THE FOOT

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PREFACE TO THIRD EDITION

THE need for a new edition of this book in wartime has provided an opportunity for including fresh matter not only upon such obvious accompaniments of total war as gun-shot wounds, trench foot, immersion foot, and foot fatigue in industry and the services, but also upon many other subjects in which it was felt that some further expansion was warranted, *e.g.* the influence of evolutionary changes upon ætiology, the mechanism of gait, etc.

All this, together with a number of new illustrations, has added to the size of the book, but we hope it still remains within the reasonable limits which the practitioner requires. To a large extent this increase is counter-balanced by the reduction of the margins, and the thinner paper employed; changes imposed by the regulations of the Book Production War Economy Agreement.

Some of the opinions expressed are likely to be thought unorthodox. Where this is so I have tried to support my view by such arguments as appeared to me relevant, while not neglecting to explain the opposite viewpoint. I am anxious, however, that the reader should not regard me as a complete heretic, for I realise to the full that in many of these matters the last word has not yet been said and that they are still *sub-judice*. Indeed, it is the biased dogmatism of some of our forebears that has produced many of the difficulties of understanding to-day; we should take special care, therefore, not to fall into the same error. In medical subjects, as in much else, it is always wise to assume that nothing is known permanently or completely, and that fresh viewpoints, or even the revival of old ones in modern guise, are always possible.

In order not to disturb the reading of the text the more important references have been collected together at the end of the book. To the authors of these articles I am indebted for much useful information, some of which is now included here.

A considerable number of readers in various parts of the world have been good enough to send me accounts of the characters and deformities of the unshod feet of native races. I should like to express my gratitude to them, for such information is always very welcome.

For permission to reproduce Figs. 13 to 17 from an article in the *British Medical Journal* I have to thank the Editor.

N. C. L.

51, Welbeck Street, W.1.
March, 1943.

PREFACE TO FIRST EDITION

THERE is abundant evidence that much industrial incapacity, in addition to social discomfort, is caused by diseases of the feet. Frequently the responsible lesion is a comparatively trivial one, and the sufferers find that their complaint receives but scant attention when they present themselves for advice. To some extent, an overcrowded medical curriculum is to blame for a lack of interest in these conditions, for the student finds little time to devote to such apparently minor matters, although he discovers later that they constitute a considerable portion of his practice. It is with the object of remedying this defect that this book has been written.

It deals with those conditions which are likely to come into the purview of the practitioner and the general surgeon ; the major orthopædic procedures connected with the treatment of severe talipes have been deliberately omitted.

It is hoped, too, that the book may be of some interest to the Chiropodist and the Masseuse, even though its scope is beyond the requirements of those undertaking these ancillary services.

The majority of the illustrations are original ; where this is not the case due acknowledgements have been made in the text.

I have to thank Mr. I. Affleck for help with the photography, and Mr. D. Trevor, M.S., F.R.C.S., for dissections to confirm certain anatomical points. My wife, also, has given me much valuable help in many ways, particularly with the proofs and the index.

It is a pleasure to record the unfailing courtesy of the publishers during the production of the book.

N. C. L.

51, WELBECK STREET, W.1.
1935.

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THE FOOT

CHAPTER I

THE EVOLUTION OF THE FOOT

In no other region of the body is an understanding of evolutionary history, as a preliminary to the study of anatomy and physiology, more essential than it is in the foot. Many of the disabilities to which it is prone are due, not to present-day circumstances, but to some fundamental weakness or trend in its evolution. In addition, this is a region in which evolutionary change may be suspected of occurring at a comparatively rapid rate, reckoned in geological chronology, and in which, therefore, in accordance with a general biological law, variations dependent upon this will be frequently encountered.

Unfortunately our knowledge of evolutionary history is very imperfect, derived as it is from the study of sparse fossil remains, and especially is this so in the case of the intimate details of man's emergence from a common ape stem to his present very distinctive state. The foot is particularly badly served in this respect, for in many of the most interesting and important fossil remains no trace of it has been unearthed. There is thus much room for speculation and the opinions of authorities vary tremendously; nevertheless, it is possible to piece together a story which will not be far from the truth and from which deductions, admittedly tentative, but none the less useful, can be drawn.

The first point to be noted is that the limbs of man are based upon a biologically ancient architectural plan which was established when the amphibia first emerged countless

ages ago. In all the subsequent changes, whether it be the evolution of the reptiles, birds or mammals, and whatever secondary modifications have occurred, this has remained the primitive limb type. It consists of three segments, in the case of the lower limb, the thigh, the leg and the foot with five digits. This standardised three-sectioned pentadactyl limb is thus very deeply embedded in the germ plasm of all the higher animals. So little is known regarding the origin

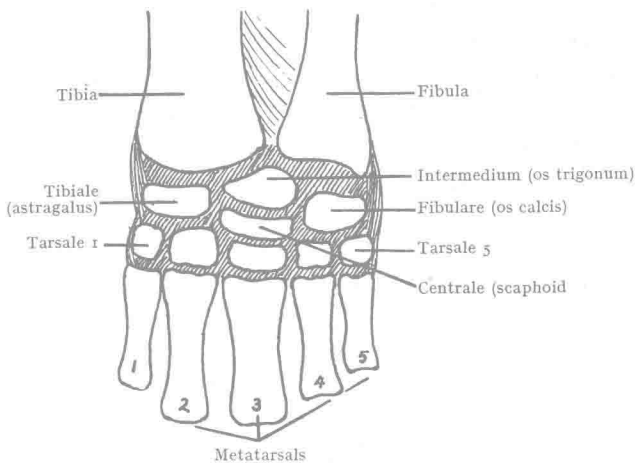

FIG. 1.—Tarsal bones of a tortoise, showing primitive arrangement from which the various later types have evolved. It will be seen that the same essential elements are present in the human foot despite the great biological separation of the two types (after Keith).

of this type of limb that it would be idle to indulge in much theoretical speculation. Some see in it a mere reduction of the multiple chains of bones to be found in the fins of the fishes and would explain the appearance of supernumerary digits as an atavistic return to this condition, but there are other explanations of these extra digits just as acceptable, for it is quite probable that the immediate ancestry of the amphibia with their five digits has not been discovered. However this may be, it is certain that the primitive penta-

dactyl limb is the foundation upon which all the subsequent variations have been built, but whereas in the case of some animals the later modifications have rendered the limb almost unrecognisable, *e.g.* the single toe of the horse or the wing of a bird, in man and the apes the primitive type has been retained with surprisingly little change, so that it becomes possible to draw up a comparative table of the bones of, say, the tortoise and those of the human foot (Fig. 1). This point has a further significance in that excessive differentiation and specialisation render an animal insufficiently plastic to respond to the changes in its environment, and it is perhaps due to the lack of specialisation and retention of plasticity in his limbs that man owed his ability to turn his subsequent mental development to such good account.

Man's Ancestry

The facts of anatomy, and especially of embryology, undoubtedly indicate a close relationship between man and the apes, and we may therefore assume that both arose from a common stock existing sometime in the mammalian epoch. How far back we have to travel to find this common stock is not known with accuracy. Some would place the divergence of the human from the ape stem in the Miocene period, perhaps 20,000,000 years ago, and of the apes from the monkeys in the Oligocene period. A study of the considerable differences between the human foot and that of the apes and monkeys, together with a knowledge of its embryology and especially of the very early indications of the development of an arch, has led the author to believe that the separation of the humanoid stock from the apes must have occurred at a very early period and might tempt one to place the demarcation even farther back than is usually accepted. However this may be, it appears likely that our ancestry at this time was represented by certain

quite small animals leading an arboreal existence. Perhaps the nearest approach among present-day animals to such a creature is in the case of the lemurs, and it is therefore of some interest to know that not only do the lemurs resemble mankind very closely in certain embryological features, but that in the development of the great toe they more closely simulate man than any of the monkeys or apes. It is to be noted, however, that Professor Le Gros Clark, in his informative *Early Forerunners of Man*, brings forward evidence to show that while the lemurs must be included in the primates, they differentiated independently of the other primates, so that it is impossible to postulate a lemuroid phase in the ancestry of the higher primates, including man. He also suggests that the human phylum became differentiated from the anthropoid ape phylum at an earlier age than is generally conceded, even when the common ancestor was not much larger than the present day gibbon. This idea would certainly fit in well with the deductions we have already drawn as to the evolution of the human foot.

From an intensive study of the human hand and foot as compared with those of the apes and monkeys, Wood Jones has shown very convincingly that mankind had no direct four-footed ancestry, but that the stock from which he diverged was from the first arboreal. This would agree with the above suggestions, but it seems assured that the humanoid stock at a very early period returned to the ground after already having learnt the elements of an upright progression during their arboreal apprenticeship.

Whether this change in the mode of life was enforced upon the animal by its increasing bulk and weight, as appears to be the case with the present day anthropoids, is not known with certainty, but the relative proportions of the tarsal and metatarsal segments of the foot would seem to imply that man became one of the giant apes at an early stage, an idea that finds some support in fossil remains.

It may be assumed, therefore, that the foot became adapted for its present purposes at a very early date in the rise of the humanoid stock, and the emancipation of the hand thus brought about, by enabling it to form unrestricted " contacts "

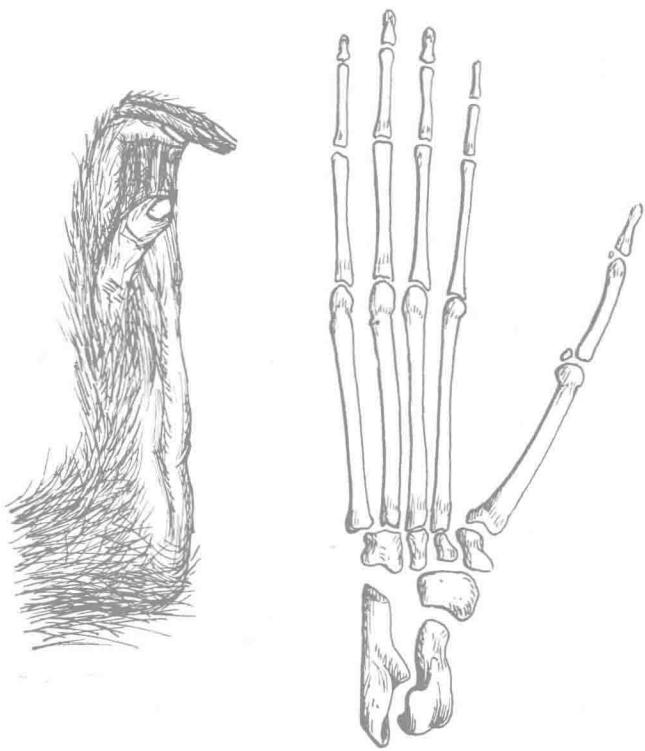

FIG. 2.—Foot of an arboreal pronograde ape with skeleton of same. Note the preponderance of the digital elements and the comparative insignificance of the tarsal bones.

with its environment, undoubtedly had a most important educational influence upon the rapidly developing brain.

The diagram (Fig. 3) represents these ideas as to man's evolution in schematic form. Pro-anthropoid forms (dryopithecus, *i.e.* tree ape) were widely distributed in the Miocene period, but with the exception of the progenitors of man,

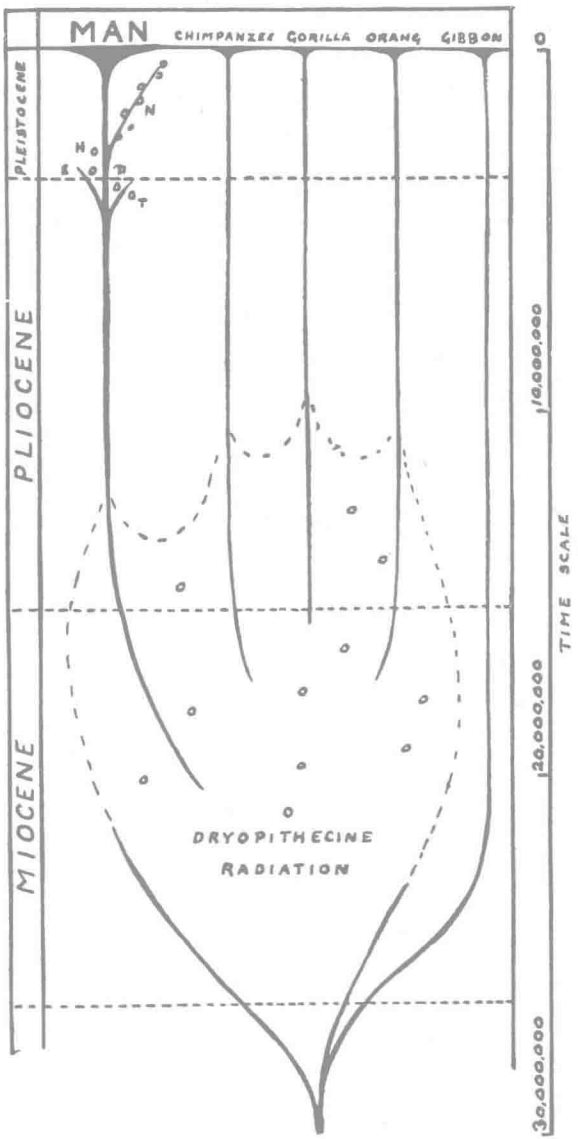

FIG. 3.—Scheme to show how the progenitors of man, the chimpanzee, the gorilla and the orang, arose from the widespread dryopithecine radiation of the Miocene period. H, Heidelberg man; N, Neanderthal man; E, Piltdown man; P, Pithecanthropus (after Morton).

the chimpanzee, the gorilla and the orang, all had disappeared before the middle of the Pliocene. Among the extinct forms are to be found apes much larger than any now existing, but from our point of view it is to be regretted that the available fossils consist mainly of jaws, with their characteristic dental pattern, and of an occasional femur. Nevertheless, by applying those changes in the feet which are known to be associated with terrestrial progression, to a generalised dryopithecine pattern, D. J. Morton has been able to picture what the hypothetical pre-human foot must have been like (Fig. 4).

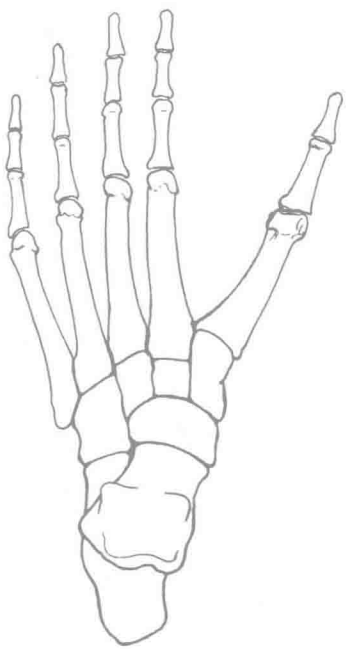

FIG. 4.—Sketch of a hypothetical pre-human foot, indicating terrestrial modifications affecting a dryopithecine pattern, similar to those which distinguish the foot of the gorilla from that of the chimpanzee (after Morton).

As will be seen, his model indicates a fairly large great toe which is still separated by a wide gap from the rest of the foot ; the lateral toes are shortening and their axes have twisted so that they now face the ground instead of being directed somewhat inwards as they are in the lower forms. The functional axis of the foot, that is, the plane in which movements occur at the ankle joint (obtained from the direction of the articular surface of the astragalus), passes between the first and second metatarsals, and very nearly corresponds to the plane in which the foot moves as it rises to the " take off " position.

This latter plane (leverage axis) depends upon the relative

prominence of the metatarsal heads, and, when the first is sufficiently long, passes between it and the second. The correspondence of these planes indicates, according to Morton, perfection in the adaptation of the foot for terrestrial progression, and is ultimately achieved in the human foot. He believes that this pre-human form of foot was a flexible and very muscular grasping organ having a moderate heel but without any indications of an arch.

It must be emphasised that this construction is hypothetical only, but is founded upon sound analogical evidence.

In the absence of any precise knowledge of man's direct ancestry it becomes necessary to draw deductions from a consideration of the comparative anatomy and physiology of present-day apes and of the indications to be obtained from a study of human embryology. It must never be overlooked that such deductions are subject to error and will depend to some extent upon the values placed on the various factors by the individual student.

Here we shall follow the account given by Sir Arthur Keith, although not of necessity committing ourselves to all the deductions which he draws; some of these are further considered in other chapters.

Pronograde and Orthograde Types of Foot

In general the primates, as far as the feet are concerned, may be divided into two main groups, the pronograde and the orthograde. In the former all four limbs are adapted for climbing and prehension, while in the latter certain modifications are seen in the hind limb which adapt it for progression on the ground, albeit such "walking" is at best a clumsy and hesitant shuffle. In the pronograde animal the bough is grasped between the first toe on the one side and the outer four toes on the other; the posterior tarsal section is freely movable on the anterior and the

poorly developed heel is normally kept raised and carries none of the weight (Fig. 5).

In the orthograde ape the ability of "opposing" the great toe to the others is becoming lost and this digit falls more and more into alignment with the others; the heel is kept applied to the ground, although it rarely bears much of the weight, and many of the muscles which formerly served prehension and the suspension of the heel become secondarily converted to stabilisers of the foot and especially of the great toe. This change is brought about by a stiffening of the tarsal joints and by a modification of the strength and attachments of certain muscles which we can now examine in greater detail.

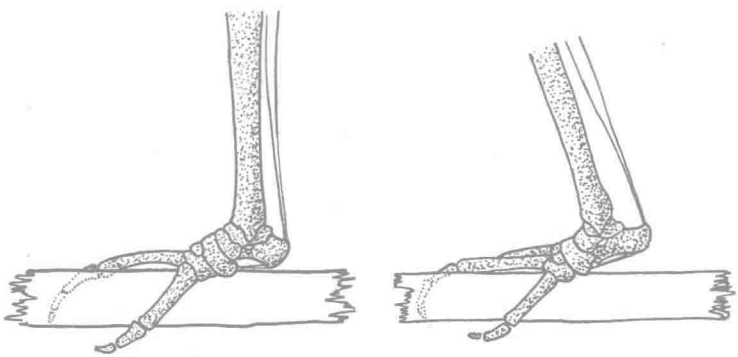

FIG. 5.—The grasping foot of two different types of ape. On the left an orthograde, the Gibbon, and on the right a pronograde type, Semnopithecus. Note the continuity of the plantaris and the plantar fascia (after Keith).

MUSCULAR EVOLUTIONARY CHANGES

The plantaris in the pronograde animal passes over the heel to combine with and help form the plantar fascia, but with the increasing prominence of the heel in the higher apes the tendon becomes attached thereto and so is severed from the plantar fascia. In some of the apes, *e.g.* the gorilla, the muscle has subsequently disappeared altogether, in others it is

inconstant, but in man it is almost always present, acting as an adjuvans to the other calf muscles. The tibialis anticus

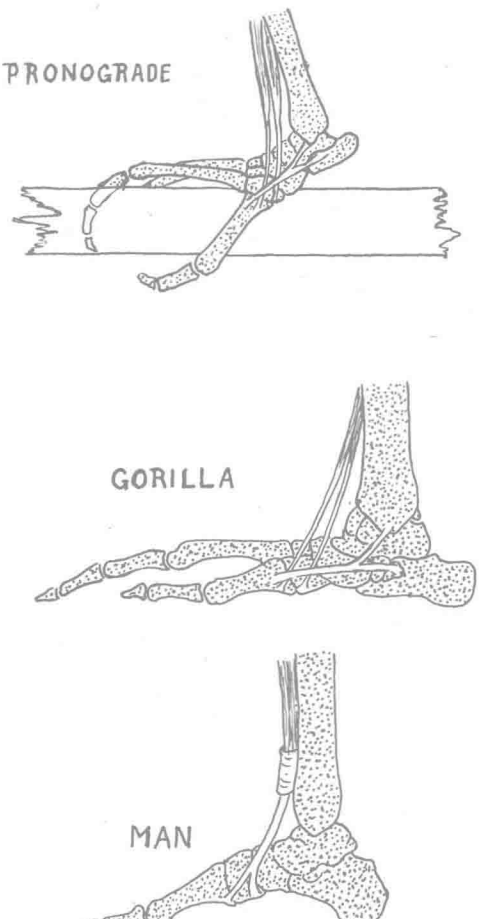

FIG. 6.—Division of the tibialis anticus in three types. Modifications of the internal Y-shaped ligament are also shown. Note an arch is present in man only (after Keith).

in the lower primates is a double muscle with insertions into the first metatarsal and internal cuneiform, while in the higher types there is a progressive diminution in the per-