THE EXTENSOR APPARATUS OF THE FINGER

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The study of the movements of the digits has attracted the attention of many workers (see Bunnell, 1942, 1944; Duensing, 1944; Braithwaite, Channell, Moore & Whillis, 1948, for the literature). But though agreement has been reached on many points there are others that are still poorly understood, particularly the peculiar interactions of the joints on each other.

LIMITATION OF FLEXION AT THE TERMINAL JOINT

When a finger is fully flexed on the palm (fig. 1A) the middle joint (proximal inter-phalangeal) is bent to an acute angle, while the distal joint (distal inter-phalangeal) is bent to about a right angle, with some variation in different individuals. From

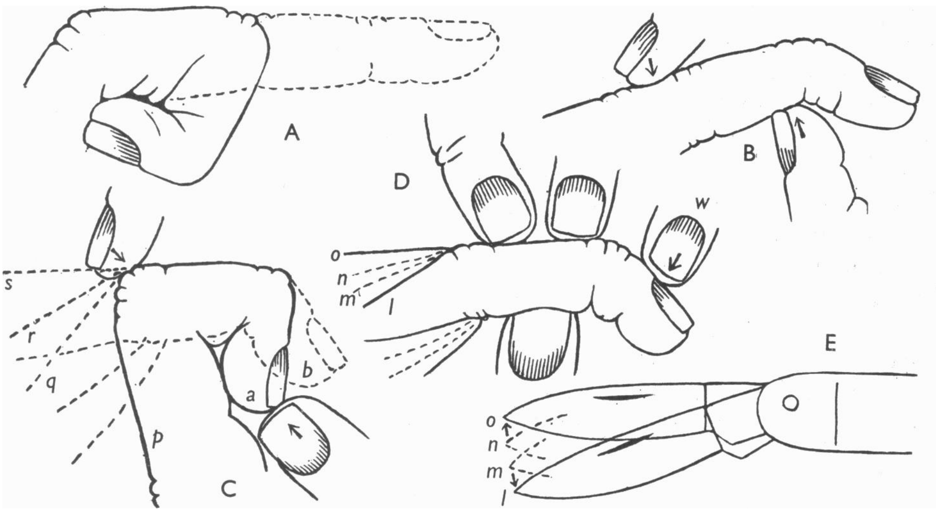

Fig. 1. Linked movement in the living subject. A, flexion and extension of middle finger; B, flexion of terminal joint with middle joint fixed in extension; C, effect of gradual extension of middle joint on flexion of terminal joint; D, production of snapping movement at middle joint; E, snapping in pocket-knife.

this position the finger can be extended completely. But when the middle joint is fixed in extension (fig. 1B), and an attempt is made, either by the subject or by the experimenter, to flex the terminal phalanx, it is found that it can, in most subjects, no longer be bent to a full right angle, but only through 45° or 60°.

Now if the middle phalanx be fixed in position while the distal joint is kept passively flexed by pressure between the finger and thumb (fig. 1C), the linked motion by which changes in the middle affect the distal joint can be studied in detail. As the middle joint extends from a position of full flexion, it has at first, position *p* to *q*, no effect on the distal joint. As it passes through the middle part of its range, *q* to *r*, the distal joint extends from *a* to *b*, but the last part of the movement, *r* to *s*, has no effect.

A reciprocal movement of the middle joint when the distal joint is moved is difficult to demonstrate in the living subject. If, however, the middle phalanx is fixed, and at the same time pressure is maintained on the dorsum of the terminal phalanx by the finger (Fig. 1 D) a new phenomenon appears. Near the position of full extension, between *m* and *n*, the joint works smoothly, but on either side of this range a distinct springiness is felt, for the middle joint tends to spring suddenly into full extension, *n* to *o*, or into partial flexion, *m* to *l*. The sensation is similar to that felt on opening the blade of a pocket knife, for this again, beyond the neutral range, tends to spring into a fully open or a partially closed position. Thus the pressure on the terminal phalanx has induced a 'snappiness' in the middle joint, and made its motion similar to that of the well-known 'Schnappgelenke' found, for example, in the elbow of the horse and the knee of wading birds, fully discussed by Palmgren (1929, *a* and *b*) and Fick (1931), who bring together all previous work on the subject. In animals the snap-mechanism is often of biological significance, but in man it is only an epiphenomenon, induced by artificial conditions.

Schloffer (1909, p. 551) described the limitation of flexion at the distal joint, and suggested that it was due to an attachment of the dorsal aponeurosis through the joint capsule to the dorsum of the middle phalanx, but there is, in fact, no such attachment (Fig. 2A). Duensing (1944, p. 150) suggested that the limitation was due to a tautness in the side-slips (*s.sl.*) of the extensor aponeurosis when the middle joint was extended. But in a preparation in which the aponeurosis is cut (Fig. 2B, C) the link movement still takes place, and indeed in both directions, for not only does extension of the middle lead to partial extension of the terminal joint, but also flexion of the terminal joint induces some degree of flexion of the middle joint. Again, as Fick (1931) and many earlier workers have shown, snap-joints have peculiarities of their ligaments, which are attached eccentrically beyond the main axis of movement, so that they are at maximum tension at the labile phase ('kritische Stellung', 'punto morto'), and, once movement has started, tend to pull the joint in one direction or the other (Fig. 2F).

THE LINK LIGAMENTS

Dissection reveals two ligamentous bands, one on either side of the digit, passing from the sides of the distal part of the proximal phalanx, where some of the fibres are continuous with the proximal annular fibres of the fibrous flexor sheath, across the collateral ligaments of the middle joint, to join the extensor tendon on its way to the terminal phalanx (fig. 2A, *l.l.*). So long as these 'link' ligaments are intact the linked motion between the joints is found, but when they are cut it is lost. Forcible flexion of the terminal joint puts tension on the ligaments, which then tend to pull the proximal phalanx into partial flexion or full extension (Fig. 2D, E), with the characteristic springy motion.

The link ligaments have escaped the notice of most authors, but seem to be the structures shown as unlabelled slips by Seifert (1919, Abb. 1), who makes no comment on their significance. They are quite distinct from the thin fasciae which connect the dorsal aponeurosis to the sides of the capsule of the middle joint figured by Bunnell (1942, fig. 5A).

LIMITATION OF EXTENSION IN THE TERMINAL JOINT

It is well known that when the middle joint is fully flexed the distal joint cannot be fully extended by active movement (fig. 3A), though it offers no resistance to passive extension (Fig. 3B). If now the middle phalanx is fixed (Fig. 3C) and the middle joint gradually extended, it is found that in the range w to x there is no change in the degree of active extension possible, from x to y the range gradually increases till the terminal joint can be fully extended, and from y to z there is no further change.

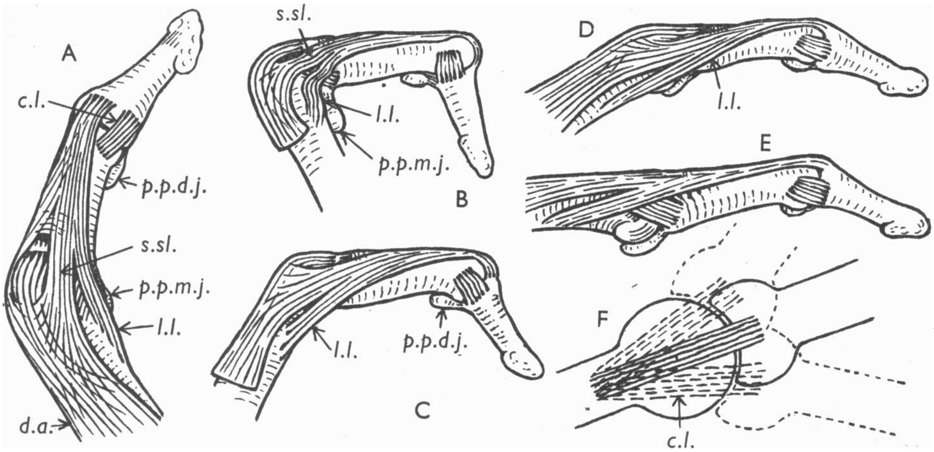

Fig. 2. Linked movement in an anatomical preparation. A, general dissection of a middle digit to show linked ligaments; B, link ligaments slack when middle joint is flexed; C, link ligaments tightened by extension of middle joint; D and E, movement of link ligament across axis of middle joint; F, snap mechanism after Fick (1931). For lettering see key on p. 259.

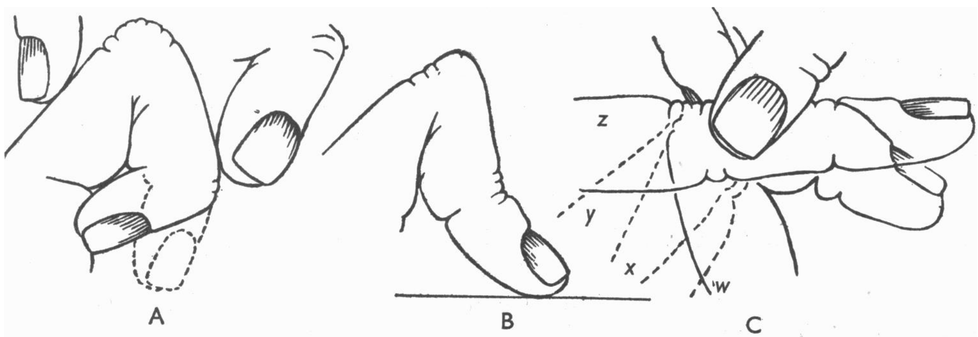

Fig. 3. Extension in distal joint. A, limits of active movements when middle joint is flexed; B, passive extension of terminal joint; C, effect of extension of middle joint.

This limitation is due to a slackness of the side-slips of the extensor aponeurosis when the middle joint is flexed, for in that position the side-slips lie on the volar side of the joint axis, and cannot be tensed by muscle action on the dorsal aponeurosis (Fig. 2B). As the middle joint nears its position of extension the side-slips pass more dorsally in relation to the joint (Fig. 2C), and transmit tension on the aponeurosis to the terminal phalanx. The dorsovolar shift of the side-slips and its physiological effects are discussed fully by Schöning (1887), Bunnell (1942, 1944), Duensing (1944) and others, but still seem little known, so that the whole of the extensor system may be shown lying dorsal to the middle joint even when that joint is flexed (e.g. Braithwaite *et al.* 1948, fig. 2).

COMBINED EFFECTS OF THE LINK AND SHIFT MECHANISMS

Starting from a fully flexed position (Fig. 1A), the basal joint can be extended independently of the other two, but the middle and distal joints usually extend together. The relative amount of movement in the two joints can be controlled to some degree, presumably by the independent action of the flexor digitorum sublimis on the middle joint, but the degree of independence is limited. For in the earlier stages of the movement the tendon to the terminal phalanx is absolutely slack owing to the volar shift mechanism, and in the later stages the link mechanism comes into play and the terminal joint extends with the middle. Thus in most individuals there is little power of independent movement of the two joints.

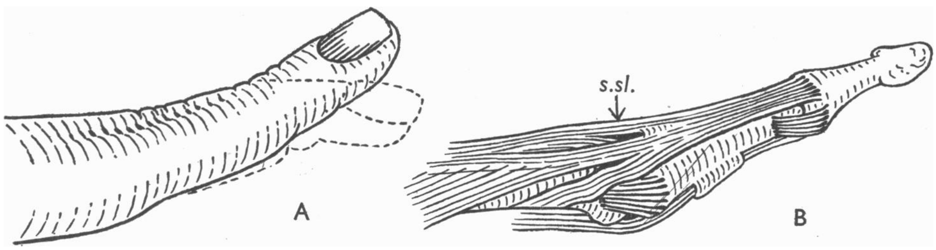

Fig. 4. Independent control of terminal joint. A, in living subject; B, anatomical mechanism. For lettering see key on p. 259.

Exceptional individuals who can move the terminal joint independently of the others can only do so after fixation of the middle joint in a position of hyperextension, by a constant tension on the dorsal aponeurosis, whose taut side-slips can be seen beneath the skin (Duensing, 1944, cf. my Fig. 4). Tension on the profundus tendon then gives flexion of the terminal joint without unlocking the middle joint. But most individuals cannot hyperextend the middle joint sufficiently for it to become locked.

LINK ACTION OF THE INTEROSSEI

A dissection of a finger (Fig. 5) shows that the general arrangement of the interosseous muscle with its tendon resembles that of a link ligament, and suggests that when the muscle is isometrically contracted its 'ligamentous action' will be similar to that of the ligament. The two structures have in common a proximal bony attachment, a volar relationship to a proximal joint, and a distal attachment to the dorsal aponeurosis. In fact, if in a fixed specimen with mobile joints and the interossei intact the proximal (metacarpo-phalangeal) joint is extended, the middle joint is vigorously extended at the same time. This linked action plays a part in the smooth stretching of the fingers, when the proximal and middle joints are extended at the same time. It is the counterpart of that described by Braithwaite *et al.* (1948), in which the common extensor contracts isometrically and the interossei actively.

ARRANGEMENT OF THE EXTENSOR ASSEMBLY

Some details of the anatomy of the extensor assembly, aptly so named by Bunnell (1942), may now be considered. Figs. 5–8 were prepared from a dissection of a single formalin-fixed right middle digit.

The two heads of the interosseous muscle combine in the intermetacarpal space but the common mass soon splits to form two distinct bellies, a superficial (*s.b.i.*) passing to the dorsal aponeurosis, and a deep (*d.b.i.*) passing to the base of the proximal phalanx, with some attachment to the palmar pad of the proximal joint. This is in agreement with Bunnell's dissection (1942, fig. 6D), but not with his

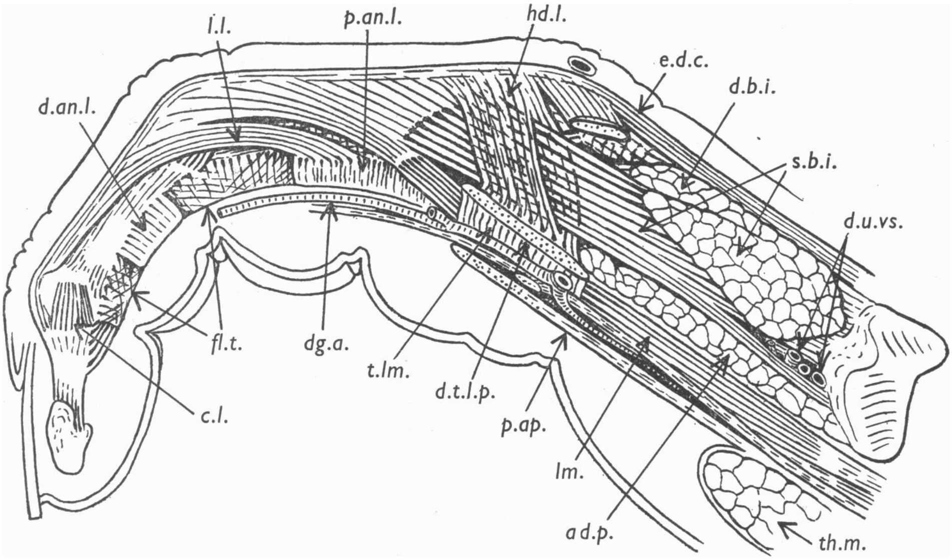

Fig. 5. Dissection of middle finger to show the extensor assembly. For lettering see key on p. 259.

diagram (fig. 5A), which shows the bellies combined nearly as far as their insertion, nor with Braithwaite *et al.* (1948, fig. 1). Salsbury (1937, p. 395) has pointed out that if a single-bellied interosseous muscle were inserted into the proximal phalanx it could not act as an extensor of the middle or distal joints. But as, in fact, the muscle splits distally into two distinct bellies Salsbury's difficulty does not arise. The partial subdivision of the interossei has been described before, and it has even been suggested that three muscles should be recognized in each intermetacarpal space (review and literature in Forster, 1916).

The palmar pad (*p.p.*) of the metacarpo-phalangeal joint is a mass of dense fibrous tissue with closely interwoven bundles of collagenous fibres, and is not a fibro-cartilage as suggested in some text-books. It is held in place by a pair of collateral ligaments of the pad (*c.l.p.p.*), adjacent to, but distinct from, the collateral ligaments of the joint (*c.l.*), and by the well-known distal attachment to the base of the proximal phalanx. The pads of adjacent digits are attached together by the deep transverse ligaments of the palm, made of ordinary ligamentous tissue. The distinction between pads and ligaments is an old one, but Braithwaite *et al.* (1948, p. 187) have reverted to the description of the whole mass of pads and ligaments as a single structure, their deep transverse palmar ligament or deep intermetacarpal ligament, the latter a most inappropriate term as the structure is not directly attached to the metacarpal bones. The structure of the corresponding pads and ligaments of the foot has been discussed in some detail by Haines (1947).

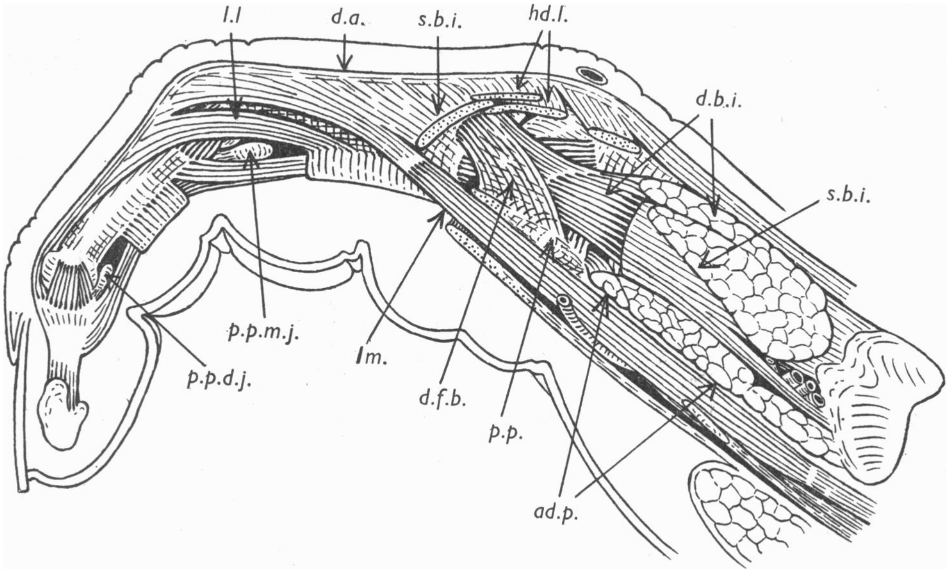

Fig. 6. As Fig. 5, with superficial belly of interosseous cut away and the fibrous flexor and lumbrical tunnels opened. For lettering see key on p. 259.

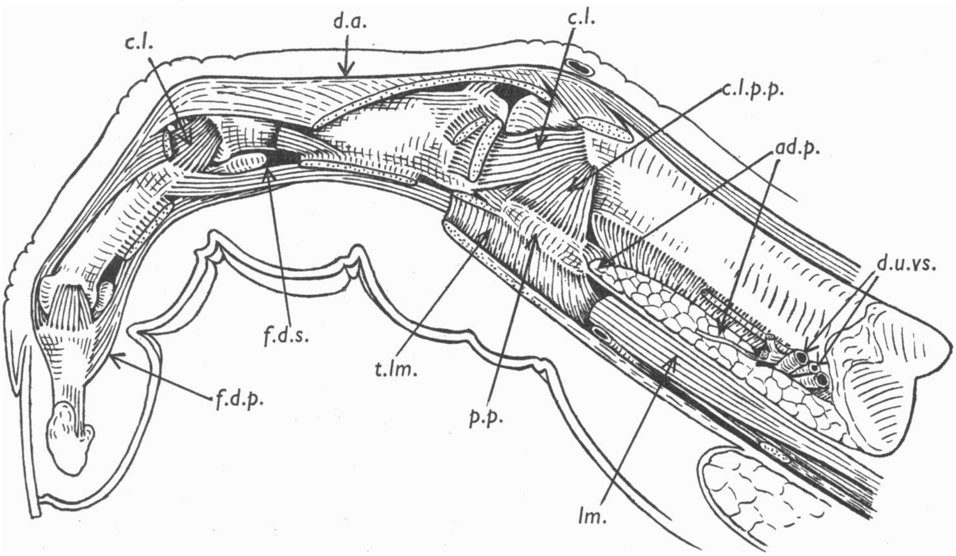

Fig. 7. As Fig. 6, with deep structures exposed. For lettering see key on p. 259.

In the region of the metacarpo-phalangeal joint the extensor apparatus is represented by the so-called 'dorsal expansion'. Attached to either side of this expansion is a sheet of transversely running fibres, the two sheets forming with the expansion the 'transverse metacarpophalangeal fascia' of Salsbury (1937, p. 401), the 'dossière' of Montant & Baumann (1937, p. 314) and the 'extensor hood' of Braithwaite *et al.* (1948, p. 187). Since, however, the transverse fibres are distinct from the longitudinal fibres it seems better to break up the structure into a hood ligament on either side, and an extensor tendon passing distally into an extensor aponeurosis.

Each hood ligament is attached at its volar end to the palmar pad of the proximal joint, a point first stated clearly by Braithwaite *et al.* (1948, p. 187), though Salsbury (1937, p. 402) had already seen a well-defined band passing between the palmar edge of the interosseous and the side of the joint capsule. The ligament splits to enclose the interosseous muscle to which it is closely bound, particularly distally where the muscle is becoming aponeurotic. Another fibrous band (*d.f.b.*) is sometimes found passing to the phalanx between the hood ligament and the deep insertion of the interosseous. The fibrous tunnel for the lumbrical (*t.lm.*) is attached dorsally to the palmar pad and deep transverse ligament, and through it the palmar aponeurosis

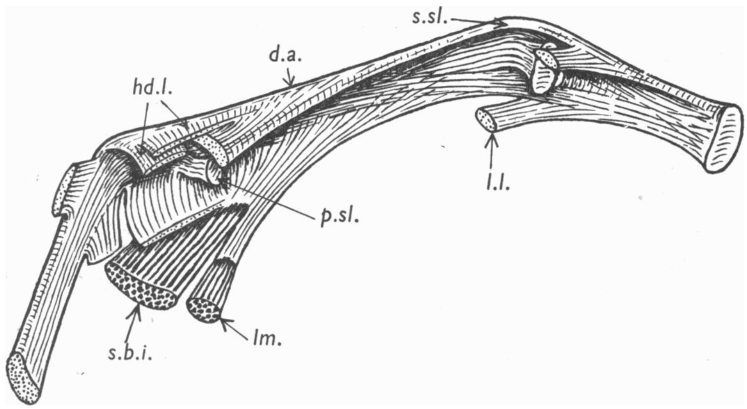

Fig. 8. Dorsal aponeurosis and its appendages. For lettering see key on p. 259.

(*p.ap.*) is firmly attached to the palmar pad (cf. Grodinsky & Holyoke, 1941). Thus opposite the metacarpal head a continuous series of strong fibrous structures attaches the extensor tendons to the palmar aponeurosis.

These various bands presumably serve to maintain the extensor tendon, the interossei and the palmar pad in place, particularly, as suggested by Salsbury (1937), to prevent the interossei moving too far away from the axis of the proximal joint when that joint is flexed, and so losing their power of extension at the middle and distal joints, but their action is not yet fully understood. Bunnell's suggestion (1942, p. 12 and fig. 8C) that the hood ligaments are necessary to give the interossei a purchase on the proximal phalanx and so allow them to flex the proximal joint, is inacceptable, for the interossei are not directly inserted into the ligaments.

A slip passes from the deep surface of the extensor tendon to the dorsum of the proximal phalanx near its base (*p.sl.*). This slip has been fully discussed by Hauck (1923) and Duensing (1944), and is very clearly figured by Bunnell (1942, fig. 5B), but recently Sunderland (1945, p. 196) found only a loosely arranged band of deep fibres. In most individuals, however, the slip is strong and well defined, though since it is slack in all positions of the proximal joint except in full hyperextension its presence does not normally interfere with the action of the common extensor on the more distal joints.

The drawings of Hauck (1923, fig. 7A), Bunnell (1942, fig. 5A) and Duensing (1944, fig. 1) all show an insertion of some fibres of the interossei and lumbrical directly into the middle phalanx with the middle slip of the extensor aponeurosis, as well as a main insertion, through the side-slips of the aponeurosis, into the terminal phalanx. Braithwaite *et al.* (1948, fig. 1) show no such insertion, and state (p. 187) that the muscles join the side slips of the aponeurosis after these slips have diverged from the central insertion into the middle phalanx. My own work confirms that of the earlier authors, for in fact all the muscles inserted into the dorsal aponeurosis are bound together on the dorsum of the proximal phalanx. So whatever their action on the proximal joint all the muscles inserted on the aponeurosis must have the same actions on the middle and distal joints. This agrees well with the clinical and physiological conclusions of Duensing (1944) and Sunderland (1945).

SUMMARY

1. A pair of link ligaments attached proximally to the sides of the proximal phalanx and distally to the extensor aponeurosis is described.

2. These ligaments limit flexion in the distal joints of the finger when the middle joint is extended.

3. This linked motion combines with the volar shift of the side slips of the dorsal aponeurosis and with the ligamentous action of the interossei to give smooth combined movements of the digits.

4. Some details of the extensor assembly are reviewed, particularly the insertions of the interossei, the hood ligaments and their attachments to the palmar pads, and the insertion of some fibres of the interossei and lumbricals on the middle phalanx.

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The author deeply regrets his failure to consider the important recent paper by Landsmeer, J. N. F. (1949), 'The anatomy of the dorsal aponeurosis of the human finger and its functional significance', *Anat. Rec.* **104**, 31–44. Landsmeer's 'oblique band of the retinacular ligament' is the structure here referred to as the link ligament.

KEY TO LETTERING

ad.p.	adductor pollicis
c.l.	collateral ligament
c.l.p.p.	collateral ligament of palmar pad
d.a.	dorsal aponeurosis
d.an.l.	distal annular ligament
d.b.i.	deep belly of interosseous
d.f.b.	deep fibrous band
dg.a.	digital artery
d.t.l.p.	deep transverse ligament of palm
d.u.vs.	deep ulnar vessels
e.d.c.	extensor digitorum communis
f.d.p.	flexor digitorum profundus
f.d.s.	flexor digitorum sublimis
fl.t.	flexor tunnel
hd.l.	hood ligament
l.l.	link ligament
lm.	lumbrical
p.ap.	palmar aponeurosis
p.an.l.	proximal annular ligament
p.p.	palmar pad
p.p.d.j.	palmar pad of distal joint
p.p.m.j.	palmar pad of middle joint
p.sl.	proximal slip
s.b.i.	superficial belly of interosseous
s.sl.	side slip
t.lm.	tunnel for lumbrical
th.m.	thenar muscles

p-s, l-o, and w-z in Figs. 1 and 3 are explained in the text.