

STRUCTURE AND FUNCTION AS SEEN IN THE FOOT

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PREFACE

IN some measure this book is supplementary to "The Principles of Anatomy as seen in the Hand." Those principles that were especially elaborated in the earlier volume have therefore been treated in less detail here, while such as are pre-eminently displayed in the structure and function of the Foot have been given more attention.

Dr. E. L. Patterson, Lecturer in Anatomy in this University, undertook the reading of the manuscript and I am deeply indebted to him for the care and patience he devoted to the task. To Dr. T. E. Barlow, Assistant Lecturer, I owe my thanks not only for access to his unpublished work on the development of the foot, but for permission to use his serial sections of human embryonic material. For all the really difficult and exacting work that goes to the making of any book I am indebted to Miss Dobson, Secretary to the Department of Anatomy.

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CONTENTS

CHAPTER	PAGE
I. INTRODUCTORY, DEALING WITH THE STUDY OF THE FOOT	I
II. THE PRINCIPLES OF TERMINOLOGY	5
III. THE HUMAN FOOT IN PHYLOGENY	11
IV. THE FOOT IN ONTOGENY	18
V. DIGITAL FORMULA	32
VI. METATARSAL FORMULA	39
VII. EXTERNAL CHARACTERS	44
VIII. THE FASCIAS	53
IX. THE BONES	66
X. THE ACCESSORY BONES	83
XI. THE SESAMOID BONES	93
XII. THE JOINTS	101
XIII. THE EXTRINSIC MUSCLES	124
XIV. THE MORPHOLOGY OF THE EXTRINSIC MUSCLES	145
XV. THE INTRINSIC MUSCLES	158
XVI. THE MORPHOLOGY OF THE INTRINSIC MUSCLES	182
XVII. THE ACTIONS OF THE MUSCLES	197
XVIII. THE MOVEMENTS OF ADDUCTION, ABDUCTION AND OPPOSITION OF DIGITS	212
XIX. THE MOVEMENTS OF FLEXION AND EXTENSION OF THE TOES	219
XX. TENDONS, TENDON SHEATHS AND BURSÆ	226
XXI. THE ARCHES OF THE FOOT	243
XXII. THE FOOT AND THE BRAIN	263
XXIII. THE SENSORY NERVES	271
XXIV. THE MOTOR NERVES	293
XXV. THE VASCULAR CHANNELS	303

CHAPTER I

INTRODUCTORY, DEALING WITH THE STUDY OF THE FOOT

For the most part we have but little pride in our feet and it is a pity that this is so. There is, no doubt, much to be said by way of justification for such an attitude and probably there are few who have any real regrets that their feet are hidden from the sight of their fellows by being encased within their boots. Our lives would not gain much in æsthetic pleasure did we all go bare-footed as do some of the happier sections of mankind, for the booted foot of the so-called higher races has a justifiably shamefaced appearance when deprived of its wonted covering. Once babyhood is passed, there is little that is particularly pleasing in the appearance of most people's feet.

It is very much the other way with our hands. Many take real delight in the appearance of their hands and find æsthetic pleasure in regarding the hands of others. All this is readily understandable when the criterion is merely one of æsthetics. But it is justifiable from no other point of view. That anyone, knowing anything about evolutionary progress or even having regard to the simplest facts concerning animal types, should praise the perfections of the human hand at the expense of the human foot is an absurdity. But regrettably, even the human anatomist is rather given to treating the foot as a sort of poor relation of the hand. He is rather apt to suggest, by his method of treating the subject, that the foot is something that should be like the hand but which, because of its lowly functions, falls short of attaining to its perfections.

Even the zoologist, whose range of the animal kingdom should permit of a wider view, has tended to convey the same idea in his schemes of classification. He has decided that the Sub-order of the Primates in which Man is included should be designated as Bimana, since it contains the animal distinguished by the possession of two hands.

That a ridiculously simple and primitive appendage such as the hand should be thus lauded is illogical. An appendage, built on the basal plan prevailing in the manus of the tortoise and singularly

like that of a lowly marsupial in its general make-up, confers no distinction on Man other than that of a priceless heritage from remote ancestors wise enough to let well alone and so refrain from converting this simple thing into something more specialised. All that can be said for Man and his hand is that he is lucky that his phylum sprang from so lowly a stock as to have possessed this precious birthright and that, having it, they did not tamper with it. But it is very different with the human foot. Man's foot is all his own. It is unlike any other foot. It is the most distinctly human part of the whole of his anatomical make-up. It is a human specialisation and, whether he be proud of it or not, it is his hall-mark and so long as Man has been Man and so long as he remains Man it is by his feet that he will be known from all other members of the animal kingdom. He may speak slightly of feet of clay and imagine his form to be divine with perhaps the exception of his feet, but with all his conceit he must not ever forget that it is, in fact, his feet that confer upon him his only real distinction and provide his only valid claim to human status.

We may, therefore, assume that we have every guarantee that the foot is a proper subject for examination for its own sake. If on occasion, during this examination, we are led farther afield, it will be because some of the principles seen in the anatomy of the foot are of more general application and are worthy of notice on this account. We will refrain from treating the foot as an imperfect hand, for to do so is destructive of all proper understanding of its structure and function; nevertheless the anatomy of the corresponding parts in the fore limb will need repeated notice. Such comparisons as are made between the two members will be limited to those that seem to be more or less instructive from a functional point of view. As an intellectual discipline in morphology, there is no doubt that the establishment of homologies between the bones, ligaments, muscles, and other constituent parts of the hand and foot is an attractive study. It is one of the most delightful bypaths of comparative anatomy and, as such, has had a wealth of patient work devoted to it. The subject is of interest to every medical student, but it is one that should not be developed with any idea that it might possibly be a fitting question by which to test the medical student's knowledge of human anatomy. For in some ways an over-developed sense of the basal unity of the structure of both hand and foot may destroy a just appreciation of the fact that

functionally the two members are so fitted for their own proper roles that fundamental dissimilarity is more evident than is any underlying likeness. As an academic study the establishment of homologies has much to recommend it : but for the man who would treat the disabilities of the human foot it is far more important that his knowledge of the part should be of that intimate kind by which each bone, ligament, joint, and muscle is known as an individual entity and not by reference to corresponding structures in other parts. The hand is the hand and the foot is the foot and no basal archetypal similarity in plan can ever make them, as functioning parts, in any way alike.

It is probably the experience of most teachers of anatomy that the student is generally better acquainted with the intimate structure of the hand than he is with that of the foot. There are many reasons, inherent in the method of study, that may account for this. But whatever the reason may be, the result of this state of affairs is the same—it becomes natural to translate into the foot those items of real knowledge that have been gained from the study of the hand. Since the action of, say, the extensors and flexors of the fingers is so readily demonstrated and appreciated, it is an easy transition to the assumption that the action of the corresponding muscles of the toes may be inferred from the knowledge gained from the dissection and examination of the hand. No such assumption could be more destructive of any proper realisation of the functions of the foot. It would be an exaggeration to say that it were better for the surgeon who would treat the disabilities of the foot had he never learned of the structure and function of the hand : but there is a very real element of truth in such an over-statement. Every detail of the structure and function of the parts of the foot must be studied and realised for its own sake ; none may be inferred justly from a study of the corresponding details in the hand. The hand is a tactile, testing, grasping organ ; the foot has long since become an organ, the functions of which are the support and propulsion of the body in bipedal orthograde progression. Although it is impossible to study the structure of the foot in an intellectual way without certain references to its homologies with the hand, no attempt is made here to undertake the task with that archetypal thoroughness that distinguishes such classics as Richard Owen's work "On the Nature of Limbs." The great Cheselden described his own work on human anatomy as being "adorned with the comparative" and

the compilers of many modern textbooks have had pride in the generally useless and commonly erroneous tags of morphology appended, by way of leaven, to the necessarily rather dull lump of description of structures as displayed in formalin-hardened cadavera. These things have their uses. They may help towards a real appreciation of the meaning of the arrangement of parts comprised within a whole. They may provide an explanation for the form, position, and even the existence of certain structures. But they must not be permitted to intrude to the extent that they provide a false security for assumptions as to function by analogy, no matter how perfect the analogy may appear to be.

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CHAPTER II

THE PRINCIPLES OF TERMINOLOGY

There is no more vexed question in anatomical literature than that of terminology and there is certainly no subject upon which agreement is less easy to come by between the clinical and the anatomical teacher, let alone the unfortunate students who try in vain to satisfy them both. Here there is no intention of adding to the confusion of a subject already confused. It is necessary only to explain the use of certain terms employed here and to call attention to some of the confusions that the student must be prepared to encounter in his more extended reading. This caution applies especially to the terms employed for position and direction, particularly when these are used in the description of parts of the limbs.

In the original B.N.A. terminology (1895), there was a special section embracing a series of terms classified as "Termini ad extremitates spectantes." In it were included the antithetic terms : Proximalis and Distalis ; Radialis and Ulnaris, and Tibialis and Fibularis. In the German revision (1931), there are included the additional terms : Volaris and Dorsalis, and Plantaris and Dorsalis.

In two of the tentative English revisions (1917 and 1928) the term "Palmaris" was suggested as a substitute for "Volaris." In the interim report (1929) and in the final revision of 1933, however, the whole of this useful section was entirely omitted. Presumably, since the Committee stated that the report contained all the terms considered necessary, this section was regarded as being superfluous. For descriptive purposes in dealing with the topography of the limbs, we are therefore confined to the use of terms no more precise than medial and lateral—when lateral is supposed to denote only the *outer* side, while medial denotes the *inner* side. Such a fashion is in itself a strange misuse of English words and it cannot be said to have added to precision in descriptive terminology. Moreover, the Committee "decided to retain the erect attitude as the basis for descriptive terms." Unfortunately, this resolve to employ terms only as they apply to the erect attitude also entails the curious convention that Man habitually stands erect with the palms of his hands directed to the front. It is owing to this ancient folly in

human anatomy that the human anatomist regards the thumb as being on the outer (lateral) side of the hand, while the corresponding digit—the big toe—is on the inner (medial) side of the foot. It is bad enough that the anatomy of the sole of the foot is often described as though the foot was normally turned upside down, the confusion is increased when everything that is on the tibial side of the foot is labelled as medial, while on the radial side of the hand it is termed lateral. It was to obviate this confusion that the B.N.A. revision introduced the terms “radialis” and “ulnaris” for the fore limb and “tibialis” and “fibularis” for the hind limb. There can be no confusion if we speak of the radial side of the hand and the tibial side of the foot. The terms “tibial” and “fibular” to represent the two sides of the whole of the lower limb and foot have been used as far as possible throughout the descriptive anatomy dealt with here.

But it is obvious that general terms that are capable of application to both limbs are much to be preferred if they are available and are at all familiar. “Proximal” and “distal” are two such terms and they are generally understood and should be included in the recognised scheme of the terminology of the limbs. “Plantar” and “dorsal,” and “Palmar” and “dorsal” are also in common usage and the B.N.A. substitution of “volar” for “palmar” as applied to the hand has nothing to recommend it.

For both extremities the ideal terminology is to consider the limb as having a central axis and a pre-axial margin and a post-axial margin (see Fig. 1). The nomenclature committee stigmatised terms that are “equally applicable to the erect attitude, the fœtus in utero, and the pronograde vertebrate,” because they have “created many difficulties and do not commend themselves to the Committee.” Far from creating difficulties, many of these terms are essential for clarity in description. That some of them, such as pre-axial and post-axial, are unfamiliar to medical students is the fault of the teacher, for the realisation of the pre-axial and post-axial aspects is essential in understanding the order of cutaneous nerve distribution in the limbs. If the student appreciated the fact that the cephalic vein in its whole extent indicates fairly well the pre-axial margin of the fore limb, while the internal saphenous vein does the same for the hind limb, he would have little difficulty in accustoming himself to a more scientific attitude than that in which he is at present left, wondering why the action of abducting the thumb carries it to

the lateral side, whereas abduction of the big toe implies moving it to the medial side. If we say that abducting the thumb carries it in a radial direction and abduction of the big toe moves it to the tibial side, there can be no ambiguity. But if we say that abduction of the first digit of manus and pes implies movement in a pre-axial direction, the statement is still more precise and is of universal application. Here, since they are not terms familiar to medical students, they are introduced only on occasion, but it is to be hoped that their employment even to this limited extent will assist, rather

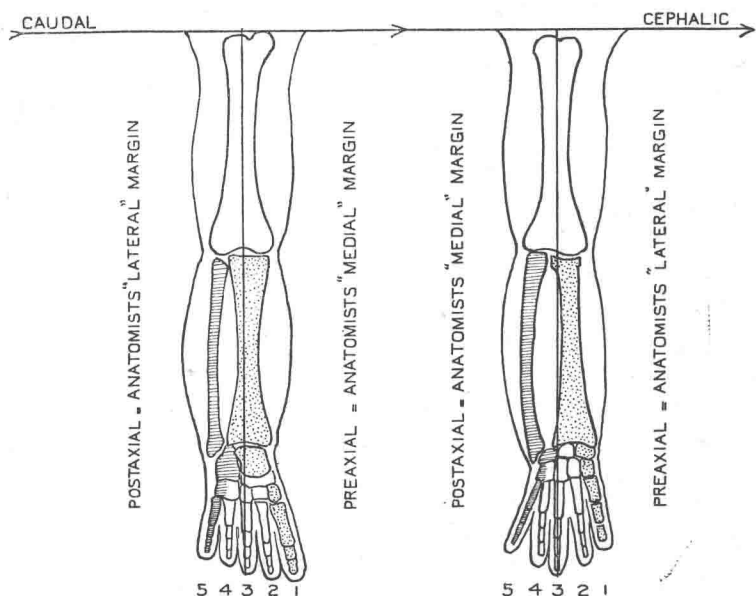


FIG. 1.—The limbs of the right side to show the homologies of the parts as a guide to nomenclature.

than confuse, the student in his efforts to obtain a clear idea of the homologies of the limbs.

As for the terminology of movements, there is at present a deplorable lack of uniformity in usage. There is a central axis of the limb and movements of the various parts of the limb should always be described in relation to this axis: whereas movements of the whole limb should be described in relation to the median axis of the body. This rule is not internationally respected, and though the student may be familiar with a muscle that he knows as the *abductor hallucis*, because it draws the big toe from the middle line of the

foot, he must be prepared to recognise the same muscle under the name *adductor hallucis* in continental literature, since by some anatomists it is so named because it draws the big toe towards the middle line of the body.

Here, then, we will adhere to a terminology that recognises that the limb has a central axis and pre-axial and post-axial margins ; that it has proximal and distal extremities and that the foot has dorsal and plantar surfaces. Bending the fingers and the hand itself in a palmar direction is universally known as flexion. Bending the toes in a plantar direction is also universally recognised as the act of flexion. But, unfortunately, bending the foot in a plantar direction is, by some anatomists, known as extension and bending it in a dorsal direction at the ankle joint, flexion. The student, if he extends the scope of his reading, must therefore be prepared for the usage that describes the muscles centred on the *tendo calcaneus* as the extensors of the foot at the ankle joint. Since the movements of the digits are so definitely similar in hand and foot there can be no sort of justification for designating the corresponding movements of the hand and foot themselves by antithetic terms. Flexion of the ankle joint is the action of moving the foot in a plantar direction, and it would be far better to adhere to this usage than to resort to the unsatisfactory compromise effected by speaking of plantar-flexion and dorsi-flexion. We may lay down some principles regarding the terminology of aspect and direction in the limbs, since these things are not dealt with as entities in the latest revision of the B.N.A. : but the time has passed when it is permitted to indulge in reflections on the method of naming individual structures. Nevertheless, there are some general principles that may be discussed without creating any suspicion that further attempts are being made to disturb well-established, even if not ideal, usage in nomenclature.

It may be said that anatomists have no system of nomenclature, no recognised criteria by which names should be bestowed or retained. There was a time when numerical systems were much in vogue and structures were designated, wherever possible, by numbers according to their numerical position in the group to which they were assigned. Save in the case of the ventricles of the brain (where it is especially misleading), some serial structures (where it is unavoidable) and the cranial nerves, this system of nomenclature is no longer in general use. In giving a name to a structure such as a muscle that does something, has definite topographical relations and per-

haps a characteristic form, it is conceivable that any of these things might be employed as a criterion in systematic nomenclature. All these factors have from time to time served as a basis upon which to assign a name to any individual muscle. In this way the same muscle has been named by different anatomists and at different times, as *quatuor radium peculiariter agentium secundus* and as *octavus manus exterior musculus*, according to its numerical order in the particular group to which the author fancied it to be most properly assigned. At a later period, this same muscle has been known as the supinator, since it was mistakenly supposed to effect the movement of supination of the forearm. Again, it has been and is at present known as the brachio-radialis because of its topographical position and attachments or as supinator longus because it is an elongated muscle in distinction to the shorter muscle that was supposed to be its functional partner. Most structures have passed through some such transition in nomenclature and the anatomist has unfortunately never been able to decide as to the criterion, topographical, functional, morphological, or descriptive that he is to accept as his guiding principle in nomenclature. The cuneiform bones have suffered in this way since, as they form a series of three elements, they have been named both in order of position and in order of size by different writers. Thus the middle cuneiform of one osteologist is the bone intermediate in size, whereas the middle cuneiform of some other writer is the one that is central in position and these two criteria, of course, apply to two different bones in the series and the medial cuneiform of modern terminology is not either of them.

Not only has the anatomist no settled criteria for guidance in nomenclature ; he has not even availed himself of the sheet anchor of the taxonomist and recognised the claims of priority in the bestowal of accepted names. It is obvious that a scheme of anatomical nomenclature that could be extended from human to comparative anatomy would be the ideal one, for under such a system any structure would be appropriately known by the same name in any animal. Herein lies the snare in naming structures from the shape they happen to assume in the human body. Should the name implying shape prove to be inappropriate when reference is made to the common mammalian form, there is little to be gained by changing the name unless the substitute is of more universal application. It is, for instance, a little difficult to see what is gained

by changing such well-known Lyserian names as "trapezium" and "trapezoid" into "os multangulum majus and minus" or "unciform" into "os hamatum." It is vain to hope that, since there is a recognised terminology for the bones of the carpus and tarsus that applies to all animals, we shall some day employ the only rational system of nomenclature for these things.

Again, nomenclature based on assumed function is liable to mislead when the original assignment of the name was made on an insufficient understanding of function. Although the term "opposition" has been very much misused in describing the movements of certain digits, no one could suppose that the muscle named "opponens digiti minimi" was capable of producing any such movement. In cases where departure is made from the terminology of the English B.N.A. 1933 revision, note is made of the fact and reasons for the departure are stated.

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CHAPTER III

THE HUMAN FOOT IN PHYLOGENY

The phylogenetic story of the human foot has of necessity become so hopelessly involved with the question of the origin of Man himself that most of the literature concerning it has become coloured by the contending theories regarding the larger issue. Briefly, there are those who, following the immediate post-Darwinian teaching as it was enunciated by Huxley, regard Man as being descended from the Anthropoid Ape stock and in particular from some member of that stock sufficiently like the Gorilla to warrant the use of the term "gorilloid." Such a belief was implicit in the writings of most anatomists half a century ago. But there are others who, though freely admitting the anatomical resemblances between Man and the great apes in general and, in certain special features, between Man and the Gorilla in particular, do not regard Man as being an end product of the Anthropoid Ape stem, but postulate that the human stock and the stock of the great apes branched off from an earlier common Primate stem.

Those who look upon Man as being derived from a "gorilloid" stock see human foot structures as being direct developments from those present in the Gorilla. Those who derive Man from an earlier stock, from which the giant apes also arose, see, in the Gorilla foot, an inception of some of those specialisations already achieved in Man.

These two points of view agree in realising that the specialisations of both Gorilla and human feet are the outcome of a change from arboreal to terrestrial life; but whereas the one view regards the "gorilloid" ape as being the pioneer in this enterprise, the other pictures Man as having embarked on the business in very distant Primate days and the Gorilla as having taken to it all too late to make a real anatomical success of it. Upholders of this last thesis therefore regard the foot changes present in the living Gorilla as being, so far as they go, parallel developments to those existing in Man, called forth in the giant ape in response to the same functional demands as those that had evoked them in Man.

So much has been written on this subject that here it will be enough to give only a very brief résumé of the question and, as far

as possible, in making such a summary, to avoid unnecessary controversial matter.

The so-called "gorilloid" theory has been very strongly advocated by W. K. Gregory (1916, etc.), by D. J. Morton (1922, etc.), and by Adolph H. Schultz (1924, etc.), and others in America. The use of the term "gorilloid" by the advocates of this thesis is unfortunate, for though the term might be supposed to denote an animal like a Gorilla, it cannot be said that the creatures pictured by all the supporters of this view appear to be identical. Morton (1924), for instance, sees the animal in which human foot structures were initiated as a "relatively small-sized," "active and agile" Primate, with "arms and legs of equal length or nearly so" and with the "erect posture habitual." Such an animal would appear to be so very unlike a Gorilla that, unless the term "gorilloid" is unduly elastic in its connotation, it would seem wrongly bestowed. Gregory, on the other hand, would seem to have in mind some animal far more like the living Gorilla. All his writings seem to show that the foot from which he derives the foot of man is very akin to that of the existing animal: and in the process of conversion of the one into the other, he sees no difficulty whatever. His recipe (1916) is as follows: "In order to transform a gorilla-like foot into a human foot it is chiefly necessary (*a*) to increase the length of the hallux; (*b*) to adduct it, and rotate it on its own axis so that its plantar surface shall be applied to the ground instead of facing towards the other digits. (*c*) Next it would be necessary to shorten still further the phalanges; and (*d*) to narrow the whole foot, that is, to make all the digits parallel instead of divergent. (*e*) The tuber calcis and cuboid must be enlarged; and (*f*) the whole foot must be "pronated" or made to face downwards rather than inward. As a result, (*g*) the trochlea of the astragalus is made more symmetrical, deeper on the tibial malleolar facet, (*h*) the head of the astragalus is widened. Those who lose sight of the fundamental principle of the change of function . . . will hardly realise that by the foregoing relatively slight morphological changes a gorilloid type of foot could be easily made over for service on the ground." I think it is not unfair to add that neither will those who do keep constantly in mind the fundamental principle of the change of function readily appreciate the simplicity of the process. As Gerrit Miller (1920) observes concerning Gregory's recipe for the conversion: "He offers no suggestion as to the manner in which an

arboreal foot like that of a great ape could be so used on a flat surface as to stimulate or even to permit the process of carrying out such an evolution."

If the human foot were, in fact, to be derived from a foot like that possessed by any of the living anthropoids, it would seem that the Gorilla has slender claims for special selection. The Gorilla has evidently been forced into leading a more or less terrestrial life because its bulk when adult is too great to permit it to live as a truly arboreal animal. But before the change in habit took place, it had perfected a very efficient grasping foot. Although it has taken to a partly terrestrial life it has never succeeded in attaining to orthograde bipedal progression. No matter how much its admirers may praise its attempts at walking upright, the Gorilla remains a thoroughly quadrupedal mammal when walking on the ground. Moreover it is a quadrupedal mammal that is only able to secure any stability, when placing its weight upon its grasping hind foot, by spreading its big toe as widely from the axis of its foot as possible. This action is, of course, the very antithesis of anything likely to lead to the human specific character of the completely adducted hallux, or indeed to initiate any of the changes postulated by Gregory (see Fig. 2). Possibly enthusiasm for the "gorilloid" origin of human foot characters would not have been so long sustained had it not been for the disastrous introduction (1923) of the "highland" gorilla. Accounts of the foot of this animal—known as *Gorilla beringei*—have been given as confirmation of their opinions regarding the origin of the human foot by Gregory (1934, etc.), Schultz (1925, etc.), Morton



FIG. 2.—An anthropoid ape supporting itself in an erect posture by holding to a pole. Its left foot is in its primitive grasping position; its right foot, supporting part of its weight, shows the wide abduction of the hallux rendered necessary by this action. (From a photograph by Underwood and Underwood, reproduced by Miller, 1920.)