very nature of this study makes it difficult to support assertions with any form of proof other than that provided by the photographs and by the confirmatory evidence of the reader's own hands.

FIG. 1
A power grip posture.

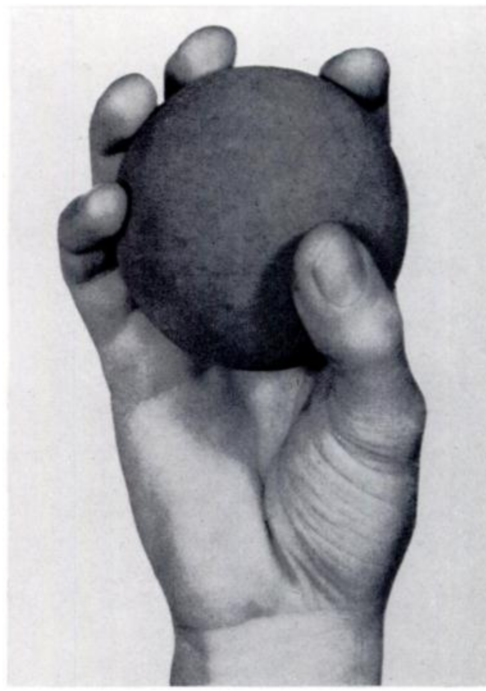

FIG. 2
A precision grip posture.

FACTORS INFLUENCING THE POSTURE OF THE HAND DURING FUNCTION

The shape of the object—The terms "ball grip" and "cylinder grip" have been used by Griffiths (1943) to designate postures similar to, though not identical with, the fundamental postures described above. Griffiths's terms have a considerable graphic value but are unsatisfactory in that they suggest that the posture of the hand is conditioned, essentially, by the shape of the object held. In fact, a ball or a cylinder may be held in either one of these two fundamental postures with equal security. For example, a short slender cylinder of wood may be gripped as securely between the tips of the opposed digits as between the flexed fingers and the palm. Which of the two postures is adopted depends solely upon the purpose to which the wooden rod is to be put. A wooden rod, as such, has multiple potentialities and can be used as a tool in a variety of ways. If, for example, it is to be used for writing, it will usually be held between the tip of the thumb and the opposed digits (Fig. 3); but if, on the other hand, it is employed for the purpose of hammering a nail, it is most likely

* The terms precision grip and power grip are used in a dynamic as well as a static sense in the same way that flexion and extension are employed to describe both the posture and the movement.

to be held clamped between the flexed fingers and the palm and reinforced by the thumb (Fig. 4). In other words the shape of the rod itself, in this example, has no bearing on the posture adopted by the hand. Another illustration of the same point is provided by the activities shown in Figures 5 and 6. In Figure 5 the right hand, which is in the process of unscrewing the tightly screwed-up lid of a jar, is in a power grip posture. In Figure 6 the

FIG. 3
Wooden rod held in a writing position.

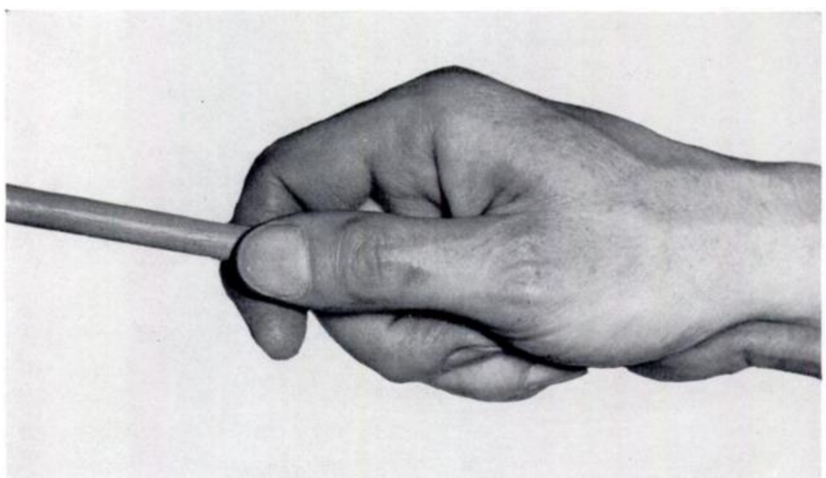

FIG. 4
Wooden rod held in a hammering position.

lid of the jar is loose and the hand has adopted a precision grip posture to facilitate the terminal stages of unscrewing as well as the final removal of the lid. The lid in becoming loose on its thread has undergone a change in physical relationship to the jar but there has been no change in its outward physical form. This change in relationship is reflected in the adoption by the hand of a form of prehension that is best adapted to the exercise of precision.

It may with truth be pointed out that certain tools with cylindrical handles are habitually gripped between the flexed fingers and palm in a power grip. Rather than refuting the present

FIG. 5
As the lid is started the right hand is in a power grip posture.

FIG. 6
As the lid becomes loose the right hand assumes a precision grip posture.

hypothesis that the shape of the handle has no influence on the type of grip employed, this apparent anomaly merely indicates that, as a result of past experience, hand tools designed for a particular operation are manufactured in a form to suit the hand during that activity.

The size of the object—In the intermediate size ranges either the precision grip posture or the power grip posture provides equally effective stabilisation. In the larger sizes, however, the posture of election is that which provides the greatest span of the hand compatible with stability. Thus a sphere of large diameter is supported preferably by both hands, but if one hand only is available it is held in a precision grip between the tips of the widely spread finger and thumb. At the opposite extreme, very small objects tend to be held between the pulp surfaces of the index finger and thumb—also a precision grip posture. Stability in this latter instance is more a matter of sensory acuity than mechanical support. Thus, although size contributes to the choice of grip at the extremes of the size range, it is clear that this factor has no general application.

Miscellaneous factors—Certain other physical factors such as the weight, the texture, the temperature and the wetness or dryness of the object may, under certain conditions, influence the type of grip employed; other factors such as fear, distaste and hunger may also condition the grip in certain circumstances.

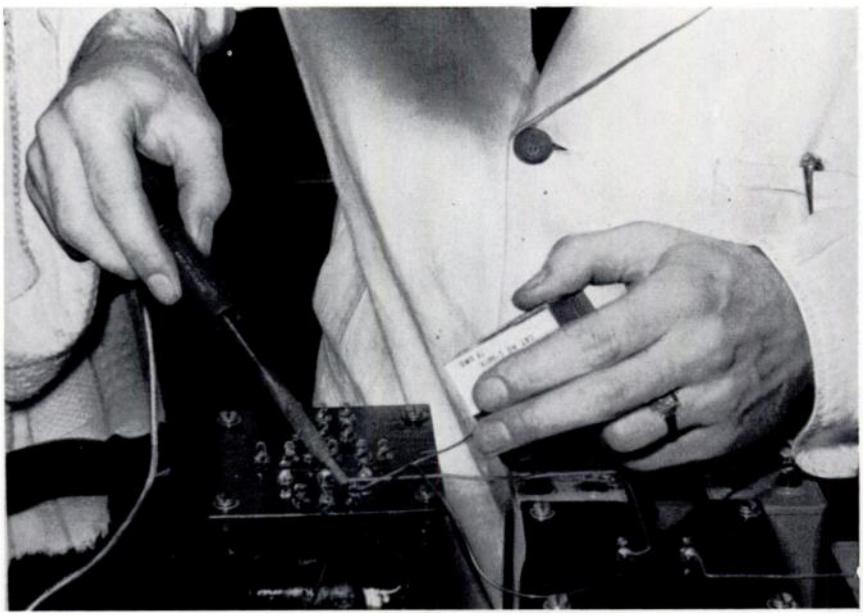

FIG. 7
The right hand is in a precision grip posture, the left in a power grip posture.

The influence of intended activity—During the performance of a purposive prehensile action the posture of the hand bears a constant relationship to the nature of that activity. If prehensile activities are to be regarded as the application of a system of forces in a given direction then the nature of prehensile activity can be resolved into two concepts—that of *precision* and that of *power*. Although in most prehensile activities either precision or power is the dominant characteristic, the two concepts are not mutually exclusive. In some manual operations the application of power is of primary importance and the need for precision only secondary (Fig. 5); in others, need for precision is pre-eminent while that for power is subordinate (Fig. 6). It appears that the predominance of either precision or power requirements in any given activity determines the posture of the hand.

While it is fully recognised that the physical form of the object may in certain conditions influence the type of prehension employed it is clear that it is the nature of the intended activity that finally influences the pattern of the grip. Thus it becomes possible to divide prehensile movements of the hand into two main types by determining whether the dominant characteristic of the movement is one of precision or of power. It seems convenient and appropriate, therefore, to refer to the operations of precision grip and power grip. These terms are simple and at the same time have the advantage of reflecting the functional affinities of the grip in a specific manner. It is a matter of common observation that if prehensile movement is arrested at any moment of activity, the hand inevitably exhibits some phase of either precision grip or power grip (Fig. 7), and it appears that these two, therefore, embody the whole range of prehensile activity of the human hand.

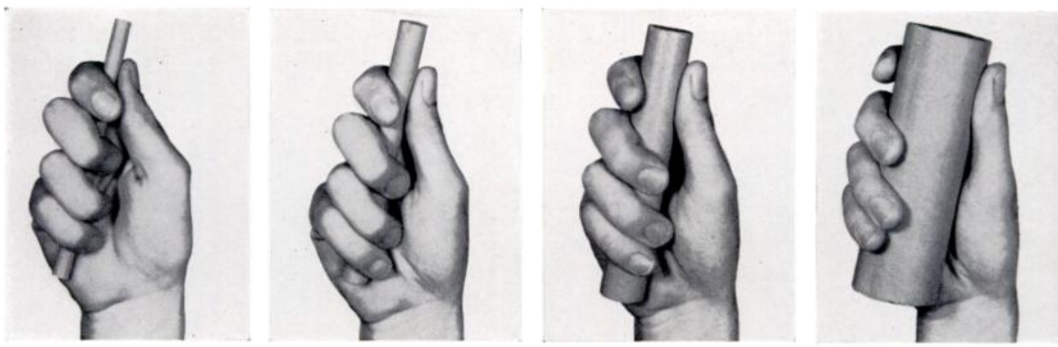

FIG. 8
An arbitrarily chosen series of postures illustrating some of the phases of the power grip complex.

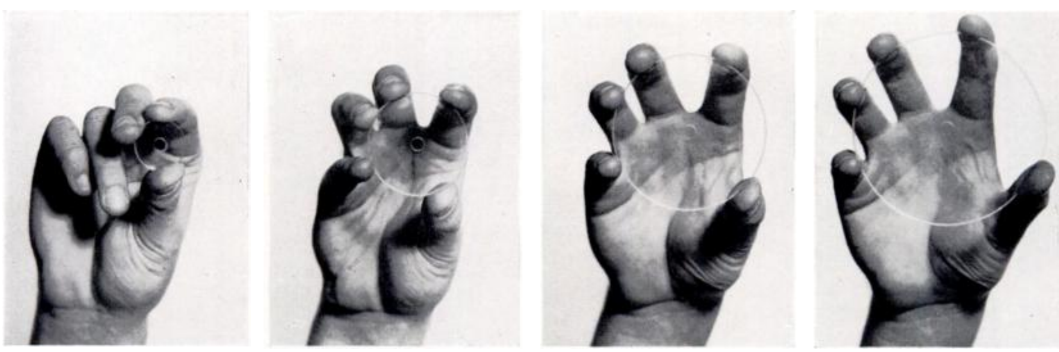

FIG. 9
An arbitrarily chosen series of postures illustrating some of the phases of the precision grip complex.

ANATOMICAL FEATURES OF POWER AND PRECISION GRIP

As pointed out above the terms power and precision grip have a dynamic as well as a static connotation. In their dynamic sense they are used to refer to movements of the hand as a whole in the same way, for example, as flexion is used to refer to the movement at a single joint. Whereas the phases of flexion are capable of being represented mathematically as degrees of movement, no such quantitative measure can be applied to power and precision grip, which, though simple enough in concept, are, in the final analysis, extremely complicated biomechanical operations involving movements in all the joints of the hand at the same time. Thus, while it is possible to recognise the almost infinite number of phases within the grip complexes, it is impossible to treat these phases biometrically. A selection of some of the phases of each grip are illustrated in Figures 8 and 9.

The essential anatomical features of the two grips become evident when the thumb and fingers are considered separately.

The posture of the thumb—The position of the thumb differs fundamentally in the two grips (Figs. 8 and 9). In the power grip it is adducted* at both metacarpo-phalangeal and carpo-metacarpal joints, while in the precision grip it is abducted at both these joints. During activity the thumb is always in one or other position, for in the mid-position or position of rest (Ellis 1878) the carpo-metacarpal joint is unstable by virtue of its lax ligaments and incongruous joint surfaces. Only in abduction and adduction does the thumb fulfil the basic need for stability (Napier 1955). In precision grip the thumb forms one jaw of a clamp, the opposing jaw being formed by part or whole of the flexor surfaces of the fingers. In this grip the thumb is not only abducted and medially rotated at the carpo-metacarpal but also at the metacarpo-phalangeal joint (Napier 1952), and is thus in opposition† to the remaining digits. This posture of the thumb ensures that the sensory surface of the digits is employed to the fullest advantage, thus providing the greatest opportunities for delicate adjustments of posture in response to the activity of the skin receptors.

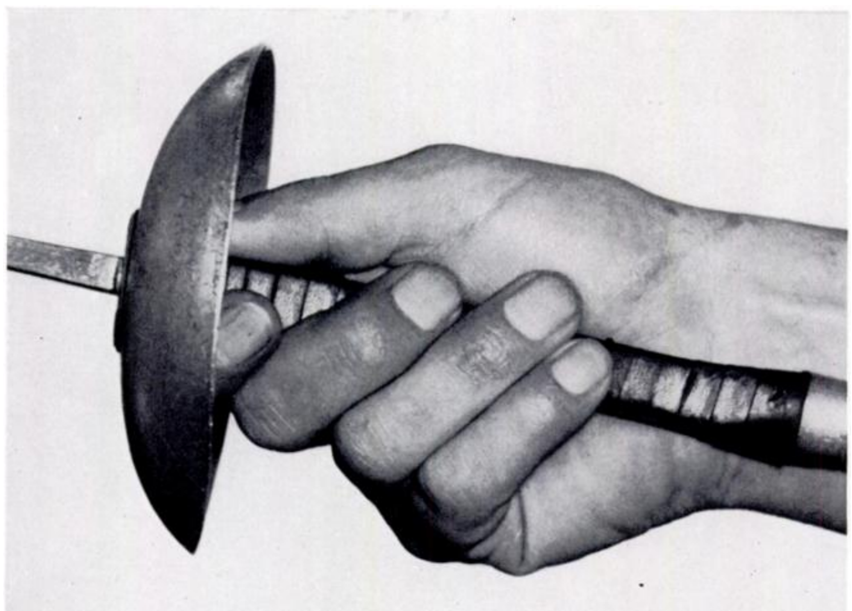

FIG. 10
A power grip posture in which the element of precision plays a large part. (The subject of this photograph is a fencing master.)

It has already been pointed out that the concepts of power and precision have to be considered in both the power grip and the precision grip, but that it is the predominance of one or the other that is responsible for the anatomical characteristics of the grip. The element of precision in the power grip complex is reflected in the posture of the thumb. When there is little or no demand for precision the thumb becomes wrapped over the dorsum of the middle phalanges of the digits, where it acts purely as a reinforcing mechanism. When an element of precision is required in what is predominantly a power grip the thumb becomes adducted so that by means of small adjustments of posture it can control the direction in which the force is being applied (Fig. 10).

* In the crudest phases of the power grip—the coal-hammer grip—the thumb is fully abducted. This is a special case and will be discussed below.

† The term opposition of the thumb is defined as a movement which results in the pulp surface of the thumb becoming diametrically opposed to the pulp surface of one or all of the remaining digits for the purposes of prehension (Napier 1955).

The main function of the hand in power grip is to provide a means of resisting any system of forces that may be applied to the object within its grasp. These forces can be resolved into three forces of translation and three couples of rotation as illustrated in Figure 11. It can be seen that when the thumb is wrapped over the dorsum of the digits it can best resist certain of these forces and couples by providing a powerful buttress on the lateral side. The effect of this buttress is lost, however, when the thumb becomes adducted and aligned in the long axis of the cylinder, with the result that some of the power of the grip is sacrificed in the interests of precision.

In general, therefore, the greater the force required of the grip as a whole, the more the thumb is required to act as a reinforcing and buttressing mechanism and the less it is able to contribute to precision. This is well illustrated in a functional manner by the posture of the hand gripping a series of hammers of different types and sizes (Figs. 12 to 15). These photographs show postures that were adopted without any prior instruction by a craftsman well versed in the use of an appropriate hammer for a specific operation. It can be seen that the thumb becomes increasingly abducted, flexed and medially rotated as the hammer becomes

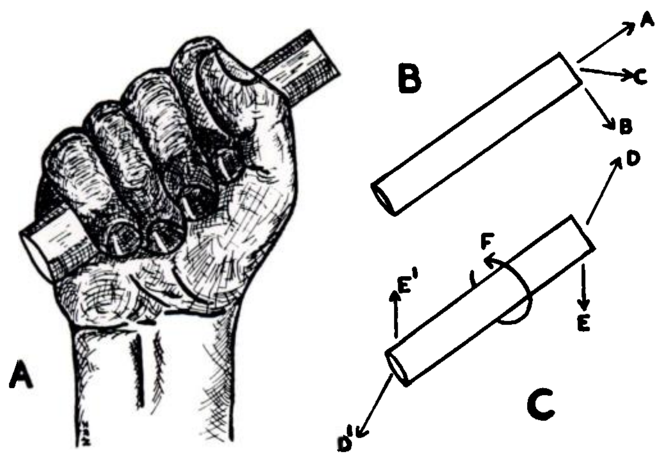

FIG. 11

The thumb forms a powerful buttress to the lateral side of the hand. B shows the forces of translation capable of acting on a rod held as in A. C shows the couples of rotation capable of acting on a rod held as in A.

longer and heavier. Eventually a stage is reached (Fig. 15) where the thumb, no longer in contact with the hammer handle, has ceased to contribute any element of precision to the operation, being wholly occupied in reinforcing the clamping action of the digits. This latter grip, which is termed the coal-hammer grip (Fig. 16) is the crudest form of prehensile function and constitutes one extreme, as it were, of the power grip range. Such precision as accompanies its use is achieved by movements of the rest of the upper limb and the body as a whole. The bunched fist (Fig. 17) is merely another example of the coal-hammer grip, applied, as it were, to an empty hand and constituting in itself a weapon.

The posture of the fingers—The relative positions of the fingers in power grip and precision grip differ considerably, but the postures in each are well suited to the function they have to perform. During power grip the fingers are more or less flexed, forming one jaw of the clamp, the palm forming the other jaw. The degree of flexion of the fingers and the area of the palm involved vary according to the dimensions of the object held (Fig. 8). The fingers are flexed, laterally rotated and inclined towards the ulnar side of the hand; hypothenar elevation forms an important part of the grip by providing a muscular cushion on the ulnar side of the hand to oppose the thenar eminence.

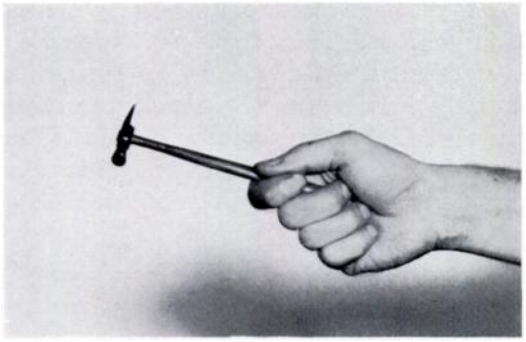

FIG. 12

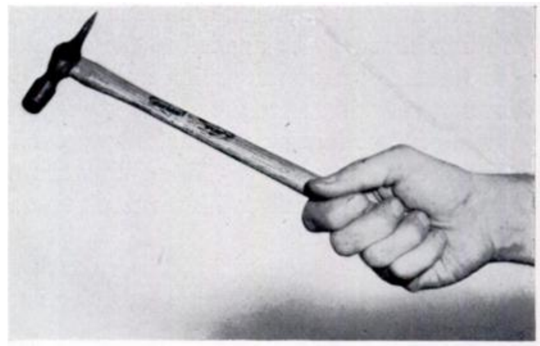

FIG. 13

FIG. 14

FIG. 15

A series of hammer grips demonstrating the changing relationship of the thumb to the shaft of the hammer as the size of the tool increases. Figure 12—A pin hammer. Figure 13—A Warrington hammer. Figure 14—A cross-pein hammer. Figure 15—A ball-pein hammer.

FIG. 16

FIG. 17

Figure 16—The coal-hammer grip. Figure 17—The bunched fist. Note that the ulnar deviation characteristic of a power grip is apparent in both these figures.

During the precision grip the fingers are flexed and abducted at the metacarpo-phalangeal joints, which serves to increase the span of the hand and to produce a degree of axial rotation of the digits. The extent to which the fingers are flexed and axially rotated depends largely on the size and shape of the object that they are to contain (Fig. 9). As the size of the object diminishes the need for precise handling becomes proportionately greater and, in order to facilitate this, there is a shift of the axis of the precision grip towards the thumb and index finger, digits which are best adapted to exercise fine control.

FIG. 18
A combined grip.

The posture of the hand on the forearm—The relationship of the hand to the forearm differs strikingly in the two grips (Figs. 8 and 9). In the power grip the hand is deviated towards the ulnar side and the wrist is held in the neutral position between full extension and full flexion; in this position the long axis of the thumb coincides with that of the forearm. In the precision grip the hand is held midway between radial and ulnar deviation and the wrist is quite markedly dorsiflexed. In passing from the power grip to the precision grip position, the thumb moves from a position of adduction to one of abduction and is thus no longer in the line of the long axis of the forearm. Realignment of the thumb in relation to the forearm is achieved by correcting the ulnar deviation of the hand and further dorsiflexing the wrist.

Combined grips — Although, as a general rule, it is true to say that if the motion of the hand be arrested at any moment of activity it will inevitably show some phase of power grip or precision grip, there are certain activities of the hand in which the two grips are combined at one and the same time. The precision grip element is usually the dominant one and the inner three digits, which are redundant when a small object is handled, are free to be utilised in a purely supplementary role (Fig. 18). In terms of everyday activity this composite grip is employed when, for example, a knot is tied in a piece of cord (Fig. 19).

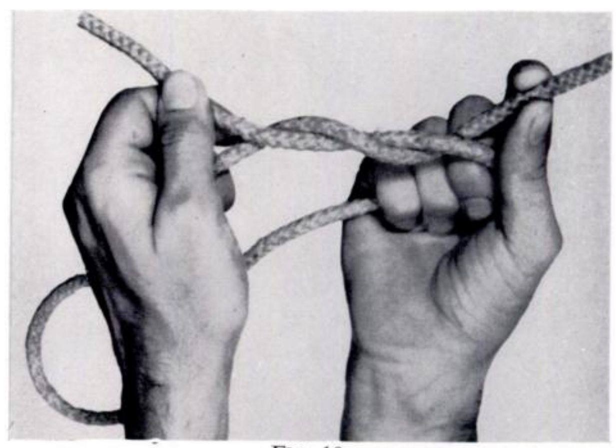

FIG. 19
A combined grip. Note that the index finger and thumb are in a precision grip posture while the remaining digits are in a power grip posture in both figures.

The hook grip—Some mention must be made of a type of prehensile grip in which the thumb plays little or no part. This is the so-called hook grip which requires relatively little muscular effort to maintain and is employed under conditions when precision requirements are minimal and when power needs to be exerted continuously for long periods, as for example when shopping baskets or suitcases are carried (Fig. 20). The hook grip is also used when for any reason it is impossible to obtain more than a finger-tip hold, as, for example, during the opening or closing of one half of a sash window. This latter function is to all intents and purposes, however, non-prehensile. In the normal individual this grip has limited potentialities and is therefore only rarely used, but in the disabled individual with paralysis of the intrinsic muscles of the hand, it is virtually the only form of prehension possible.

CONCLUSION

It is perhaps rather surprising to find that the prehensile movements of the human hand may be resolved into two such simple conceptions as precision grip and power grip. This feeling of surprise would seem to stem from a proneness to confuse movements with purposive

FIG. 20
The hook grip. Note the passive role of the thumb in this grip.

activities, the multiplicity of the latter tending to obscure the fundamental simplicity of the former. There is, too, possibly an understandable lack of objectivity which leads one to suppose that the hand of man is, in the words of a nineteenth century authority, " the most perfect and complete mechanical organ that nature has yet produced." While the perfection and completeness of its accomplishments are not in doubt, the implicit idea that such an organ is a specialisation of man is open to criticism. In many respects the human hand is a remarkably primitive structure, the pitfalls of extreme specialisation shown, for example, by the gibbon, the potto and the baboon having been avoided in its phylogenetic history. In its pentadactyl form, the relative length of its digits, the arrangement of its musculature and in the generalised nature of its movements, man's hand shows an ancient simplicity of structure and function. The human hand is little better endowed, in a purely material sense, than that of any generalised primate in whom the thumb is present and specialised. In this connection Wood Jones (1941) wrote: "We shall look in vain if we seek for movements that man can do and a monkey cannot, but we shall find much if we seek for purposive actions that man can do and a monkey cannot." The heart of the matter lies in the term "purposive actions," for it is in the elaboration of the central nervous system and not in the specialisation of the hand that we find the basis of human skill.

SUMMARY

1. The prehensile movements of the hand as a whole are analysed from both an anatomical and a functional viewpoint.

2. It is shown that movements of the hand consist of two basic patterns of movements which are termed precision grip and power grip.

3. In precision grip the object is pinched between the flexor aspects of the fingers and that of the opposing thumb.

4. In power grip the object is held as in a clamp between the flexed fingers and the palm, counter pressure being applied by the thumb lying more or less in the plane of the palm.

5. These two patterns appear to cover the whole range of prehensile activity of the human hand.

My thanks are due to the Medical Research Council who provided a grant for this work; to numerous colleagues who have contributed both ideas and criticisms to this study; to D. A. Fenton, G. Fraser and L. Grayson whose hands are used as models; to A. L. Wooding of the Photographic Department of St Thomas's Hospital Medical School and to Mrs J. M. Thomas of the Photographic Unit of this medical school for their excellent photographs.

REFERENCES

ELLIS, T. S. (1878): The Position of Rest in Fatigue and in Pain. British Medical Journal, **i**, 84.

ELLIS, T. S. (1889): The Human Foot. London: J. & A. Churchill.

GRIFFITHS, H. E. (1943): Treatment of the Injured Workman. Lancet, **i**, 729.

GRIFFITHS, H. E.: Personal communications.

JONES, F. Wood (1941): The Principles of Anatomy as Seen in the Hand. Second edition. London: Baillière, Tindall & Cox.

MCBRIDE, E. D. (1942): Disability Evaluation. Third edition. Philadelphia, London, Montreal: J. B. Lippincott Company.

NAPIER, J. R. (1952): The Attachments and Function of the Abductor Pollicis Brevis. Journal of Anatomy, **86**, 335.

NAPIER, J. R. (1955): Form and Function of the Carpo-metacarpal Joint of the Thumb. Journal of Anatomy, **89**, 362.

SLOCUM, D. B., and PRATT, D. R. (1946): Disability Evaluation for the Hand. Journal of Bone and Joint Surgery, **28**, 491.