quite how to dispose of it the manufacturers have never explained—it is insoluble and may eventually cause obstruction to a normal sanitary system.

The patient seldom needs encouragement to take a full normal diet after leaving hospital, but a warning should be given to avoid eating the skins of certain fruits and vegetables, such as plums and tomatoes, since these can cause an obstructive bolus at the stoma. Extra salt should be taken whenever the small bowel discharges become more fluid. Full activity can be undertaken, for it is possible to play cricket, golf, tennis, football and even swim and dive without disturbing the bag, which being slender remains imperceptible even under a bathing dress. If any complication to the stoma arises which makes the management of the ileostomy impossible, the patient must return to

hospital. Prolapse, retraction and fistula can only be treated by a revision of the ileostomy performed through a laparotomy incision; reconstructive operations confined to the stoma are ineffective and frequently lead to further trouble.

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FLAT FOOT

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Introduction

Among the foot defects which cause disability, flat foot is one of the commonest. Normally the body weight is borne through two half-columns with the medial border of each foot raised from the ground (Wood Jones, 1943). The resulting arch may be high or low, yet still be healthy; but in flat foot the arch is not merely low, it has collapsed inwards (Fig. 1).

Aetiology

(a) Anatomical Causes

There are four groups of anatomical peculiarities which predispose to flat foot. The inheritance of many of these peculiarities explains the frequent familial incidence of the disorder.

1. *The lower limb may be wrongly 'set' on the trunk.* The entire limb may be externally rotated or the leg only may be rotated from the knee downwards. In either case, the patient stands like Charlie Chaplin and the line of body weight falls too far medially (Fig. 2). As a result, when the body moves forward in walking the force of body weight imposes considerable strain upon the apex of the arch and tends to topple it over.

2. *The leg may be wrongly 'set' on the thigh,*

FIG. 1
 1ST NORMAL ARCHES
 2ND LOW ARCHES
 3RD FLAT FEET

(Reproduced by courtesy of the Royal Society of Medicine)

FIG. 2.—If the limb is externally rotated or the knee valgus, the line of weight falls too far medially and the arch is liable to collapse.

for example, in knock knees. Here, too, as in external rotation, the line of body weight falls too far medially. The combination of knock knee and flat foot is common in children aged two to six years.

3. *The foot may be wrongly 'set' on the leg.* A short calf muscle or Achilles tendon prevents adequate dorsi-flexion of the ankle (unless the knee is bent). In walking, the knee is straight and, as the front leg swings forward, the back leg must dorsiflex considerably at the ankle. If adequate dorsiflexion is hindered by a tight calf the Achilles tendon bowstrings across the outer side; this is accompanied by a topple of the arch to the medial side.

4. *The forefoot may be wrongly 'set' on the hindfoot.* The forefoot may be varus, with the soles of the feet tending to face each other; this is sometimes due to a relatively short tibialis anticus muscle, and sometimes to a short or elevated first metatarsal (Morton, 1935). Whatever the cause, as the weight comes on to the forefoot in walking the first metatarsal head is forced down from its elevated position on to the ground; the apex of the arch is pushed downwards and inwards and flat foot results. Perkins (1948) has emphasized that the varus forefoot is commoner than generally supposed, but the deformity may not be recognised unless the foot is correctly examined with the heel held square. Once weight is on the foot the obvious deformity is the valgus heel (Fig. 3).

There is, in addition, a rare *congenital flat foot* in which the foot is convex on its plantar surface ('boat-shaped'), the talus being in the equinus position and the forefoot dorsiflexed.

(b) *Physiological Causes*

The bony arch of the foot is potentially unstable.

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FIG. 3.—A varus forefoot has the sole facing inwards. When weight is taken the varus forefoot masquerades as a valgus heel.

It is bound together by ligaments, but these are capable of resisting short term stress only; indeed, their main function is to act as sensory end organs, and when they are stretched appropriate muscles are reflexly brought into action. Even the most anatomically perfect foot will become rapidly and grossly flat unless it has muscles of good bulk and tone to support it. The physiological fault may lie in the muscle itself or in its nervous control.

1. *Inadequate nervous control.* We are not here concerned with the gross and obvious inadequacies which result from poliomyelitis or spina bifida, for in these conditions flat foot is overshadowed by other disabilities. An example of inadequate nervous control is *infantile flat foot*. A baby has to learn to balance first its head, then its trunk and eventually to balance the whole body on the feet. This difficult art is not required during the early months of life; but sometimes the balancing reflexes fail to develop even after the child has begun to walk. In that event the arch inevitably collapses with body weight. Myelination of the pyramidal fibres to the foot is incomplete at birth and the plantar responses in babies is extensor. If the infantile flat foot persists into early childhood the extensor responses may persist too, and it is tempting to assume that balancing cannot be easily learned until myelination is complete (Apley, 1948).

2. *Inadequate Muscles.* After illness or enforced recumbency the muscles may temporarily be weak and the arch consequently falls when walking is resumed.

A more lasting form of muscle weakness accompanies a generally poor posture. The child (often a pre-adolescent girl) presents a familiar

FIG. 4.—Spasmodic flat foot; the tendons stand out clearly.

flabby contour with head stuck forward, mouth open, chest flat, back rounded and abdomen protruberant. The gluteal muscles are concerned largely with posture (Wiles 1949). They help to straighten the hip and knee, and to twist the limb outwards. This twist cannot be imparted to the foot which is anchored to the ground, and so the rest of the limb turns outwards *relative* to the foot. As a result, the arch is lifted and the line of weight corrected only when the glutei work properly.

Relative inadequacy of muscle is well illustrated by the fat middle-aged housewife whose increase in weight imposes great strain upon the arch. Moreover, a housewife stands still for long periods of time, for example, when washing dishes. Prolonged standing is more harmful to the feet than walking because, during walking, the muscles

supporting the arch alternately contract and relax which is the best training for a muscle.

(c) *Infective Causes*

In all probability there are no 'infective' causes of flat foot. Gonorrhoea has been blamed but with inadequate evidence. There is, however, the condition known as *spasmodic flat foot* which behaves like an infective arthritis of the subtaloid and midtarsal joints. The name is unfortunate for, although the condition is spasmodic (in the sense that it is associated with spasm) it is not a true flat foot. The patient, who is usually in his early 'teens, develops pain soon after starting an active job. The peronei and extensors are seen to be in spasm (Fig. 4), and movement at the subtaloid and midtarsal joints is abolished. Although spasmodic flat foot is usually thought to be infective in origin, X-rays sometimes show a bar of bone joining the calcaneum to the scaphoid (Badgley 1927), or bridging the calcaneum and talus (Harris and Heath, 1948). The condition is usually treated by rest in plaster or by arthrodesis. Because it is a quite separate entity from flat foot it will be omitted from the remainder of this paper.

Pathology

(a) *The Alteration in Shape*

1. The apex of the arch 'drops'; it may do so at the talo-scaphoid joint, at the scapho-cuneiform joint, or at both joints, (Ewan Jack, 1953). The exact site can best be shown by lateral radiographs.

2. A flat foot is one in which the apex of the arch is not merely low but has also shifted medially. The apex having toppled over the heel necessarily becomes valgus. This valgus heel has often been described as a cause of flat foot and theoretically this may be true; it is much more likely, however, to be an inevitable sequel.

3. Shephard (1951) has shown that the subtaloid and midtarsal joints are functionally one hinge joint comparable with the radio-ulnar joint, and that supination and pronation are the only movements at this composite joint. In the earlier descriptions I have referred to the apex of the arch dropping and shifting medially; these are merely individual components of pronation, a movement which is also accompanied by slight abduction. As a result, the tuberosity of the scaphoid becomes unduly prominent.

4. The alterations in shape of the foot which have been described usually occur slowly over a period of months or years. Occasionally, however, they develop quickly as after a long period of bed rest. The rapid stretching of the ligaments which then occurs is painful. Presumably microscopic tears occur in the ligaments; these tears evoke a

FIG. 5

(a) The foot is not only flat.

(b) Its apex has shifted medially.

(c) The scaphoid tuberosity becomes too prominent

response which is inflammatory in the sense that it is the initial change towards repair, with swelling and lymphocytic infiltration. This is the condition known as *acute foot strain*.

(b) The Effects of Flat Foot

Should alterations in shape persist they are followed by degenerative changes in the joints. In consequence the foot becomes stiffer (*rigid flat foot*), a change accentuated by advancing years. As osteoarthritis supervenes the joints are necessarily used near the extremes of range; the capsule is continually being stretched, and pain is produced. Fortunately, the owners of stiffish feet often possess equally stiff boots or shoes, which limit the joint excursion and may succeed in keeping this excursion within the painless range.

More serious are the effects upon the forefoot. The intrinsic muscles function at a disadvantage and are constantly being squashed on to the ground. They therefore weaken, and weak intrinsic muscles result in claw toes and *metatarsalgia*, often with painful callosities. Moreover, the dropping of the arch, combined with weak intrinsic muscles, leads to a splaying of the metatarsals. Shoes prevent the great toe from splaying and *hallux valgus* with bunion formation results. This is by no means the only factor in the production of a *hallux valgus*, but it is a significant one. It is important to realise that foot troubles, except in their earliest stages, rarely occur in isolation. Weak muscles result not only in flat foot but also in forefoot disorders: and not only do these groups of conditions arise from a common cause, but one may predispose to the other. In the foot one

trouble leads to another. The presenting symptoms, and even the more immediately obvious signs, are often only distantly related to the fundamental cause.

Clinical Features

(a) Symptoms

At one time high arches were much admired. Later it became fashionable to say that flat foot was a condition which troubled doctor more than patient, and that 'fine athletes have flat feet.' Neither statement is true. High arches are nearly always troublesome and flat foot is a considerable nuisance even though it may remain painless until middle life. There are three main symptoms:—

1. *Alteration in Shape.* The growth of the school medical service has made alterations in shape of the foot a common cause for referring children to orthopaedic clinics. Almost equally common is the complaint of alteration in shape of the shoes which wear badly and unevenly, needing repair or renewal every few weeks. Adults less often complain of the altered shape of their own feet until secondary changes such as *hallux valgus* supervene.

2. *Pain.* Pain resulting from flat foot is rare in adolescents, and almost unknown in children. If spasmodic flat foot is excluded the pain in young people is due to rapid stretching of ligaments. This acute foot strain is rare, and occurs either after unaccustomed prolonged standing or following recumbency. Pain is felt exactly where the apex of the arch is toppling, that is, on the inner

side of the sole of the foot underneath the scaphoid, an area which is also tender.

Adults not infrequently complain of painful flat foot. The inner border of the foot aches, and the ache increases as the day goes on, sometimes radiating up the shin. When flat foot has been present for many years, and especially if stiff cramping shoes have been worn, pain occurs as a result of osteo-arthritic changes. The foot is stiff and the joints may be tender.

3. *Associated foot troubles.* In middle life flat foot is often accompanied by splaying of the metatarsals, hallux valgus, claw toes and metatarsalgia. All these disorders may result from the flat foot or may share with it a common aetiology; and all these conditions sometimes produce pain. The pain may occur at the site of a bunion, under the metatarsal heads, or on the dorsum of a hammer toe. The important point is that treatment is required for the foot as a whole and not merely for the forefoot.

(b) Signs

General examination. First, the patient as a whole must be assessed. The age and build are noted. If the foot changes are severe a neurological examination may be advisable.

Examination of the foot. A simple routine will be described during which certain questions must be answered: Is it a true flat foot? If so, are there any underlying anatomical abnormalities? Is the musculature adequate? And are there any sequelae?

The patient stands on a stool with both lower limbs bare from the mid-thigh downwards. The feet should be pointing forwards and so should the patient's face—this is important for if he looks down at his feet he loses balance and the foot assumes an abnormal posture. The legs are inspected for abnormal rotation and for knock knees. Next, the feet themselves are examined; if the arch has toppled over the scaphoid tuberosity will appear unduly prominent in addition to the arch being too low. The patient is now asked to turn round. In a flat foot the heel is valgus, the tendo achillis angulating laterally near its insertion. The patient should next stand on his toes. Unless the foot is rigid the arch re-forms, the prominent scaphoid tuberosity disappears and the tendo achillis straightens.

The patient now sits and each foot is examined in turn while held with the heel square. It is then possible to see if the forefoot is varus and if the first metatarsal is short and elevated. The forefoot is also examined for associated disorders such as hallux valgus, hammer toe and callosities.

Next, the foot is palpated for tenderness: first under the arch, then at the midtarsal region and

finally at the forefoot. With the heel still held square and the knee straight, movements of the foot are tested. First the ankle; does it dorsiflex above a right angle? If there is a tight tendo achillis, this dorsiflexion does not occur without the heel moving into valgus as the tendon takes its short cut. The subtaloid, midtarsal and metatarsophalangeal joints are each examined in turn to determine their range of movement.

Treatment

An arch which is merely low is not pathological and should not be treated. The treatment of a true flat foot may be summarised thus:—

1. Treatment of the Anatomical Causes (mainly in children).
2. Treatment of the Physiological Causes (at all ages).
3. Treatment of the Pathological Sequels (mainly in adults).

(a) Treatment of the Anatomical Causes

1. Limbs which are externally rotated predispose to flat foot. There is no good method of correcting this rotation. Teaching the child to walk with toes turned in is difficult and probably useless.

2. Because knock knee leads to the stress of body weight falling too far medially, it is customary to compensate by raising the inner side of the heel of the shoe; up to the age of five an eighth of an inch, and three sixteenths in older children. This traditional treatment elevates the child's heel and the mother's morale, but does little more. Fortunately the legs have nearly always grown straight without treatment by the time the child reaches six years of age.

3. A tight tendo achillis is easily compensated by raising the child's heel. Two extra thickness of rubber usually suffice. Some surgeons maintain that a tight tendo achillis can be stretched by physiotherapy. I have tried asking the physiotherapist to treat only one foot and my impression is that treatment has no effect; some tendons become normal and others do not. Probably the force of manipulation is expended upon the midtarsal joint and leaves the tendo achillis unaffected. There is a peculiar fear that high heels are a first step on the primrose path. Mothers are nearly always reluctant to allow an adolescent daughter to wear a raised heel. It is not necessary, however, to raise the heel more than $\frac{1}{2}$ in. above the normal, though flat sandals require raising by at least 1 in.

Some surgeons advise operative elongation of the tendo achillis. This procedure alters the shape of the calf, and should never be done in girls. The heel should be raised until the girl is old enough to wear shoes which are normally made

FIG. 6.—External rotation of the limb restores the arch. The ball of the great toe must press firmly into the ground.

with a higher heel. Even in boys the operation is very rarely indicated and then only if shortening persists and is not compensated for by a $\frac{3}{4}$ in. raise of the heel. If operation is required it is best done, not by subcutaneous tenotomy, but by a formal exposure, lengthening the tendon and suturing it in the elongated position. The leg should be held in plaster for six weeks.

4. Treatment of a varus forefoot is difficult. It is tempting to raise the inner border of the sole of the shoe, a method which may sometimes prevent the arch from toppling over, but which perpetuates the causal deformity and should not be employed in children. On the contrary it is better to raise the inner side of the *heel* and either leave the sole unaltered or to raise its *outer* side; this is at first uncomfortable, but has the advantage that every step forces the forefoot to untwist (pronate). Catterall (1952) employs a spring pronating device attached to the shoe, which serves the same purpose. A quicker method is to manipulate the foot under anaesthesia with two Thomas's wrenches; plaster is then applied in the over-corrected position for three months. If the varus forefoot is due to a short elevated first metatarsal, osteotomy has been advocated (Lambrinudi, 1937) to correct the deformity, followed by a bone graft, and Stamm (1953) now uses a curved osteotomy for this purpose.

(b) Treatment of the Physiological Cause

A child who needs shoe adjustment should also

be given a short course of muscle training, because the faulty position of the foot so often leads to faulty muscle balance. In addition, the physiological faults should be dealt with as follows:—

Infantile flat foot due to delay in learning to balance cannot be treated. There is no way of hurrying myelinisation. Having made quite sure that there is no spina bifida the surgeon should reassure the mother that in almost every child these reflexes will develop, but that, as with other processes such as speech, the onset may be delayed in an otherwise normal child. Once the plantar response has changed to become flexor, the arch usually develops within three to six months. It is customary to wedge the inner side of the heel, a practice which delights the mother and makes it only slightly harder for the child to walk.

Weak muscles following rest should be treated before the patient gets up. Regular intermittent contractions of the long and short muscles should be taught and practised, and faradic foot baths may help. When the patient first gets up it should be for short periods of time only, which should be spent in walking rather than standing. If the period of bed rest has lasted many months, sponge-rubber insoles may temporarily be worn; they are not a substitute for training but an addition to it.

More often inadequate muscle is part of a general postural disorder. Treatment is then designed to 'tone up' the body by outdoor games, gymnastics, postural training and the like. Many preadolescent girls cannot be taught to stand

correctly, and continue slouching until the age when they hold themselves more correctly as part of the process of normal sexual display.

Inadequate muscle is common also in middle age; not only should the muscles be strengthened, but any obesity also requires treatment.

In almost all instances of flat foot, however, whether the cause is primarily anatomical or physiological, muscle training is worth while. The normal exercises taught by physiotherapists are those of walking on tiptoe, walking on the outer border of the foot and picking up objects with the toes. All these are useless, and walking on the outer side of the foot is actually harmful if the forefoot is varus. Much the best method is to teach the patient to twist his knees outwards while keeping the forefoot on the ground: the ball of the great toe must not be allowed to lift, or the exercise loses its point (Fig. 6). When this exercise is correctly performed a normal arch often forms and, if the training is enthusiastic and prolonged, good results are often possible. It is surprising how young a child can be taught this drill, and how soon the habit of standing correctly is acquired. The rotation exercise described is particularly valuable in children with a varus forefoot. The exercises are sometimes worth while in older people, in whom they may be supplemented by faradic foot baths, though many surgeons doubt whether electrical stimulation is of any value.

(c) *Of the Pathological Sequels*

1. When the arch has toppled over it can to some extent be restored by a support. So long as the foot is supple this support should be soft and pliable: it is best made of sponge rubber covered with leather and should only support the medial longitudinal arch. Like a suit, it fits better if made for the individual and not bought 'off the peg.'

Ewen Jack (1953) advocated naviculo-cuneiform fusion in young patients if the 'break' in the arch occurs at this joint and if conservative treatment failed.

2. *Acute foot strain* is rare, and is easily treated. If severe, the patient should spend 48 hours in bed. As a rule, exercises, faradic foot baths and a support bring relief within two or three weeks,

and when the muscles become adequate the support may be gradually discarded.

3. Once the flat foot has become *rigid*, painful osteoarthritis is likely to develop. Treatment is designed to limit the excursion of the affected joints: pain is prevented by avoiding stretching the fibrosed capsule. For a labourer a strong boot with a thick rockered sole (like the Army boot) is often sufficient. In other patients a support helps; only if the foot is very rigid should the support be made of thin spring steel, though this type is commonly sold for all manner of flat feet. Pain which is not relieved by these simple measures can be treated by arthrodesis of the osteo-arthritic joints, and giving the patient a rockered sole to his shoe.

4. In adults flat foot is often accompanied by forefoot troubles. These should be dealt with *secundum artem*. Bunions and hammer toes may be treated conservatively or by operation. Painful callosities and metatarsalgia require redistribution of pressure which is achieved by adding to the arch support a strip of sponge rubber at the level of the metatarsal necks. In addition, exercises to strengthen the intrinsic foot muscles should be practised.

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