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THE
SENSE OF TOUCH
IN MAMMALS AND BIRDS/

WITH SPECIAL REFERENCE TO THE
PAPILLARY RIDGES

BY
WALTER KIDD, M.D., F.Z.S.

AUTHOR OF "USE-INHERITANCE," AND "THE DIRECTION
OF HAIR IN ANIMALS AND MAN"

WITH 164 ILLUSTRATIONS FROM
DRAWINGS AND MICRO-PHOTOGRAPHS

LONDON

ADAM AND CHARLES BLACK

1907

PREFACE

THE following contribution to the study of the sense of touch in Mammals and Birds is based upon certain papers and exhibitions of specimens communicated to the Zoological Society of London, the Anatomical Society of Great Britain and Ireland, and the *Journal of Anatomy and Physiology*. The chief of these was read before the Zoological Society, but was not published in the *Transactions*. Two very extensive and important papers, one by Miss Inez L. Whipple, and another by Prof. O. Schlaginhaufen, had been published a very short time before my paper was read, and as these covered much the same ground, and as, not knowing of their existence, I had not discussed them, its publication became impossible without very great alterations and additions. It seemed better, therefore, to incorporate it with certain other microscopical studies of the skin-structures of the hand and foot in mammals, and make it a small introduction or anatomical basis for the consideration of the sense of touch.

I have to thank the Editors of the *Journal of Anatomy and Physiology* for permission to reproduce certain illustrations, and the Prosector of the Zoological Society's Gardens for a large series of hands and feet of Mammals and feet of Birds, which were placed at my disposal for study. I also wish to thank Mr. R. I. Pocock for assistance he has given me, and for some valuable impressions taken from dead specimens of Anthropoid Apes, without which my series of impressions would have been incomplete.

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INTRODUCTION

THE sense of touch in the lower animals might be held to include an extremely wide range, and could not be fairly limited to mammals and birds if it were not that the most important part of the subject centres round this sense as found in the hand and foot. Its present consideration has, therefore, special reference to the papillary ridges and papillæ of the corium; and this alone affords a wide enough area of investigation, considering the very large number of mammals in which these structures are present. Such varied developments of the sense of touch, as are seen in the surface of the tongue, in tactile hairs, especially the vibrissæ on the muzzles of felidæ, the antennæ and tactile hairs of insects, the highly sensitive vascular snouts of moles, the delicate vibrissæ of the snouts and the tactile organs of the wing-membranes and ear-conchs of bats, in whom the sense of touch seems to be developed almost to perfection—these, to take a few of the striking adaptations among animals for the sense of touch, are examples of a different kind and are not included in this study.

It is clear that the sense of touch is a very important element in the complex life of man, and, from the time of Weber, it has been studied on experimental lines with valuable results. These will be referred to in their own place under the physiological section of the subject. But it is necessary to state that the method of treatment of the sense of touch here pursued is exclusively anatomical. Certain experiments have been made by biologists on this sense in the lower animals, notably those of Spallanzani in 1793, on the delicacy of the tactile sense of bats, in whom the sense of sight was artificially destroyed, and these yielded most interesting results. But the investigation of a sense so much dependent on direct communication between the

experimenter and the animal which is the subject of his experiments, does not well lend itself to purely physiological study. We do not know yet the language of any ape or monkey in spite of Garner's researches into the subjects in tropical forests, and though in the case of some of the domesticated animals, we might obtain some useful results, the prospects here are very limited. There is, no doubt, a field of this nature to be worked by the physiologist; and it is with a view to providing some anatomical materials for the study of the sense of touch in the lower animal that this work has been undertaken. The facts here described are purely anatomical, and no disrespect to the great department of biology, called physiology, should be supposed, because a physiological subject is treated upon anatomical lines. The two departments of biology, anatomy and physiology, are only to be studied apart from one another because of the growing complexity of the physiological side, and the slowly increasing knowledge of anatomy, so that specialisation is necessary, but not because of their essential difference.

In such a subject as we have before us it is legitimate to do the best one can with the material provided by Nature, and in the investigation of the palmar and plantar surfaces of many animals, there is found a very great variety of the epidermis and the corium, which demands an interpretation. The hand and foot being the most general and most important parts of the bodies of Mammals and Birds concerned in the sense of touch, these parts deserve particular examination.

The methods pursued concern two orders of phenomena, the macroscopical and the microscopical modifications of the skin. The former chiefly deals with the description and illustrations of the papillary ridges found on the palmar and plantar surfaces of eighty-six Mammals, and these ridges are shown in drawings taken from the species examined.

A short, general description of the character of the surface of the palmar and plantar skin in all the species is also given, not only in those which present papillary ridges, but in others, such as Marsupials, Rodents, Carnivores and Insectivores, in which papillary ridges are seldom to be found. This examination

shows that there are numerous modifications of the epidermis, and it would appear that some of these are premonitory of the development of the papillary ridges in higher zoological groups. The greater part of the macroscopical branch of the subject consists of detailed description and illustrations of the papillary ridges. The microscopical portion is also shortly described and much illustrated by photomicrographs and drawings from sections of the skin. For this purpose nearly all the specimens have been hardened in alcohol, a few in other preservative fluids, and, in most cases, many sections from each species and from all the main regions of the hand and foot have been made. In all of them careful note has been kept of the position and direction of the sections, so that each illustration may be considered to be correctly "orientated." The more minute microscopical details of the skin have not been attempted, methods of staining so as to bring out the nerve-endings and nerve fibrils being not necessary for the purpose in view, which is to show the outlines in a large number of animal forms of the surface of the epidermis and of the papillary layer of the corium. Nearly eight hundred sections in all have been made, and eighty-six species of Mammals and Birds have been examined macroscopically, and, in most cases, also microscopically. The Birds have been taken out of their zoological order, and as being much fewer and of less importance to the subject than Mammals :

The following have been examined :

Monotremes.

Ornithorhynchus anatinus.

Echidna hystrix.

Marsupials.

Didelphys azaræ.

Thylacinus cynocephalus.

Petaurus sciurus.

Potorous tridactylus.

Æpyprymnus rufescens.

Petrogale penicillata.

Macropus antilopinus.

Macropus derbianus.

Edentates.

Myrmecophaga jubata.

Ungulates.

Hyrax capensis.

Rodents.

Sciurus vulgaris.

Sciurus cinereus.

Sciurus prevosti.

Xerus capensis.

Arctomys marmotta.

Gerbillus (tripoli.)

Arvicola amphibius.

Mus decumanus.

Mus musculus.

Myopotamus coypu.

Erethizon dorsatus.

Hystrix cristata.

Cælogenys paca.

Hydrochærus capybara.

Lepus cuniculus.

Carnivores.

Felis leo (born dead).

Felis domestica.

Viverra civetta.

Genetta tigrina.

Arctigolidia trivergata.

Herpestes griseus.

Crossarchus fasciatus.

Suricata tetradactyla.

Proteles cristatus.

Canis familiaris (Dachshund, Great Dane).

Ursus Americanus.

Procyon lotor.

Procyon cancrivorus.

Cerculeptes caudivolvulus.

Lutra vulgaris.

Mellivora indica.

Mustela vulgaris.

Mustela erminea.

Otaria pusilla.

Insectivores.

Erinaceus europæus.

Talpa europæa.

Chiroptera.

Pteropus medius.

Primates.

Lemur brunneus.
Lemur rufifrons.
Lemur catta.
Lemur mungoz.
Galago crassicaudata.
Nycticebus tardigradus.
Nycticebus javanicus.
Hapale jacchus.
Midas ursulus.
Chrysothrix sciurea.
Cebus fatuellus.
Papio hamadryas.
Papio porcarius.
Papio babouini.
Papio mormon.
Cynopithecus niger.
Macacus inuus.
Macacus nemistrinus.
Macacus cynomologus.
Macacus silenus.
Macacus pileatus.
Cercopithecus æthiops.
Cercopithecus collaris.
Cercopithecus hagenbecki.
Cercopithecus patas.
Cercopithecus lalandi.
Cercopithecus callitrichus.
Cercopithecus diana.
Cercopithecus campbelli.
Cercopithecus cynosurus.
Hylobates hainanus.
Hylobates lar.
Hylobates hoolock.
Simia satyrus.
Gorilla savagei.
Anthropopithecus troglodytes.
Man.

Birds.

Apteryx mantelli.
Rhea Americana.
Fulica atra.
Perdix cinerea.
Lagopus.
Ciconia alba.

Ardea egretta.

Aquila audax.

Falco subtutes.

Tinnunculus alaudarius or *Falco tinnunculus.*

Corvus corax.

The terminology employed in the following descriptions of the macroscopical and microscopical studies of palmar and plantar skin will most easily be explained by the accompanying simple diagrams. These represent the hand and foot of an Azara's opossum which is a Mammal low in ordinal rank though relatively high in intelligence and activity of habits. It possesses a development of the leading structures of the hand and foot which may well serve as a type for the study of higher Mammals. Certain terms employed by Miss Whipple in her exhaustive memoir* referred to elsewhere will be used as affording intelligible and unobjectionable descriptions of the parts of the hand and foot.

Fig. 1 represents the hand and Fig. 2 the foot of a simple and typical Mammal. The digits on each are called, D. 1, 2, 3, 4, 5, beginning with the thumb, or pollex, of the hand and the great toe, or hallux, of the foot. The terms ulnar and radial are used to indicate the outer and inner border respectively of the hand, and fibular and tibial to indicate the outer and inner borders of the foot. The expression "outer" and "inner" are here used for convenience of description though not properly applicable to the hand and foot of Man who forms an exception to all lower Mammals, for in Man, the radial is the outer and the ulnar the inner border of the hand in his usual upright position with the palm of the hand directed forwards. However, with this exception no mistake need be made in the use of these two common terms. In Man as well as the lower Mammals the terms, fibular and outer and tibial and inner, applied to the foot always correspond to one another. Miss Whipple usefully divides the pads or eminences of the ventral surfaces of the Mammalian hand and foot into three groups which she illustrates in the case of *Microtus*

* "The Ventral Surface of the Mammalian Chiridium." Inez L. Whipple, 1904.

agrestis (Field Mouse). These she calls, *Apical*, *Interdigital* and *Proximal*.

In Figs. 1 and 2 they are marked as follows :

A. *Apical* of which there are five.

I. *Interdigital* of which there are four.

P.P. *Proximal* of which there are two.

FIG. 1.—DIAGRAM OF TOPOGRAPHY OF MANUS. (*Azara's Opossum.*)

These eleven primary pads are very general in the Mammalian hand and foot, and are rightly looked upon by Dr. Wilder and Miss Whipple as essentially *walking-pads*. They are found as low down in the Mammalian series as Marsupials and in forms which do not employ the hand and foot for prehension. These pads situated on the tips of the digits, interdigital spaces, and proximal portion of the hand and foot are of great value to the animal possessing them, on account of their "buffer" action.

The meaning of the patterns of ridges found on them is a different question. Certain other regions, such as the phalangeal joints, show pads in some animals which Miss Whipple calls secondary. Only two other terms require notice, the thenar and hypothenar

FIG. 2.—DIAGRAM OF TOPOGRAPHY OF PES. (*Azara's Opossum*.)

regions of the hand, corresponding to the eminences at the bases of the first and fifth digits of the hand.

It is very interesting to note the value of this grouping of the apical and interdigital pads. The latter do not lie in the same axis as the former, by which arrangement a large surface between the digits would be left without a specially tactile area, but they lie just in those intervals between the digits which ensure that the

action of the two rows of pads shall supplement one another during the various movements of the parts of the hand or foot. If the interdigital pads had been placed instead at the bases of the digits, much of their value in assisting prehension, walking, and the sense of touch would have been lost.

The terms employed in the microscopical section are simple and few and only such as are found in the usual anatomical descriptions of the skin. Figs. 52, 53 will be more particularly referred to in their proper place, and the terminology of the parts given.

PART I
MACROSCOPICAL

CHAPTER I

CHIEF MODIFICATIONS OF THE EPIDERMIS OF THE PALMAR AND PLANTAR SURFACES

GREAT diversities of epidermic structure are found on the ventral surfaces of the hand and foot of different mammals when these are examined either with the naked eye or a lens. The coarse arrangement of the epidermis here referred to needs a short notice before the more specialised groupings of it are described.

The eighty-six species of mammals and eleven of birds under consideration present all the chief forms of epidermic modification, and these may be divided into eleven types, seven of which are leading types and four mixed, as follows :

- (1) Smooth epidermis.
- (2) Corrugated epidermis.
- (3) Scales.
- (4) Nodules.
- (5) Hair.
- (6) Rods.
- (7) Papillary ridges.

The mixed types are :

- A. Epidermis more or less corrugated, with coarse transverse ridges on the digits.
- B. Corrugated epidermis with papillary ridges.
- C. Nodules with papillary ridges.
- D. Hair with coarse transverse ridges and smooth pads.

(1) *Smooth epidermis* is only found in one of the eighty-six mammals examined, the Earth Wolf of the Cape, *Proteles cristatus*.

(2) *Corrugated epidermis* is found in sixteen forms, and the

degree of corrugation which may be found with the smoother form varies greatly. It has seemed simpler to place the bare and corrugated epidermis in separate classes, though gradual transitions between smooth and very corrugated surfaces are found among these sixteen forms, and even in the same form. According to the size and habits of the particular animal, the epidermis is very differently modified. Thus, the smooth, hard, almost shining pads of *Proteles cristatus*, the Earth Wolf of the Cape, a clumsy, nocturnal burrowing animal like a hyæna, show the epidermis of its hand and foot little modified, as one might expect from its habits. Then *Echidna hystrix*, one of the egg-laying mammals of Australia, has a hard, slightly corrugated epidermis in which are set sparse strong hairs, a modification in keeping with its simple burrowing habits of life and primitive character. The Carnivores which exhibit this type of epidermis show more variation in the way of corrugation, as in *Viverra civetta* and *Suricata tetradactyla*. *Hydrochærus capybara*, a large stoutly-built rodent with aquatic habits, has a large webbed foot and epidermis rough and considerably corrugated.

The species which represent this early and simple type of epidermis are, *Ornithorhynchus*, *Echidna hystrix*, *Hystrix cristatus*, *Xerus capensis*, *Cælogenys paca*, *Hydrochærus capybara*, *Viverra civetta*, *Arctigolidia trivergata*, *Genetta tigrina*, *Crossarchus fasciatus*, *Suricata tetradactyla*, *Mellivora indica*, *Herpestes griseus*, *Procyon lotor*, *Procyon cancrivorus*, *Hyrax capensis*.

(3) *Scales* are among the early modifications of the epidermis, and occur in nine of the eighty-six mammals examined. They are found in five of the Marsupials, one Edentate, one Rodent, one Insectivore, one Bat. The Coarsest of these forms is the Edentate, *Myrmecophaga jubata*, or Great Ant-Eater, which has extremely clumsy fore and hind feet covered with dense epidermis modified into flat scales. These scales are not placed in any definite lines or order, as those of the Marsupials are in some cases. The scales of the common English mole are relatively large and very strong, especially in the forefoot, which

is so much used for digging. Scales are said by a recent writer * to be the earliest condition of which papillary ridges in the Primates are the final development. The species which present scales are *Potorous tridactylus*, *Petrogale penicillata*, *Macropus antilopinus*, *Macropus derbianus*, *Epyprymus rufescens*, *Myrmecophaga jubata*, *Talpa europæa*, *Pteropus medius*, *Myopotamus coypu*.

(4) *Nodules* have been only found alone in one species, the Canadian Tree Porcupine, *Erethizon dorsatus*. The epidermis is in this form modified into very well-defined rounded nodules, which cluster closely over all the palmar and plantar surfaces, the tips of the digits being somewhat corrugated, but without nodules. The modification in this species is very remarkable, and presents an efficient series of closely-set buffers on the more prominent parts of the hand and foot. It may be noted that the Canadian Tree Porcupine also has a powerful prehensile tail on which there is little hair on the distal portion, and it is here covered all round with ridges similar to those found on the Primates, but still more resembling those on the flexor surface of the tails of American opossums.

(5) *Hair*.—One species only has been found covered entirely with hair, the Rabbit, *Lepus cuniculus*. This peculiarity seems to be characteristic of the Leporidae. It furnishes a most efficient method of protection for the footpads, and the rod-like extensions of the epidermis among which the hairs are densely set, serve to conduct sensations to the deeper layer of the skin much in the same way as tactile hairs of other regions.

(6) *Rods*.—This arrangement of the epidermis resembles thick, close and short bristles extending from the corium, and is best exhibited in the coarser pads of the large Carnivores. A typical example of this may be seen in the great footpads of the Great Dane. It affords a good protection to the softer parts of the feet in rapid progression over rough ground. The species in which these bundles of rods compose the pads are *Thylacinus cynocephalus*, *Canis familiaris* (Dachshund and Great Dane), *Felis leo*, *Felis domestica*, *Ursus Americanus*.

* Miss Whipple.

It may be noted that all these belong to the order of Carnivores except the Tasmanian wolf, a marsupial with many features resembling the Carnivores.

(7) *Papillary ridges* only reach their full development in the Primates, and thirty species of these have been examined, in which the whole of the palmar and plantar surfaces are covered with ridges and their intervening furrows. The thirty species are: *Hapale jacchus*, *Midas ursulus*, *Papio mormon*, *Papio cynocephalus*, *Papio porcarius*, *Papio hamadryas*, *Papio babouini*, *Cynopithecus niger*, *Chrysothrix sciurea*, *Cebus fatuellus*, *Macacus cynomologus*, *Macacus nemistrinus*, *Macacus pileatus*, *Macacus inuus*, *Macacus silenus*, *Cercopithecus ruber*, *Cercopithecus callitrichus*, *Cercopithecus diana*, *Cercopithecus lalandi*, *Cercopithecus campbelli*, *Cercopithecus cynosurus*, *Cercocebus aethiops*, *Cercocebus collaris*, *Cercocebus hagenbecki*, *Hylobates lar*, *Hylobates hainanus*, *Hylobates hoolock*, *Simia satyrus*, *Anthropopithecus troglodytes*, *Gorilla savagei*.

Besides these representatives of the main groups of Primates, it is probable that every species of this order, if examined, would show this particular modification of the Primates, and that it is a character of ordinal rank. Of course its highest development is found in the hand and foot of man.

Of the four mixed types A is the simplest, the epidermis being corrugated in varying degrees, and the digits furnished with coarse transverse ridges. There are four forms which present this modification: *Mus decumanus*, *Mus musculus* (the brown rat and house mouse), *Arvicola amphibius*, and *Arctomys marmotta*. No similar modification has been found outside the Rodent order.

B.—Corrugated epidermis covering the greater part of the palmar and plantar surfaces, but showing localised small groups of papillary ridges on certain of the pads (digital palmar or plantar). *Petaurus sciureus*, *Sciurus vulgaris*, *Sciurus prevosti*, *Sciurus cinereus*, *Cerculeptes caudivolvulus*, *Lutra vulgaris*, and *Erinaceus europaeus* are the forms found with this particular arrangement.

C.—Nodules associated with papillary ridges are characteristic

of the palmar and plantar surfaces of the Lemurs and Azara's opossum or *Didelphys azaræ*. In the Great Galago and the Slow Loris and Javan Loris they are less marked, papillary ridges being largely predominant. But in the four Lemurs examined nodules predominate largely on the digits, palmar and plantar surfaces, and they vary greatly in size. The larger of the nodules present fine papillary ridges, which can be seen with a lens, running in an oblique direction across them. It may be noted here, as will be seen later from another point of view, that *Lemur brunneus* shows a greater proportion of nodules than *Lemur catta*, and that this probably is associated with the higher development of the latter species. The species coming under this division are *Didelphys azaræ*, *Lemur brunneus*, *Lemur catta*, *Lemur rufifrons*, *Lemur mungoz*, *Galago crassicaudata*, *Nycticebus javanicus*, *Nycticebus tardigradus*.

D.—In certain forms a large portion of the digits, palmar and plantar surfaces are covered with hair, from which the digital, and palmar and plantar pads, and nails or claws, project. This is familiar in the case of the Domesticated Canidæ and Domestic Cat. Among other of the species here dealt with it appears in *Mustela hibernica*, *Mustela vulgaris*, *Gerbillus*.

The eleven *Birds* examined show one type only of epidermic modification, though the degree of this varies greatly. In all of these the plantar epidermis is coarsely corrugated without being formed into any well-defined ridges, and is continuous with the smoother scales which clothe the rest of the foot. Among these eleven birds *Aquila audax* shows the greatest degree of projection of the epidermis, modified on the plantar pad almost into rods like those of the Canidæ.

Apteryx mantelli, *Rhea Americana*, *Ciconia alba*, *Lagopus*, *Perdrix cinerea*, *Ardea egretta*, *Fulica atra*, *Corvus corax*, *Alcedo ispida*, *Tinnunculus alaudarius*, *Falco subtutes* are the species here examined.

CHAPTER II

DESCRIPTIONS OF THE PAPILLARY RIDGES

Range of Subject.—The observations which follow are concerned mainly with the Primates, and deal with the hand and foot equally, but the area has been extended to some lower orders of Mammals, such as an Insectivore, a Carnivore, a Rodent, and a Marsupial, in which groups interesting developments of papillary ridges are seen on the palmar and plantar surfaces. The range then of the subject is wide, extending from Marsupials through the Primates up to Man. The hand and foot of man have been only studied from the point of view of comparative anatomy, without reference to Dr. Galton's classical work on the human finger-prints, which is mainly statistical and may be of considerable biometrical importance, in addition to its value as a means of identification of individuals.

Method of Treatment.—The papillary ridges may be illustrated either by direct drawings, or by one of the various methods of printing, which are described by Dr. Galton, and these prints may be taken either from the living or the dead subject.

The method of delineation here chosen has been as follows: In the case of Man impressions have been taken with printer's ink both of the hand and foot, and from several of these belonging to the same individual a representative drawing has been made of the ridges of the hand and foot. This has been compared with the arrangements found on numerous other individuals, and has shown a resemblance to them so close that the main groups of ridges on the digits, palm and sole, here depicted may be taken to represent for the purpose in view, the normal human type. Of course, individual variations are not here dealt with as they do not come within the scope

of the present inquiry. This method is coarser than that of Dr. Galton, who reproduces the exact print from the fingertips of each person, and his line of study is intimately associated with the noting of each ridge and furrow of the part. In the case of the anthropoid apes impressions have been taken from living specimens of Chimpanzee and Gibbon, and from one of Orang and Gorilla, recently dead. In the cases of the dead, as well as the living specimens, it has been necessary to make numerous prints of each, because it is almost impossible to exhibit in one print the whole of the palmar or plantar surface, especially when the tips of the digits, and other portions of these, have to be brought into the same picture. In taking human prints it is most difficult to obtain a whole picture of hand or foot on account of the blurring of the ink which occurs in one part while pressure is being made in another. Considering this, it is not surprising that impressions from living anthropoid apes are difficult to make, many prints of each being required, and that with monkeys, which are still more restless and timid, it is impossible. From the numerous prints taken of each specimen a composite picture has been produced, showing the whole area on which papillary ridges are found. Among Monkeys, Rodents, Insectivores and Marsupials dead specimens only have been used. From the smaller of these, whose hands and feet are too small to print successfully, drawings have been made directly, with the help of a lens. In the greater number of the monkeys many impressions have been taken of the dead subject, and the drawings made from these, and verified by reference to the specimens, and on each of the illustrations given a note is made as to the particular method adopted in each case. By thus using impressions from living and dead specimens in all the more important cases, and by making drawings from these with reference to the specimens, it has been possible to avoid the suggestion of Dr. Hepburn* as to the drawings of Alix that they appear to be rather "interpretations" than drawings.

* *Op. cit.*

DESCRIPTION OF THE PAPILLARY RIDGES AND GENERAL
MODES OF ARRANGEMENT

The ridges and adjoining furrows which cover the palmar and plantar surfaces of all Primates and a few lower forms in a smaller degree, may be compared to the ridges of a ploughed field, over which some such object as a light roller has been passed, the effect of this being to produce a series of ridges with flattened tops. This can be well seen with a lens when the ridges are examined in profile, and is their normal condition in man and the lower animals in nearly all the palmar, plantar and digital regions. Thus the angles at which each ridge rises out of its adjoining furrows are the same on both sides, but it has been shown that there is a departure from this normal shape of the ridges in certain regions of the hand and foot of man, and occasionally in certain other Primates. This change of shape I have called *Imbrication of the Papillary ridges*, and it will be more fully described in the microscopical portion.

The surfaces of the ridges show the openings of sudoriparous glands which are plentiful wherever ridges are found. Microscopically the ridges show abundant papillæ with tactile corpuscles, and these as well as the sudoriparous glands are absent from the furrows between the ridges.

The modes of arrangement of the ridges are extremely different in different forms. The earliest and simplest found is that on the footpads of a squirrel, in which the ridges are arranged in lines radiating from the centre of a circular or nearly circular eminence. A transverse arrangement is the commonest and simplest of the common types, and with this may be classed the oblique type. On the palm and sole many Primates have the ridges arranged in a longitudinal manner. The next and highest development is that in which the ridges are grouped into arches, loops, ellipses and whorls. These three most specialised forms of pattern, arches, loops and whorls, culminate in the digits of man, both in the hand and foot, and in the former case have received great attention from Dr. Galton, forming a basis for a particular and elaborate classification of

patterns. The main types of arrangement, then, are *radiating*, *transverse* and *oblique*, *longitudinal*, *arches*, *loops*, *ellipses* and *whorls*.

FIG. 3.—AZARA'S OPOSSUM. *Didelphys Azaræ*. Manus, right. Drawing from dead specimen. A. Papillary ridges on enlarged group of nodules.

FIG. 4.—AZARA'S OPOSSUM. *Didelphys azaræ*. Pes, right. Drawing from dead specimen.

Descriptions of Specimens.—In each case the hand or foot is, for the sake of clearness, divided into regions: (1) Digits; (2) Palmar or Plantar surface and the signs D. 1; D. 2; D. 3; D. 4; D. 5 are used to indicate the separate digits, beginning from the pollex and hallux, and the anterior and posterior organs are spoken of as Hand and Foot, the papillary ridges as P.R.

AZARA'S OPOSSUM (*Didelphys azarae*).

Hand. (Fig. 3.) All five digits well developed with strong curved nails.

(a) Digits ; palmar surface, broad.

P.R. ellipses on terminal phalanges.

„ middle and proximal phalanges covered with transverse rows of nodules, which are themselves marked with oblique fine papillary ridges.

FIG. 5.—SQUIRREL-LIKE PHALANGER.
Petaurus sciureus. Manus, right. Drawing from dead specimen.

FIG. 6.—SQUIRREL-LIKE PHALANGER.
Petaurus sciureus. Pes, right. Drawing from dead specimen.

(b) Palmar surface.

Three interdigital eminences, oval and fleshy.

One large eminence at base of D. 1 and small thenar eminence.

One small hypothenar eminence.

P.R. wide ellipses on all eminences except the ulnar interdigital, where they are oblique.

„ all the rest of the surface covered with nodules irregularly placed.

Foot. (Fig. 4.) More slender than hand.

D. 1 well developed with broad, fleshy pulp and no nail.

D. 2, 3, 4, 5 long and furnished with long sharp, curved nails.

(a) Digits.

P.R. ellipses on all terminal phalanges.

P.R. middle and proximal phalanges covered as those of hand with rows of nodules marked with P.R.

(b) Plantar surface.

Three interdigital eminences.

One long fleshy eminence at base of D. 1.

One small eminence on fibular border.

P.R. well-developed whorls on two interdigital eminences, wide ellipses on all the other plantar eminences.

„ rest of plantar surface occupied by nodules as on hand.

SQUIRREL-LIKE PHALANGER (*Petaurus sciureus*).

Hand. (Fig. 5.) Digits slightly curved towards ulnar side; and claw-like, elongated curved nails.

(a) Digits.

P.R. on terminal phalanges in narrow ellipses.

„ arranged longitudinally on middle phalanges.

„ longitudinal, or proximal indefinite.

(b) Palmar surface.

Three interdigital, one thenar, one hypothenar eminence.

P.R. transverse on all except thenar eminence, where they are oblique.

Foot. (Fig. 6.) Digits claw-like, and nails long and curved.

(a) Digits.

P.R. in broad ellipses on terminal phalanges.

„ elsewhere indefinite.

(b) Plantar surface.

Three interdigital eminences, central short; two lateral elongated; large eminence on tibial side of plantar surface; small on fibular; small eminence on heel.

P.R. on central interdigital eminence oblique.

„ on lateral interdigital eminences transverse.

„ longitudinal and oblique on tibial eminence.

„ transverse on fibular eminence.

„ absent on heel.

COMMON SQUIRREL (*Sciurus vulgaris*).

Hand. (Fig. 7.) Digits long, claw-like; nails long and curved. D. 1 much reduced in size; no nails.

(a) Digits.

P.R. absent on terminal phalanges and represented by a roughened granular surface.

„ indefinite and transverse on middle and proximal phalanges.

(b) Palmar surface.

Three interdigital eminences, thenar and hypothenar, all oval in shape.

P.R. radiating on all.

Foot. (Fig. 8.) Digits long, claw-like; nails long and curved. D. 1 well developed, with long curved nail.

(a) Digits.

P.R. absent on terminal phalanges, represented by a rough granular surface.

„ indefinite transverse ridges on middle and proximal phalanges.

FIG. 7.—COMMON SQUIRREL. *Sciurus vulgaris*. Manus, right. Drawing from dead specimen.

FIG. 9.—KINKAJOU. *Cerculeptes caudivolvulus*. Manus, left. Drawing from dead specimen.

(b) Plantar surface.

Three interdigital eminences, oval in shape.

Fleshy oval eminence at base of D. 1.

Small eminence on tibial and fibular borders.

P.R. oblique and longitudinal on all plantar eminences.

KINKAJOU (*Cerculeptes caudivolvulus*).

Hand. (Fig. 9.) Short digits, with very strong pointed nails, webbed to second joint; palmar portion thick, with fleshy pads.

(a) Digits.

P.R. terminal phalanges, a few well-marked ridges on tip of each pulp surrounding it, so as to form rounded arches with concavity in proximal direction. These ridges here and on rest of hand merge into a tessellated arrangement of the epidermis

P.R. middle and proximal phalanges occupied by this tessellated grouping of epidermic scales.

(b) Palmar surface.

Three interdigital eminences.

Thenar divided into two portions.

One hypothenar.

FIG. 8.—COMMON SQUIRREL. *Sciurus vulgaris*. Pes, left. Drawing from dead specimen.

FIG. 10.—KINKAJOU. *Cerculeptes caudivolvulus*. Pes, left. Drawing from dead specimen.

- P.R. All these eminences show a few rather widely separated ridges.
- „ ulnar eminence ; wide loops open to ulnar side.
 - „ central eminence ; P.R. longitudinal.
 - „ radial eminence ; wide loops open to radial side.
 - „ thenar eminence ; arches open to radial side in distal portion.
 - „ „ transverse in proximal portion.
 - „ Hypothenar eminence ; slightly curved concavity in proximal or transverse direction.

Foot. (Fig. 10.) Somewhat longer than hand; digits rather longer; palmar portion strong and thick; webbed; strong, sharp nails.

(a) Digits.

P.R. terminal phalanges similar to those of terminal phalanges of hand.

„ middle and proximal phalanges also similar to those of hand.

(b) Plantar surface.

Three interdigital eminences: one tibial, divided into two portions; one fibular eminence.

P.R. Interdigital eminence on fibular side; wide ellipses.

„ central eminence on arches open in distal direction.

„ „ tibial side transverse.

„ eminence on tibial border transverse on distal portion.

„ „ „ arched open in proximal direction on proximal portion, merging into tessellated arrangement.

„ eminence on fibular border, a few ridges in wide ellipse.

„ „ „ on distal portion, and on remaining portion; all tessellated.

CAPE SEA LION (*Otaria pusilla*).

Foot. (Fig. 11.) Skin black with faint greenish tinge. Digits and plantar surface covered with wide coarse Papillary Ridges, most of which are longitudinal, and on the central portion of the plantar surface obliquely inclined on each side towards the median line of this surface. When examined more closely the main ridges are divided by oblique branching lines, as shown in the enlarged portion of skin at the side.

COMMON HEDGEHOG (*Erinaceus europæus*).

Hand. (Fig. 12.) Short thick digits, with long sharp nails; thick fleshy footpads.

(a) Digits.

P.R. few and oblique on terminal phalanges of D. 1, 2, 3.

(b) Palmar surface.

P.R. few and transverse on central and radial eminence; radiating on thenar and hypothenar eminences; elsewhere absent.

Foot. (Fig. 13.) Elongated in shape, digits of variable length—D. 1 very short; D. 2, 3, 4 longer; D. 5 short. Nails long.

(a) Digits.

P.R. Terminal phalanges oblique on D. 2, 3, 4.

(b) Plantar surface.

One large and one small interdigital eminence; large, nearly circular eminence on fibular side midway between heel and clefts of digits; on this eminence alone are P.R. in radiating form.

FIG. 11.—CAPE SEA LION. *Otaria pusilla*. Pes. A. Showing papillary ridges dividing into branched grooves.

BLACK-HEADED LEMUR (*Lemur brunneus*).

Hand. (Fig. 14.) Elongated; digits with large wide pulps and short blunt nails.

(a) Digits.

P.R. terminal phalanges in broad longitudinal ellipses on all five digits.

FIG. 12.—HEDGEHOG. *Erinaceus europæus*. Manus, right. Drawing from dead specimen.

FIG. 13.—HEDGEHOG. *Erinaceus europæus*. Pes, right. Drawing from dead specimen.

P.R. skin of rest of digits covered with nodules of varying size presenting a corrugated appearance. Some of the larger of these nodules marked with oblique P.R. which can be discovered with a lens; absent on the smaller nodules.

(b) Palmar surface.

Three interdigital eminences, two small hypothenar and one long thenar eminence.

P.R. radial eminence; loops sloping towards ulnar side, open towards radial side.

„ central eminence; wide loops; longitudinal; open in distal direction.

„ ulnar eminence; oblique P.R.

Foot. (Fig. 15.) Plantar surface; long; digits short; pulps wide, especially D. 1; nails short.

(a) Digits.

P.R. terminal phalanges; longitudinal; broad ellipses. Remaining phalanges occupied by large nodules, some of which are

FIG. 14.—BLACK-HEADED LEMUR. *Lemur brunneus*. Manus, left. Drawing from dead specimen and impressions.

FIG. 15.—BLACK-HEADED LEMUR. *Lemur brunneus*. Pes, left. Drawing from dead specimen and impressions. A. Magnified proximal and middle phalanges.

shown in drawing enlarged, where they are oblique and converge towards axis of digit.

P.R. at base of D. 1 small eminence with P.R. transverse, similar to those of plantar surface.

(b) Plantar surface.

Three interdigital eminences; soft, fleshy eminence at root of D. 1; small one on fibular border; and two small circular eminences on heel.

- P.R. on interdigital eminences radiating towards common centre.
 „ on eminence at root of D. 1 ; P.R. slope towards its long axis.
 „ „ fibular side ; P.R. in wide arched groups open
 in proximal direction.
 „ „ of heel ; no distinct P.R.

FIG. 16.—RING-TAILED LEMUR. *Lemur catta*. Manus, left. Drawing from dead specimen and impressions. A. Magnified portion of palmar surface covered with nodules.

RING-TAILED LEMUR (*Lemur catta*).

Hand (Fig. 16.) Digits moderate length ; pulps wide ; nails short.

(a) Digits.

P.R. terminal phalanges.

„ longitudinal in broad ellipses on all.

„ on remaining phalanges ; nodules of varying size.

(b) Palmar surface.

Three interdigital eminences.

One large flesh thenar eminence.

One hypothenar eminence, divided into two portions.

P.R. Well-formed whorls on all interdigital eminences.

„ whorl on thenar eminence.

„ hypothenar shows P.R. arched on distal and whorled on proximal portion of eminence.

Rest of palmar surface occupied by nodules.

FIG. 17.—RING-TAILED LEMUR. *Lemur catta*. Pes, left. Drawing from dead specimen and impressions.

Foot. (Fig. 17.) Plantar region long; digits short; pulps wide; nails short.

(a) Digits.

P.R. longitudinal, in broad ellipses on terminal phalanges. Rest of phalanges covered by nodules except proximal phalanx of D. 1, which has a small eminence with P.R. transverse, merging into eminence at base of D. 1 on plantar surface.

(b) Plantar surface.

Large fleshy eminence at base of D. 1; three large interdigital

eminences almost continuous, the fibular one running into a long, narrow eminence on fibular border.

P.R. longitudinal on two eminences, central and tibial; on the eminence at base of D. 5 (on fibular side) wide arches open in proximal direction; oblique on eminence on fibular border. Rest of plantar surface covered with nodules.

FIG. 18.—SLOW LORIS. *Nycticebus tardigradus*. Manus, right. Drawing from dead specimen and impressions.

SLOW LORIS (*Nycticebus tardigradus*).

Hand. (Fig. 18.) D. 1 broad; well developed; fleshy; with wide pulpy short nail. D. 2 short, and small pulp; short nail. D. 3, 4, 5 long with wide, fleshy pulps; short nails. Palmar portion wide and fleshy.

(a) Digits.

P.R. ellipses on terminal phalanges, which start from a centre at tips of phalanges (shown in Fig. 16).

„ middle phalanges divided in centre by a longitudinal line, from which P.R. slope away slightly to the lateral borders.

„ proximal phalanges similar on D. 1, 3, 4, 5.

„ „ on D. 2 indefinite.

(b) Palmar surface.

Five interdigital eminences.

One thenar eminence adjoining carpus.

One hypothenar eminence, fleshy.

P.R. whorl on ulnar interdigital eminence; ellipses on the remaining eminences.

FIG. 19.—SLOW LORIS. *Nycticebus tardigradus*. Pes, right. Drawing from dead specimens and impressions. I. Shows arrangement of papillary ridges on the tip of D. 3.

Foot. (Fig. 19.) Remarkable development of D. 1, showing extreme abduction and fleshy pad at base, dividing whole again into two nearly equal parts; short nail. D. 2 very short, with long curved nail. D. 3, 4, 5 long, with fleshy pulps and short nails.

(a) Digits.

P.R. ellipses on terminal phalanges of D. 1, 3, 4, 5, starting from a centre at tips as on hand.

- P.R. Fig. 16 shows tip of D. 3 with nail and pulp, over which P.R. radiate from a bare centre.
- „ D. 2 ; well-marked, small whorl on tip of terminal phalanx.
- „ middle and proximal phalanges of D. 3, 4, 5 ; show central longitudinal line from which lines of P.R. slope to lateral borders.
- „ D. 1, proximal phalanx longitudinal.
- „ D. 2, indefinite.

FIG. 20.—MARMOSET. *Hapale jacchus*. Manus, right. Drawing from dead specimen.

FIG. 22.—SQUIRREL-MONKEY. *Chrysothrix sciurea*. Manus, left. Drawing from dead specimen.

(b) Plantar surface.

Two interdigital eminences—one on fibular and one on tibial side ; space between occupied by longitudinal P.R.

One fibular eminence

One very fleshy, wide eminence at base of D. 1.

P.R. ellipses on interdigital eminences.

„ whorl on eminence at base of D. 1.

„ „ on fibular border.

MARMOSET (*Hapale jacchus*).

Hand. (Fig. 20.) Digits claw-like, with long curved nails.

(a) Digits.

P.R. terminal phalanges, longitudinal, in broad ellipses.

„ on proximal phalanges of D. 1 and D. 5, longitudinal.

(b) Palmar surface.

Three interdigital eminences, thenar and hypothenar both elongated.

P.R. in wide loops, sloping towards axis of palm, oblique on ulnar eminence.

FIG. 21.—MARMOSET. *Hapalc jacchus*.
Pes, right. Drawing from dead specimen.

FIG. 23.—SQUIRREL-MONKEY. *Chrysothrix sciurea*. Pes, left. Drawing from dead specimen.

P.R. arched on distal portion of thenar eminence; oblique elsewhere on this and hypothenar eminence.

Rest of palmar surface longitudinal.

Foot. (Fig. 21.) Long and slender; digits all long except D. 1, which is of moderate length; nails long and curved.

(a) Digits.

P.R. longitudinal in wide ellipses on terminal phalanges.

„ transverse on proximal phalanx of D. 1.

„ elsewhere longitudinal on all phalanges.

(b) Plantar surface.

One well-marked interdigital eminence at base of D. 5 ; tibial and central little raised. Long eminence on tibial border ; longer one on fibular border.

P.R. ovate whorl on eminence at base of D. 5.

„ longitudinal at bases of D. 2, 3, 4.

„ transverse, oblique and longitudinal on the long eminences on tibial and fibular borders.

SQUIRREL-MONKEY (*Chrysotrrix sciurea*).

Hand. (Fig. 22.) Digits long and well formed ; nails short, pointed.

(a) Digits.

P.R. longitudinal in ellipses on terminal phalanges.

„ second phalanges, transverse.

„ proximal phalanges ; D. 1 loops open to radial side ; D. 2, 3, 4, 5 arches ; most marked on D. 2 and 5.

(b) Palmar surface.

Three interdigital eminences ; one thenar ; one hypothenar.

P.R. wide ellipses on interdigital eminences, narrowing towards proximal end.

„ thenar eminence loops open in distal direction on distal portion, and on proximal portion P.R. arched with arches open in distal direction.

„ hypothenar eminence loops open to ulnar side.

Rest of palmar surface longitudinal.

Foot. (Fig. 23.) Long and slender digits ; nails, pointed and long.

(a) Digits.

P.R. longitudinal in ellipses on terminal phalanges.

„ D. 1, proximal phalanx transverse.

„ D. 2, 3, 4, 5, transverse on middle phalanges ; arches on proximal phalanges of all four, most marked on D. 4, 5.

(b) Plantar surface.

Three interdigital eminences nearly fused into one large eminence ; long tibial and longer fibular eminence.

P.R. longitudinal at bases of D. 2, 3.

„ loops open to fibular side at base of D. 5.

„ transverse on middle of fibular border of sole.

„ on proximal part of this eminence P.R. in.

„ loops open in proximal direction.

„ oblique at point of heel.

BROWN SAPAJOU (*Cebus fatuellus*).

Hand. (Fig. 24.) Digits straight ; nails moderately long and pointed ; palmar portion well developed.

(a) Digits.

P.R. terminal phalanges, longitudinal, wide ellipses.

„ middle phalanges, transverse on D. 2, 3, 4, 5.

„ proximal phalanges, D. 1 transverse; D. 2 loops open to ulnar side; D. 3, two symmetrical whorls; D. 4, two

FIG. 24.—BROWN SAPAJOU. *Cebus fatuellus*. Manus, right. Drawing from dead specimen and impressions.

symmetrical whorls; D. 5, single whorl on ulnar side; radial side P.R. oblique.

(b) Palmar surface.

Three interdigital eminences; large thenar divided into two portions, elongated hypothenar eminence. These all so wide that little of the palmar surface is not covered by them.

P.R. radial interdigital eminence; well-marked whorl.

„ central interdigital eminence; slightly ovate whorl.

- P.R. ulnar interdigital eminence; wide loops open to ulnar side.
 „ thenar eminence; very large ovate whorl; proximal portion P.R. transverse.

FIG. 25.—BROWN SAPAJOU. *Cebus fatuellus*. Pes, right. Drawing from dead specimen and impressions.

- P.R. hypothenar eminence, low arches open in proximal direction.
 „ „ „ small area, with transverse loops on proximal portion of this eminence.

Rest of palmar surface longitudinal and indefinite.

Foot. (Fig. 25.) Digits elongated, with long pointed nails; D. 1 short, with short nail.

(a) Digits.

P R. terminal phalanges ; wide ellipses.

„ middle phalanges ; transverse.

„ proximal phalanges ; D. 1 transverse and D. 2, D. 3, and 4 double symmetrical whorls ; D. 5 single ovate whorl.

FIG. 26.—ARABIAN BABOON. *Papio hamadryas*. Manus, right. Drawing from dead specimen and impressions.

FIG. 27.—ARABIAN BABOON. *Papio hamadryas*. Pes, right. Drawing from dead specimen and impression.

(b) Plantar surface surrounded with a border of eminences except at cleft of D. 1, with very small gaps between interdigital eminences.

P.R. loops open to fibular side on all three interdigital eminences ; on large eminence on tibial border three separate groups of

looped P.R. opening to fibular side ; and on heel loops open in distal direction. Rest of sole longitudinal and oblique.

ARABIAN BABOON (*Papio hamadryas*).

Hand. (Fig. 26.) Digits short, straight, with short nails ; palmar portion thick and fleshy.

(a) Digits.

P.R. terminal phalanges, longitudinal wide ellipses.

„ middle phalanges, transverse.

„ proximal phalanges : D. 1 and 3 transverse ; D. 2, 4, 5 oblique, converging to centre of the five digits, *i.e.*, to the median line of D. 3.

(b) Palmar surface.

Three interdigital eminences.

P.R. ovate wide whorls, on ulnar eminence inclining to radial side.

„ thenar eminence longitudinal on distal portion ; wide loops open to ulnar side on proximal portion of eminence.

„ hypothenar eminence wide transverse, and grouped into two areas of loops open to ulnar side.

Rest of palm longitudinal and oblique.

Foot. (Fig. 27.) Plantar portion large digits, especially D. 1 ; small nails, short.

(a) Digits.

P.R. terminal phalanges, wide ellipses longitudinal.

„ middle phalanges, transverse and oblique.

„ proximal phalanges, D. 1, 2, 3 oblique ; D. 4, 5 loops open to ulnar side.

(b) Plantar surface surrounded by border of fleshy eminences, except at cleft of D. 1 heel, and two gaps at clefts of D. 2 and 3 and D. 4 and 5 ; large rounded eminence at base of D. 1 ; interdigital eminences well marked.

P.R. interdigital eminences, tibial, ovate whorl sloping to fibular border ; central, ovate whorl longitudinal ; fibular, ovate whorl sloping to tibial border.

„ eminence at base of D. 1, ovate whorl ; proximal portion low arches open in proximal direction.

„ eminence on fibular border, two groups of wide loops open to fibular side ; the rest of eminence low arches open in proximal direction.

CHACMA BABOON (*Papio porcarius*).

Hand. (Fig. 28.) Digits all short, and relatively thin nails, long and blunt. Palmar portion very fleshy and surrounded with border

of very much raised eminences, except at clefts of D. 1 and 2, 3 and 4, 4 and 5, junction of ulnar with hypothenar eminence, and at proximal end of the thenar eminence.

(a) Digits.

P.R. terminal phalanges, irregular loops longitudinal.

FIG. 28.—CHACMA BABOON. *Papio porcarius*. Manus, left. Drawing from dead specimen and impressions.

P.R. middle phalanges, transverse and oblique.

„ proximal phalanges, transverse on D. 1 ; D. 2, 3, 4 arched open in proximal direction ; D. 5 loops open to ulnar side.

(b) Palmar surface.

P.R. interdigital eminences, radial, complete large whorl ; central wide loops open in distal direction ; ulnar, complete large whorl.

„ thenar eminence, large ovate whorl.

P.R. hypothenar eminence, distal portion, wide loops open to radial side ; proximal portion, loops open to ulnar side.

FIG. 29.—CHACMA BABOON. *Papio porcarius*. Pes, left. Drawing from dead specimen and impressions.

Rest of palmar surface longitudinal and oblique.

Foot. (Fig. 29.) Digits short, thick ; nails blunt and short. Plantar portion long and covered by large fleshy eminences except at

clefts of D. 1, 2 and 3, and base of 4, and at junction of fibular interdigital eminence and rest of fibular border.

(a) Digits.

P.R. terminal phalanges : D. 1, loops nearly longitudinal, open in fibular side ; D. 2, ovate whorl ; D. 3, 4, 5, ovate whorl inclined to fibular side.

„ middle phalanges, transverse and oblique.

„ proximal phalanges : D. 1 and 5, transverse ; D. 2, oblique ; D. 3, 4, loops open to fibular side.

(b) Plantar surface.

P.R. interdigital eminence at base of D. 2, wide loops opening to fibular side ; central, ill-formed ovate whorl ; at base of D. 4, 5, well-formed large whorl.

„ eminence at base of D. 1, wide arches open towards D. 2 ; on fibular border, wide ellipses in transverse position ; rest of this eminence transverse and oblique.

BLACK APE (*Cynopithecus niger*).

Hand. (Fig. 30.) Digits long, well formed ; nails short ; palmar portion well developed, eminences fleshy.

(a) Digits.

P.R. terminal phalanges, wide ellipses placed longitudinally.

„ middle phalanges : D. 2, oblique and one loop on radial side, open to that side ; D. 3, arch open in proximal direction, sloping to ulnar side ; D. 4, loops open to ulnar side ; D. 5 oblique, one loop open to ulnar side on ulnar border of phalanx.

„ proximal phalanges : D. 1, transverse ; D. 2, loops open to radial side ; D. 3, arches open in proximal direction ; D. 4, wide loops open to ulnar side ; D. 5, loops open to ulnar side.

(b) Palmar surface.

Three interdigital eminences, thenar, hypothenar.

P.R. radial and ulnar, complete whorl.

„ central, ovate irregular whorl.

„ thenar eminence, large well-formed whorl.

„ hypothenar eminence, distal portion, arches open in proximal direction ; proximal portion, ovate irregular whorl.

Rest of palmar surface longitudinal and transverse.

Foot. (Fig. 31.) Digits long ; nails short ; D. 2, 3, 4, 5 webbed partially to middle of proximal phalanges ; D. 5 up to middle phalanx. Plantar surface long and well proportioned.

(a) Digits.

P.R. terminal phalanges, wide ellipses, longitudinal.

„ middle phalanges : D. 2, oblique ; D. 3, wide loops open to

fibular side ; D. 4, wide loops open to fibular side ; D. 5, wide loops open to fibular side.

P.R. proximal phalanges : D. 1, transverse ; D. 2, loops open in proximal direction ; D. 3, arch open in proximal direction ; D. 4, longitudinal ; D. 5, longitudinal.

FIG. 30.—BLACK APE. *Cynopithecus niger*. Manus, right. Drawing from dead specimen and impressions.

FIG. 32.—MANGABEY. *Cercopithecus*. Species not determined. Manus, right. Drawing from dead specimen and impressions.

(b) Plantar surface.

Three interdigital eminences, one long eminence on fibular border, two fleshy eminences on tibial border.

P.R. eminences : loops at base of D. 2 ; central, ovate whorl ; eminence at base of D. 5, wide loops open to fibular side ; at base of D. 1, very wide loops open in distal direction ; second tibial eminence, loops open to tibial side ; on fibular

border, ovate whorl on distal part oblique and transverse on proximal part.

FIG. 31.—BLACK APE. *Cynopithecus niger*. Pes, right. Drawing from dead specimen and impression.

FIG. 33.—MANGABEY. *Cercocebus*. Species not determined. Pes, right. Drawing from dead specimen and impressions.

MANGABEY (*Cercocebus*). (Species not determined.)

Hand. (Fig. 32.) Digits and palmar surface well proportioned, nails short.

(a) Digits.

P.R. terminal phalanges, longitudinal, wide ellipses.

„ middle phalanges, transverse except D. 5, which is oblique.

„ proximal phalanges : D. 1, transverse ; D. 2, loops open to radial side ; D. 3, arches open in proximal direction ; D. 4, loops open to ulnar side ; D. 5, loops open to ulnar side and sloping.

(b) Palmar surface.

Three interdigital eminences, one thenar, one hypothenar.

P.R. radial eminence, ovate whorl lying transversely.

„ central eminence, whorl.

„ ulnar eminence, very wide loops open to ulnar side.

„ thenar eminence, ovate whorl—transverse on proximal portion.

„ hypothenar eminence, irregular loops open to ulnar side on proximal portion ; on rest of eminence transverse.

Foot. (Fig. 33.) Well proportioned ; D. 2, 3, 4, 5 webbed nearly to first phalangeal joint ; nails short ; plantar portion narrow towards heel.

(a) Digits.

P.R. terminal phalanges, longitudinal, wide ellipses.

„ middle phalanges : D. 2, 3, 4, transverse ; D. 5, very oblique.

„ proximal phalanges : D. 1, transverse ; D. 2, longitudinal loops at tibial side open in that direction ; D. 3, arches open in proximal direction ; D. 4, arches open in proximal direction ; D. 5, loops open to fibular side.

(b) Plantar surface.

Three interdigital eminences ; large one at base of D. 2 divided into two portions by a crease ; large eminence at base of D. 1 extending to near the heel ; large eminence on fibular border extending to heel.

P.R. eminence on tibial side, wide loops open to fibular side rest of eminence oblique.

„ central eminence, whorl open slightly in proximal direction.

„ eminence on fibular side, wide loops open to that side ; at base of D. 1, wide ellipses placed transversely to the digit, rest of eminence irregular loops ; on fibular border, oblique at centre of eminence ; arches on proximal portion open in proximal direction.

„ crumpled-up eminence in centre of plantar surface with P.R. transverse.

FIG-TAILED MONKEY (*Macacus nemistrinus*).

Hand. (Fig. 34.) Digits medium length, nails short, palmar portion broad.

(a) Digits.

P.R. terminal phalanges, longitudinal ellipses on D. 1, 3, 4, 5 ; D. 2, loop opening to ulnar side.

FIG. 34.—PIG-TAILED MONKEY. *Macacus nemistrinus*. Manus, right. Drawing from dead specimen.

FIG. 35.—PIG-TAILED MONKEY. *Macacus nemistrinus*. Pes, right. Drawing from dead specimen.

P.R. middle phalanges : D. 2, transverse ; D. 3, arches open in proximal direction ; D. 4, arches open in proximal direction ; D. 5, arches open in proximal direction.

„ proximal phalanges : D. 1, transverse ; D. 2, 3, loops open to radial side ; D. 4, arches open in proximal direction ; D. 5, oblique.

(b) Palmar surface.

Three interdigital eminences, one thenar (large), one hypothenar.

FIG. 36.—CRAB-EATING MACAQUE. *Macacus cynomologus*. Manus, right. Drawing from dead specimen and impressions.

FIG. 37.—CRAB-EATING MACAQUE. *Macacus cynomologus*. Pes, right. Drawing from dead specimen and impressions.

P.R. radial eminence, ovate whorl placed transversely.

„ central eminence, loops open in proximal direction.

- P.R. ulnar eminence, loops open to ulnar side.
 „ thenar eminence, ovate whorl—transverse at proximal part.
 „ hypothenar eminence, transverse and oblique on distal part;
 wide loops open to ulnar side on proximal part.

Foot. (Fig. 35.) Digits long, webbed to first phalangeal joint; nails rounded, not long; very fleshy eminence at base of D. 1.

(a) Digits.

- P.R. terminal phalanges: longitudinal ellipses.
 „ middle phalanges: D. 2, wide loops open to tibial side; D. 3, arches open in proximal direction; D. 4, arches open in proximal direction; D. 5, oblique.
 „ proximal phalanges: D. 1, transverse; D. 2, loops transverse open to fibular side; D. 3, arches continuous with arches of middle phalanx, open in proximal direction; D. 4, loops open to fibular side; D. 5, oblique.

(b) Plantar surface.

Three interdigital eminences; large fleshy eminence at base of D. 1, extending nearly to heel; long, narrow eminence on fibular border.

P.R. eminence, tibial side, wide loops open to fibular side.

- „ „ fibular, wide loops open to fibular side.
 „ „ central, longitudinal.
 „ „ at base of D. 1, wide loops open in distal direction; transverse at proximal portion of eminence; remaining surface longitudinal.
 „ „ on fibular border, arches open in proximal direction, on proximal portion, ovate whorl on distal portion.

Rest of plantar surface longitudinal.

CRAB-EATING MACAQUE (*Macacus cynomologus*).

Hand. (Fig. 36.) Digits short, nails blunt; palmar portion relatively large and fleshy.

(a) Digits.

- P.R. terminal phalanges, longitudinal ellipses.
 „ middle phalanges, transverse.
 „ proximal phalanges, D. 1 transverse; D. 2, 3, 4, 5, loops opening in proximal direction.

(b) Palmar surface.

Three interdigital eminences, one thenar, one hypothenar in two portions.

P.R. radial and ulnar eminences, well-formed whorls.

- „ central eminence, loops open in proximal direction.
 „ thenar eminence, wide ovate whorl, transverse elsewhere.
 „ hypothenar eminence, each portion with loops open on ulnar side.

Foot. (Fig. 37.) Digits rather long; D. 2, 3, 4, 5 webbed to level of first phalangeal joint; nails long and pointed, short on D. 1.

(a) Digits.

P.R. terminal phalanges, longitudinal ellipses.

„ middle phalanges, corrugated and without P.R.

„ proximal phalanges, D. 1, transverse; D. 2, 3, 4, 5, corrugated and without P.R.

(b) Plantar surface.

Three interdigital eminences; central flattened more than tibial and fibular.

Eminence on tibial border extending from base of D. 1; fibular, long and extending to heel.

P.R. central interdigital eminence, longitudinal.

„ tibial „ „ wide loops open to fibular border.

„ fibular „ „ loops open to fibular border.

„ eminence at base of D. 1; wide ovate whorl; loops on proximal portion.

„ „ on fibular border, wide loops open to fibular side, remaining portion oblique.

„ „ on heel, transverse.

LION-TAILED MONKEY (*Macacus silenus*).

Hand. (Fig. 38.) Digits and palmar portion well proportioned, nails short and blunt.

(a) Digits.

P.R. terminal phalanges, longitudinal, wide ellipses.

„ middle phalanges: D. 2, transverse; D. 3, 4, 5, arched opening in proximal direction.

„ proximal phalanges: D. 1, 2, 3 transverse; D. 4, oblique; D. 5, low arches open in proximal direction.

(b) Palmar surface.

Three interdigital eminences, one thenar large, one hypothenar.

P.R. radial interdigital eminence, ovate whorl, transversely placed.

„ central „ „ well-formed whorl.

„ ulnar „ „ „ „

„ thenar eminence, wide loops placed transversely, open to radial side.

„ hypothenar eminence, distal portion, low arches open in proximal direction; proximal portion, loops open to ulnar side.

Foot. (Fig. 39.) Digits and plantar portion well proportioned, nails short.

(a) Digits.

P.R. terminal phalanges, longitudinal; no ellipses except on D. 1.

P.R. middle phalanges, transverse.

„ proximal phalanges : D. 1, transverse ; D. 2, transverse, with low arch at distal end ; D. 3 transverse, with low arch at

FIG. 38.—LION-TAILED MONKEY. *Macacus silenus*. Manus, right. Drawing from dead specimen and impressions.

FIG. 39.—LION-TAILED MONKEY. *Macacus silenus*. Pes, right. Drawing from dead specimen and impressions.

distal end ; D. 4, loops to fibular side and arches on distal portion ; D. 5, oblique.

PATAS MONKEY (*Cercopithecus patas*).

Hand. (Fig. 40.) Well proportioned, nails short.

(a) Digits.

P.R. terminal phalanges, longitudinal wide ellipses.

P.R. middle phalanges : D. 2, transverse ; D. 3, 4, 5, arches open in proximal direction.

proximal phalanges : D. 1, 2, 3, transverse ; D. 4, 5, oblique.

FIG. 40.—PATAS MONKEY. *Cercopithecus patas*. Manus, right. Drawing from dead specimen.

FIG. 41.—PATAS MONKEY. *Cercopithecus patas*. Pes, right. Drawing from dead specimen.

(b) Palmar surface.

Three interdigital eminences ; one thenar, fleshy ; one hypothenar, divided into two portions by a crease.

P.R. interdigital eminences, all well-formed whorls, ulnar placed transversely.

„ thenar eminences, wide loops open to radial side.

P.R. hypothenar eminences, arches on distal portion and on proximal portion.

Foot. (Fig. 41.) Well proportioned ; D. 1 long, nails short.

(a) Digits.

P.R. terminal phalanges, longitudinal, wide ellipses.

„ middle phalanges, transverse.

„ proximal phalanges : D. 1, transverse ; D. 2, arches open in proximal direction ; D. 3, arches open in proximal direction ; D. 4, loops open to fibular side ; D. 5, oblique.

(b) Plantar surface.

Three interdigital eminences, not very well defined ; fleshy eminence at base of D. 1 ; eminence on fibular border extending to heel.

P.R. fibular interdigital eminence, wide loops open in proximal direction, lying obliquely.

„ central interdigital eminence, wide loops open in proximal direction, longitudinal.

„ tibial interdigital eminence, wide loops open in proximal direction, lying obliquely.

„ eminence at base of D. 1, well-formed whorl, proximal portion oblique.

„ eminence on fibular border, arches at distal portion open in proximal direction ; rest of eminence oblique.

HAINAN GIBBON (*Hylobates hainanus*).

Hand. (Fig. 42.) Digits relatively very long, nails short, palmar portion narrow and contracted.

(a) Digits.

P.R. terminal phalanges, longitudinal, wide ellipses on D. 1, 2, 3, 4 ; D. 5 loops open to ulnar side.

„ middle phalanges : D. 2, 3, 4, 5, arches open in proximal direction.

„ proximal phalanges : D. 1, transverse ; D. 2, very low arches ; D. 3, double arches ; D. 4, arches ; D. 5, arches, open in proximal direction.

(b) Palmar surface.

Three interdigital eminences, faintly marked ; small thenar and no hypothenar eminence.

P.R. on all interdigital eminences, longitudinal and oblique, except at base of D. 3, where there are arches open in proximal direction ; and at base of D. 3 a few irregular ellipses.

„ thenar eminence, oblique and longitudinal.

„ hypothenar eminence absent.

„ remaining portions of surface longitudinal.

Foot. (Fig. 43.) Digits long. D. 1 much developed ; wide pulps ; nails short ; plantar portion well developed.

(a) Digits.

P.R. terminal phalanges, longitudinal, wide ellipses.

„ middle phalanges, transverse and very low arches open in proximal direction.

FIG. 42.—HAINAN GIBBON. *Hylobates hainanus*. Manus, right. Drawing from impressions.

FIG. 43.—HAINAN GIBBON. *Hylobates hainanus*. Pes, left. Drawing from impressions.

P.R. proximal phalanges : D. 1 transverse ; D. 2, 3, 4, 5, arches open in proximal direction.

(b) Plantar surface.

All the eminences ill-defined ; low rounded eminence at base of D. 2.

Small rounded eminence at base of D. 5.

No central interdigital eminence.

Eminence at base of D. 1, prominent and rounded.

Eminence on fibular border small.

- P.R. eminence at base of D. 2, narrow loops open to fibular side ;
 eminence at base of D. 5, in radiating lines from centre of
 eminence ; eminence at base of D. 1, transverse at distal por-
 tion, wide arches at proximal portion open in distal direction.
 „ eminence on tibial border of heel, wide loops opening on tibial
 side.
 „ eminence on fibular border of heel, wide loops placed obliquely,
 open to tibial side.
 „ Rest of surface longitudinal and oblique.

ORANG (*Simia satyrus*).

Hand. (Fig. 44.) Digits long and well developed, nails short ; D. 1 very small ; palmar portion thin and long.

(a) Digits.

- P.R. terminal phalanges : D. 1, loops open to radial side ; D. 2, 3,
 4, loops open to ulnar side ; D. 5, steep arches open in
 proximal direction.
 „ middle phalanges : D. 2, steep arches open in proximal direc-
 tion ; D. 3, less steep arches open in proximal direction ;
 D. 4, steep arches open in proximal direction ; D. 5, very
 steep arches open in proximal direction.
 „ proximal phalanges : D. 1, transverse ; D. 2, loops open to
 radial side ; D. 3, bilateral loops open on corresponding
 side ; D. 4, bilateral steep arches open in proximal direc-
 tion ; D. 5, wide loops open to radial side.

(b) Palmar surface.

No definite interdigital eminences, thenar eminence fleshy
 and small, hypothenar very small.

- P.R. at base of D. 2, oblique ; at base of D. 5, oblique ; at base of
 D. 3, 4, longitudinal.
 „ on cleft between D. 1 and 2, arches open in proximal direction.
 „ thenar eminence, loops open to ulnar side ; thenar eminence,
 transverse on proximal portion.
 „ hypothenar eminence, narrow loops open to radial side ; trans-
 verse on proximal portion.

Rest of palmar surface longitudinal.

Foot. (Fig. 45.) Digits long, well developed ; pulps moderate in size ;
 nails short ; D. 1 much reduced and abducted ; plantar portion
 narrow and ill developed.

(a) Digits.

- P.R. terminal phalanges : D. 1, transverse ; D. 2, 3, 4, 5, loops
 open to fibular side.

- P.R. middle phalanges : D. 2, low arches open in proximal direction ; D. 3, 4, 5, steep arches open in proximal direction.
 „ proximal phalanges : D. 1 transverse ; D. 2, 3, arches steep, open in proximal direction ; D. 4, loops open in proximal

FIG. 44.—ORANG. *Simia satyrus*. Manus, left. Drawing from impressions taken by Mr. R. I. Pocock.

direction to fibular side ; D. 5, arches open in proximal direction.

(b) Plantar surface.

One indefinite interdigital eminence at base of D. 3 ; one small tibial, one small fibular eminence ; one on heel.

P.R. at base of D. 3, irregular ovate whorl.

„ rest of distal portion of sole longitudinal and oblique.

- P.R. cleft of D. 1, transverse.
 „ centre of sole longitudinal.
 „ at base of D. 1, steep arches open in distal direction.

FIG. 45.—ORANG. *Simia satyrus*. Pes, right. Drawing from impressions taken by Mr. R. I. Pocock.

- P.R. on tibial border near heel, wide ellipses placed transversely.
 „ on heel, wide loops open to tibial side, placed transversely.

GORILLA (*Gorilla savagei*).

Hand. (Fig. 46.) Coarse shape, stunted thick digits ; D. 1 small ; D. 2, 3, 4, 5, slightly webbed ; pulps wide, nails short ; palmar portion wide.

(a) Digits.

P.R. terminal phalanges: D. 1, loops open to radial side; D. 2, wide ellipses, longitudinal; D. 3, 4, 5, loops open to ulnar side.

„ middle phalanges: D. 2, transverse; D. 3, low arches open in proximal direction; D. 4, transverse; D. 5, oblique.

FIG. 46.—GORILLA. *Gorilla savagei*. Manus, right. Drawing from impressions taken by Mr. R. I. Pocock.

P.R. proximal phalanges: D. 1, transverse; D. 2, wide loops open to radial side; D. 3, very low arches open in distal direction; D. 4, 5, loops open on ulnar side.

(b) Palmar surface.

Three slightly developed interdigital eminences; thenar and hypothenar eminences not well marked.

P.R. on interdigital eminences, wide loops open as follows: radial and central in proximal direction, ulnar to radial side.

P.R. on thenar eminence, longitudinal and curving irregularly.

„ hypothenar eminence, oblique and longitudinal.

Foot. (Fig. 47.) Digits moderately developed; D. 1 large, with very thick pulp; other pulps large; nails short; plantar portion well proportioned.

FIG. 47.—GORILLA. *Gorilla savagei*. Pes, right. Drawing from impressions taken by Mr. R. I. Pocock.

(a) Digits.

P.R. terminal phalanges, loops open to radial side on all five digits.

„ middle phalanges, oblique and transverse.

„ proximal phalanges: D. 1, transverse; D. 2, oblique; D. 3, arches open in proximal direction; D. 4, 5, oblique.

(b) Plantar surface.

Two ill-developed interdigital eminences, with smooth space between at bases of D. 3 and 4.

One large eminence of irregular shape at base of D. 1.

One long eminence on fibular border extending to heel.

P.R. on eminence at base of D. 2 oblique ; on eminence at base of D. 5, ellipses placed transversely.

FIG. 48.—CHIMPANZEE. *Anthropopithecus troglodytes*. Manus, left. Drawing from impressions.

P.R. on surface between these two eminences, small group of arches open in distal direction.

„ on eminence at base of D. 1 and its cleft, oblique ; eminence on fibular border, transverse and oblique.

CHIMPANZEE (*Anthropopithecus troglodytes*).

Hand. (Fig. 48.) Well proportioned ; D. 1 small, D. 2, 3, 4, 5 long and moderately thick ; pulps large, nails short.

(a) Digits.

P.R. terminal phalanges : D. 1, 2, 3, longitudinal, wide ellipses ;
D. 4, 5, loops open to ulnar side.

„ middle phalanges : D. 2, low arches open in proxima direc-
tion ; D. 3, nearly transverse ; D. 4, 5, rounded arch open
in proximal direction.

FIG. 49.—CHIMPANZEE. *Anthropopithecus troglodytes*. Pes, left. Drawing from impressions.

P.R. proximal phalanges : D. 1, transverse ; D. 2, loops open to radial side ; D. 3, transverse and loops open to radial side, and low arches open in proximal direction ; D. 4 and 5, wide arches open in proximal direction.

(b) Palmar surface.

One interdigital eminence opposite cleft of D. 4 and 5.

Thenar eminence moderately developed.

Hypothenar eminence slightly developed.

- P.R. on interdigital eminence, oblique to ulnar side ; loops open in distal direction on radial side of eminence.
 „ at base of D. 2, oblique and forming an angle with P.R. of cleft of D. 1.
 „ opposite D. 3 and 4, longitudinal.
 „ thenar eminence, wide ellipses placed obliquely.
 „ hypothenar eminence, longitudinal loops open in distal direction.

Rest of palmar surface longitudinal and oblique.

Foot. (Fig. 49.) Ill proportioned ; very large D. 1 with thick, fleshy pulp ; pulps on D. 2, 3, 4, 5 wide ; nails short ; plantar portion very much developed in region of D. 1.

(a) Digits.

- P.R. terminal phalanges : D. 1, 2, 3, 4, longitudinal, wide ellipses ; D. 5, loops open to fibular side.
 „ middle phalanges : D. 2, 3, and 5, low arches, open in proximal direction ; D. 4, steep arches, open in proximal direction.
 „ proximal phalanges : D. 1, transverse ; D. 2, low arches ; D. 3, steep arches ; D. 4, very steep arches ; D. 5, oblique ; open in proximal direction.

(b) Plantar surface.

Indefinite eminences at base of D. 1 and D. 5 ; no other eminences.

P.R. longitudinal over the greater part of surface.

- „ eminence at base of D. 1, very wide ellipses ; eminence at base of D. 5, loops open in distal direction.
 „ midway between base of D. 1 and heel a group of P.R., with low wide arches, open to tibial side.

MAN.

Hand. (Fig. 50.)

(a) Digits.

- P.R. terminal phalanges show the tips occupied by lines of ridges concentric with the free edge of the nails on D. 2, 3, 4, 5. On D. 1 the lines are placed obliquely, so that when the pulp is applied to a smooth surface with the hand in pronation the ridges here occupy closely the same relation to this surface as the concentric ridges on the tips of the other four digits.
 „ terminal phalanges show on the pulps, arches, loops, and whorls as follows : D. 1, whorl ; D. 2, loops open to ulnar side ; D. 3, steep arches open in proximal direction ; D. 4, loops open to ulnar side ; D. 5, loops open to ulnar side.
 „ middle phalanges, oblique.
 „ proximal phalanges, transverse and oblique.

FIG. 50.—MAN. E. K., male, 19 years old. Manus, right. Facsimile of impression of palm and terminal phalanges of D, 2, 3. D. 1 copied from impression and rest of 4, 5, the digits copied.

FIG. 51.—MAN. H. K., male, aged 7. Pes, right. Drawing from several impressions.

(b) Palmar surface.

Three very low interdigital eminences, only seen in rather muscular subjects.

One thenar eminence, smooth and oval in shape.

One hypothenar eminence, smooth and little raised above palmar surface.

P.R. at bases of D. 3, 4, 5, small groups of arches open in distal direction ; between these P.R. longitudinal.

„ at cleft between D. 3 and 4, groups of loops opening in distal direction.

„ on remaining areas of palmar surface, P.R. longitudinal, oblique and transverse, taking these directions according to the contour of the palm.

„ on thenar eminence wide arches open towards D. 1 are found.

Foot. (Fig. 51.) Marked simplicity of patterns of ridges on plantar surface, complex on terminal phalanges, simple on remaining phalanges.

(a) Digits.

P.R. terminal phalanges arranged in rows concentric with the free edges of the nails on all five digits.

„ pulps occupied on D. 1 by whorl with lateral opening to fibular side ; D. 2, 3, 4, loops open to fibular side ; D. 5, low arches open in proximal direction.

„ middle and proximal phalanges, transverse.

(b) Plantar surface.

P.R. at base of D. 1, oblique ; at base of D. 2, 3, low arches open in distal direction ; at base of D. 4, longitudinal ; at base of D. 5, oblique.

„ on ball of D. 1, steep arches surrounded by wide curving rows, open towards base of D. 1.

„ remaining portion of plantar surface transverse, with slight obliquity at base of D. 5 and in centre of sole.

The foregoing results may be summed up as follows, and it may be first stated that the series of hands and feet have been placed in their zoological positions, and not according to the increasing complexity of the patterns in which the ridges are found ; the latter, do not, therefore, show a uniform increase of development.

The *Opossum* here described shows a high degree of development of the papillary ridges, well-marked ellipses on the digits and whorls, on the palmar and plantar pads. This fact is associated with a very high degree of intelligence and activity of habit of the animal in question.

Squirrel-like Phalanger.—The lowest species examined are Marsupials, and it is seen that these forms display a pattern more allied to those of the monkeys than does the Insectivore, Rodent, or Lemurs chosen. Thus the Squirrel-like Phalanger shows the common type of ellipse on the terminal phalanges found in most of the monkeys; five footpads, instead of the six which are common to most Primates, and these are all covered with well-marked papillary ridges.

Hedgehog.—The Hedgehog, though not the lowest in ordinal rank, shows the most rudimentary patterns of any form examined, two of the digits being tipped with a few ridges, and the footpads with irregular radiating lines like those of the Squirrel.

Kinkajou.—Of all the earlier species here described the Kinkajou is the most interesting, for it shows on the same digits and palmar and sole, rudimentary ridges merging almost imperceptibly into the tessellated arrangement of the epidermis which is so common in many lower mammals. This form is arboreal, but its hands and feet appear to be used for walking on boughs of trees rather than for prehension, this function being exercised by its large prehensile tail. Thus the transition from a tessellated surface to that of papillary ridges, as shown in Figs. 7 and 8 is the more easily understood, especially as the ridges on certain of the digits are imbricated in a distal direction. These conditions point to the sense of touch being highly important to the Kinkajou.

Common Squirrel.—The Common Squirrel has claw-like digits with very long nails, and rudimentary pulps without any papillary ridges in these regions, but they appear on the middle and proximal phalanges; the aborted pollex shows no ridges. There are five footpads, but no other than the radiating papillary ridges on the distal and more projecting margins of the pads.

Lemurs.—Both the Lemurs described have patterns far below those of the Marmoset and other monkeys. Though the apical pads on the digits of hand and foot, and the palmar and plantar pads are fleshy and well marked with ridges, these are the only portions in which any resemblance to higher forms occurs. It is noteworthy that on all the digits of the hand and foot

papillary ridges are well marked on the dorsal surfaces of the pulp and up to the free edge of the short nails, and to their lateral borders, and on the dorsal surface of the hallux these ridges approximate very closely on the two sides, leaving only a small triangular space at the base of the nail unoccupied. On the palm and sole and digits the surfaces between the interdigital pads are covered by numerous nodules of varying sizes, with narrow grooves between them, presenting a very corrugated appearance. On some of the larger of these nodules oblique papillary ridges can be detected with a lens. These represent an early stage of the more developed condition in which the digits and palmar and plantar surfaces are covered with ridges, disposed in various patterns on the eminences and spaces between them, which are characteristic of the hands and feet of the Primates. On the drawing of *Lemur brunneus* a small portion of the digits is shown enlarged, and on *Lemur catta* of the palmar surface, also enlarged, and in these positions the ridges are obliquely placed. It should be noted here that the papillary ridges of the palmar and sole of *Lemur catta* are much more developed than those of *Lemur brunneus*, and the hand of the former more developed than the foot. This difference in the two forms has probably a connection with their difference of organisation.

Marmoset.—The patterns of the Marmoset are good examples of the common monkey-type, with elliptic ridges on the terminal phalanges, longitudinal and oblique on the rest of the digits, palm and sole, except on the three interdigital pads, thenar and hypothenar of the hand, and corresponding pads on the foot.

The Squirrel Monkey (Chrysothrix sciurea) is more highly developed in regard to the patterns of the hand, and has transverse ridges on the digits of hand and foot, and thus advances a stage beyond the Marmoset, though in the same direction of development. In this form there are also seen for the first time among Primates ridges grouped in an arched arrangement on the digits of hand and foot.

Brown Sapajou.—*Cebus satuellus* shows similar characters

developed more fully, the proximal phalanges showing bilateral whorls on two, and single whorls on two other digits, instead of arches. The hand is also more complex than the foot.

Baboons.—The two Baboons present short-stunted digits, and thick fleshy hand and foot, especially *Papio porcarius*. They are notable for being the earliest to show loops on the terminal phalanges. They have well-defined whorls on palm and sole, but little variation on the digits, except for loops of ridges on the digits of the foot of *Papio porcarius*. The ridges are more marked on the most highly developed parts of the hand and foot than elsewhere.

The Black Ape and Mangabey do not present any advance on the Baboons as to the palm and sole, but marked arches, loops, and whorls on the digits of both hand and foot.

Macacus.—Three *Macacai*—*silenus*, *nemistrinus* and *cynomologus*—show a few small differences between one another, and between the hand and foot. *M. silenus* and *nemistrinus* have wide ellipses on the apical pads of the hand, indicating a higher degree of development than that of *M. cynomologus*. The hand in each of these three species is more complex than the foot. Of all three the hand of *M. cynomologus*, with marked palmar and digital whorls and loops is the most highly developed, and the foot of this species with its roughened and bare proximal and middle phalanges, is the least developed. *M. nemistrinus* has marked arches on the digits of both hand and foot, *M. silenus* both better marked ovate whorls on the apical pads, and more loops and rudimentary arches than the other two, being thus distinguished by a more uniform advance in complexity of pattern.

The Patas Monkey has well-developed patterns on the apical pads of hand and foot, arches and loops on the digits. On the fore part of the palm and sole there are whorls and wide loops, the proximal part being very simple, and the ridges here are all longitudinal or oblique.

From the highest of the monkeys to the Anthropoid Apes a considerable change is to be found; one each of the four genera has been examined.

Gibbon.—The apical pads of the digits of the Gibbon are large and fleshy, and show wide ellipses, and on the fifth digit of the hand one loop. The digits are seen to be very long, and show marked contrast as to pattern to the palmar region. No complex patterns are present, nothing higher than arches being visible. The palmar surface is exceedingly simple, and the eminences are unimportant, the ridges being disposed either longitudinally or obliquely, except in two small areas. The foot differs from the hand in having a smaller digital and larger plantar area. The apical pads resemble those of the hand, but the arches are small, and there is one rudimentary whorl, wide loops in two areas, the rest of the surface being, as in the case of the hand, longitudinal and oblique. The Gibbon may be said to have decidedly simple patterns, with the greater complexity on the digits of the hand.

Orang.—The Orang has a hand which approaches more nearly to the shape of the human hand. The hand and foot are very similar in pattern to one another as regards the distal three-fourths of the surface, in the complexity of pattern as to loops on the apical pads, highly developed arches, loops, and whorls on the rest of the digits of hand and foot. The rudimentary pollex is very simple in pattern, and thus detracts from the general human appearance of this hand, as also is the small abducted hallux placed far towards the heel. The hand and foot resemble one another closely as to the patterns, but the foot is less developed than the hand.

Gorilla.—The Gorilla has a hand and foot of more powerful appearance than any other anthropoid ape. The hand resembles a clumsy human hand, and the foot is more powerful than that of the Orang. The apical pads have well-marked loops, a few arches and loops on the palm and sole, those of the latter being less distinct. The markings of the hand and foot of Gorilla are very similar to those of lower monkeys, except for the human characters of marked loops on the pulps, open to the ulnar and tibial sides respectively.

Chimpanzee.—The hand of the Chimpanzee is the most human of all in general form, but less complex as to patterns

than the Gorilla or Orang, but more so than the Gibbon. The apical pads show simple ellipses, and are thus less human than those of the Gorilla, the remaining digits have arches and loops. The palmar and plantar surfaces are as simple as those of the Gibbon, the ridges being longitudinal and oblique.

The features by which the Anthropoid Apes stand out in contrast to all the Primates below them are: (1) marked simplicity of palmar and plantar patterns; (2) higher development of apical pads in the Orang and Gorilla; the former change is common to the whole group, the latter to only two out of the four. The patterns of the Gibbon's hand and foot point to these being simpler in organisation than those of the other Anthropoids, and that its hand is more functionally important than its foot.

Man.—The patterns on the human hand and foot present marked differences from the Anthropoid Apes. It may be well to notice a statement made by Dr. Hepburn* on this point. He says: "I find among those which have come under my notice, that although the monkey patterns are undoubtedly simpler and of less varied design than the patterns found in man, there is, nevertheless, a considerable amount of variety among them." Also "In comparing the lower monkey patterns with those of man, the most noteworthy feature is the great simplicity of the former."

These statements are not borne out by the present study, and are misleading in one important respect. They are only correct when applied to the patterns on the apical pads of the hand and foot. The striking fact as to other parts of the hand and foot is that simplicity of pattern is the characteristic in the Anthropoid Apes and man. It is instructive to see the change of function from palm and sole to digit written in these legible characters on the skin of monkeys, apes, and man, also the general arrangement of ridges on the palm and sole of the anthropoids, by which the longitudinal grouping of the ridges comes into play, subserving the prehension of spherical objects

* The Papillary Ridges on the Hands and Feet of Monkeys and Man, *Trans. Royal Dublin Society*, vol. v.

in lateral folding of the organ. This particular feature of the anthropoids does not develop so highly in man, though it is present on certain parts of the palm. It is remarkably absent on nearly all the sole of man's foot, as might be expected from its function. Indeed, one generalisation follows from the examination of this series of hands and feet, viz., that the complexity of pattern in the different regions, digital, palmar and plantar, is in close correspondence with the activity of function of the part. Thus the palm and sole of the Baboons compared with the digits, the digits of the Gibbon with the palm and sole, the terminal phalanges of man compared with any other region of any other species, bear out this statement very fully, and many other illustrations may be gathered from this series of drawings.

PART II
MICROSCOPICAL

CHAPTER I

MINUTE ANATOMY OF THE PAPILLARY RIDGES AND PAPILLÆ OF THE CORIUM

THE minute anatomy of the human skin has been very fully investigated and described elsewhere, and it is only necessary here to allude to those structures of the skin which especially concern our subject. The five strata of the superficial layer, or epidermis, need no detailed description. The three strata of living cells composing the rete mucosum or malpighian layer lie more deeply, the two superficial strata being formed of dried epithelial cells. In the various sections of the mammalian skin, which will be shown later, the rete mucosum is a very prominent feature because of its being that portion of the skin in which pigment is developed. The epidermis, developed from the outer layer of the epiblast, is moulded on the surface of the corium which is studded with papillæ, thus the two main structures of the skin are developed from different embryonic layers. the corium being formed from the mesoblast.

The corium is an extremely dense structure composed of areolar tissue the outer portion or papillary layer being very dense, whereas the reticular layer is more lax and the fibres are felted together less firmly and pass imperceptibly into the subjacent connective tissue and fat. The most notable part of the corium is that row of papillæ which irregularly stud its surface. The relation of these to the epidermis is well seen when a piece of skin is macerated, in which case the two layers are separated from one another and the projecting papillæ are seen on the corium, and on the deeper surface of the epidermis small pits corresponding to the papillæ.

In man the papillæ are large and closely set on the palmar

surface of the hand and plantar surface of the foot, and are here arranged in lines forming the curvilinear papillary ridges seen on the surface of the epidermis. They are conical and may be either single or compound and measure from $\frac{1}{200}$ to $\frac{1}{100}$ inch in height. Whereas on the face they are reduced to $\frac{1}{800}$ or $\frac{1}{500}$ inch; and in other parts with a less developed sense of touch than the hand and foot, the papillæ are broader, lower and fewer in number and irregularly scattered (Quain).

In the hand and foot the papillæ of the corium appear to possess two separate functions, some of them being vascular papillæ containing networks of fine vessels and others are set apart for the very important function of assisting the sense of touch, and these contain the bodies known as touch-corpuscles or Meissner's corpuscles, and, as a rule, no blood-vessels. These corpuscles are small, oblong bodies about $\frac{1}{90}$ inch long and $\frac{1}{80}$ inch broad and are composed of connective tissue with a capsule surrounding them, and each contains the non-medullated nerve-fibrils of a medullated nerve, and within the corpuscle the axis-cylinders ramify. Nerve-fibrils of the non-medullated kind also ramify among the cells of the epidermis. Hairs are entirely absent from the palmar and plantar surfaces, and it is probable that in other parts of the skin, where hairs exist, the rich network of nerve-fibrils found at the roots of the hairs have a tactile function, lower in degree than the highly developed papillæ of the corium found in the hand and foot.

The ducts of the sudoriparous glands are evident in many of the sections, and their openings which pass through the dark-coloured rete mucosum are situated between the papillæ of the corium, the glands lie in the areolar tissue and their ducts pass through the corium in a straight line, becoming spiral in their passage through the epidermis, open on the free surface. Their orifices are seen on the surfaces of the ridges of the palmar and plantar surfaces, being absent from the furrows between the ridges. The under-surface of the epidermis, which presents this row of projecting openings of sudoriparous ducts, is called Drüsenleisten by Schlaginhaufen and Miss Whipple.

A diagram of a section of the human skin is here given (Fig. 52A)

with the view of showing the main structures of the covering of the hand and foot, and it may be taken as a type of the various modifications of the skin in lower mammalian forms, the essential features being preserved in most of these. Indeed this is well borne out by the diagram (Fig. 52B) * of a section of the skin of the hand of *Macacus cynomologus*, which is also given by way of comparison.

The more minute anatomy of the skin is not referred to, as it

FIG. 52A.—SECTION OF HUMAN SKIN OF PALMAR SURFACE. Drawing copied from "Quain's Anatomy," vol. i. pt. 2, p. 413.

a, stratum corneum; *b*, stratum malpighii; *c*, corium; *d*, crest of papillary ridge; *e*, furrow of papillary ridge; *f*, opening of sudoriparous duct; *f1*, sudoriparous duct; *k*, stratum lucidum,

is the object of this work to show only the variations in different animal forms of the *outlines* of the papillæ of the corium and the papillary ridges of the epidermis. It is very likely that further investigations will be made into the nerve-supply of the papillæ of the lower animals, and that these structures in the case of man will be further worked out than they have been. But for the present purpose, it is not necessary to employ methods of staining for bringing out the variations of nerve-endings and nerve-fibrils in different animals and different parts of their palmar and

* Schlaginhaufen, "Gegenbauer's Morph. Jahrb.," vol. xxxiii.

plantar surfaces. Many of the papillæ of the corium shown in the illustrations are doubtless vascular, and not nerve-papillæ, but the broad fact remains undeniable that the papillary layer of the corium is essentially a sentient and tactile structure.

Imbrication.—The preceding diagram (Fig. 52A) which is copied from "Quain's Anatomy" (after Kölliker) shows the

FIG. 52B.—SECTION OF SKIN OF *MACACUS CYNOMOLOGUS*. Copied from O. Schlaginhaufen's paper in *Morph. Jahrb. (Gegenbauer)*, vol. xxxiii.

a, stratum corneum; *b*, stratum malpighii; *c*, corium; *d*, crest of papillary ridge; *ee*, furrow of papillary ridge; *f*, opening of sudoriparous duct; *g*, drüsenleiste; *h*, cut blood-vessel; *i*, duct of sudoriparous gland; *j*, papilla of corium; *k*, papille of corium.

papillary ridges of the epidermis of an even character, very much like the ridges and furrows of a ploughed field, and in many parts of the palmar and plantar surfaces of man, and in many other species this description is correct. The ridges rise out of the furrows at equal angles on the two sides. But in the course of examination of the human skin with a lens, I found that this rule is subject to a considerable exception. If the skin of the pulps of the human fingers be looked at with a lens in a strong light and in *profile*, it is found that the papillary ridges in some

parts rise out of the adjoining furrows at an angle, so that the distal side of the ridge forms an acute and the proximal side of the ridge an obtuse angle with the plane of the skin. This gives rise to a condition which I called imbrication of the papillary ridges*; and it is not unlike the arrangement of the tiles on the roof of a house. The effect of it is to expose the edges of the ridge to a more efficient contact on the distal than the proximal side of the ridge, and as, I believe, to increase very much the power of the human hand to discriminate between the surfaces

FIG. 52c.—MAN. $\times 25$. Manus D. 4. Terminal phalanx, papillary ridge imbricated in distal direction; papillæ of corium double.

of different objects. This arrangement of the angles may be reversed so that the imbrication may be proximal instead of distal. It is necessary to mention here that the angle of the papillary ridges is closely followed by the underlying papillæ of the corium which also slope forward in this case. These points are exemplified in the microphotograph here shown of a section of skin taken from the tips of the fourth digit of a young man's hand.

A few observations have been made as to the variability of this phenomenon of imbrication of the papillary ridges of the human hand and foot. The details of these are given in an appendix, but the results may be summed up as follows :

* Imbrication of the Papillary Ridges in Man, *Journal of Anatomy and Physiology*, vol. xxxix.

- (1) *H.K.* male, eight and three-quarter years.

Right Hand.

Distal imbrication found on terminal phalanges of all digits, and two middle phalanges.

Palmar surface.—Distal imbrication on two of eminences at bases of digits and on thenar and hypothenar eminences.

Left Foot.

Digits.—Imbrication proximal on terminal phalanx of two digits.

Ball of great toe, imbrication proximal; fibular border of sole over a joint, imbrication proximal; heel, imbrication proximal.

- (2) *E.K.*, male, nineteen years.

Right Foot.

Digits.—Imbrication proximal on terminal phalanx of D. 1; imbrication distal on terminal phalanx of D. 1.

Plantar surface.—Ball of great toe, proximal imbrication; outer border of sole, proximal imbrication over two joints; heel, outer border, imbrication proximal.

Left Foot.

Digits.—D. 1, 2, 3, 4, 5, imbrication proximal and faintly marked.

Plantar surface.—Ball of great toe, imbrication distal. The rest of the plantar surface showed no imbrication.

- (3) *W.K.*, male, fifty-two.

Left Hand.

Digits.—All the five digits show distal imbrication on *all* the phalanges.

Right Hand.

Digits.—D. 1, distal imbrication on both phalanges; D. 2, distal imbrication on all three phalanges; D. 3, distal imbrication on two phalanges; D. 4, distal imbrication on two phalanges, proximal imbrication on one phalanx; D. 5, distal imbrication on two phalanges.

Left Hand.

Palmar surface.—Imbrication distal on the three small eminences at the bases of D. 2, 3, 4.

Right Hand.

Palmar surface.—Imbrication distal on four small eminences at the bases of D. 2, 3, 4, 5.

In these three carefully observed cases there are shown on the one hand, the variability of this phenomenon of imbrication of papillary ridges in man, and on the other, its constancy in certain regions of both the foot and hand. We have thus:

CASE 1.—Hand and foot of the same subject examined, distal imbrication being the feature of the former and proximal of the latter.

CASE 2.—Right and left foot of the same subject examined. The right shows more imbrication on the plantar surface and less on the digits. The left shows little or no imbrication on the plantar surface, and more on the digits.

CASE 3.—Right and left hand of the same subject examined. Both show almost exactly the same amount of distal imbrication on the digits and one shows a small area of proximal imbrication. Palmar surface of one shows one more small eminence at the base of a digit, with distal imbrication, than the other.

Among the various specimens examined microscopically the hand of one working man and the foot of another, in which the epidermis was much thickened by mechanical pressure, showed no imbrication of the ridges among upwards of fifty sections taken from these two subjects. Such a result as this, naturally suggests that the phenomenon in question is one which may have some explanation in the delicacy or otherwise of the uses to which the hand and foot are applied in different classes and individuals. The examination of the matter is a slow and rather laborious one and if pursued so as to establish any generalisation would require much application of time and trouble.

The meaning of this variable imbrication of papillary ridges, will be considered in the physiological part of this work, and it is here only necessary to point out certain of the most notable sections from the skin of the mammalian hand and foot, in which the phenomenon in question is found.

Great Ant-eater.—The earliest mammal in which I have been able to find imbrication of the palmar or plantar skin is an Edentate, the Great Ant-eater; and two illustrations of this are seen in Figs. 76, 77. There are no papillary ridges here, but the hard palmar and plantar epidermis is covered with flat scales which show a distal imbrication and it will be observed also, that the papillæ of the corium preserve a corresponding slant.

Rodents.—Among Rodents, many forms show well-marked transverse ridges on the digits with a distal imbrication, as in *Microtus*, *Mus musculus*, *Mus decumanus*; but these again are not true papillary ridges.

Carnivores.—The terminal phalanges of *Cercoleptes caudivolvulus* (Fig. 105) and of *Lutra vulgaris* (Fig. 106) show well-marked distal imbrication both of the rudimentary papillary ridges, and highly developed papillæ of the corium. In *Mustela vulgaris* (Fig. 108) there is a distal slant of the papillæ, but papillary ridges are not developed.

Primates.—It is among the Primates that imbrication of the ridges, which, of course, in this order of mammals are much more highly developed, shows itself most frequently. Examples may be pointed out in Fig. 118 of *Lemur brunneus*, with proximal imbrication of ridges on the palmar surface. A very striking instance is that in Fig. 135 of the skin of the palmar surface of *Papio porcarius*; here an interdigital pad is seen in section which is made through a whorl at the apex of the pad, and marked imbrication of ridges is visible, one each side of the whorl towards the apex. *Papio porcarius* (Fig. 136) is another case of distal imbrication of the plantar surface, *Papio babouini* (Fig. 137) of imbrication on each side of an interdigital pad directed away from the centre of the pad. Figs. 138, 139 of *Papio mormon* and Fig. 140 of *Cynopithecus niger*, are good specimens of distal imbrication of the ridges, as well as the papillæ of the corium. Figs. 146, 147, 149 of *Cercopithecus callitrichus* show good examples of distal and proximal imbrication of ridges. *Macacus inuus* (Fig. 142) shows well-marked proximal imbrication of the skin of the tip of the third digit of the foot.

Anthropoid Apes do not show any more marked instances of imbrication than many of the lower members of the Simian family. Fig. 152 of the Hoolock Gibbon may be noted, especially Fig. 153, where a longitudinal section from the heel is shown in which on one point in the surface the imbrication of the ridges and papillæ of corium diverges so that on the left of the section the direction is proximal and on the right it is distal.

The three Figs. 154, 155, 156 of an Orang show different degrees and directions of imbrication of ridges, Fig. 154 of the aborted pollex or D. 1 of this creature showing marked proximal imbrication even of its low, ill-defined papillary ridges. The sections from the skin of the hand and foot of man vary a good

deal in the presence and degree of imbrication of the ridges ; but Figs. 161, 162 have been chosen as instances of distal imbrication on the digits of the hand, and Fig. 165 of proximal imbrication on part of the plantar surface of the foot. Fig. 164 is a section through the tip of the second digit of the foot, and though the specimen was somewhat macerated, indicates a marked tendency of both ridges and papillæ of the corium to distal imbrication.

Birds.—The skin of the foot of birds frequently presents an imbrication either distal or proximal, of the scales covering the digits and plantar surface, as in Fig. 166 of an *Apteryx* or Fig. 168 of the terminal phalanx of a Partridge and Fig. 170, the well-marked proximal imbrication of the scales on the terminal phalanx of the fourth digit.

These cases have been chosen out of a large number so as to show how widely distributed is this small but important phenomenon.

CHAPTER II

DESCRIPTIONS OF SPECIES EXAMINED

BEFORE entering upon the detailed description of the various sections here represented, it is necessary again to state that only the more prominent features of the skin-structures will be dealt with, viz., the papillary ridges or their equivalents, the papillæ

FIG. 56.—AZARA'S OPOSSUM. *Didelphys azaræ*. $\times 25$.
Pes. Plantar surface, pad at base of D. 1 through
a whorl of papillary ridges.

of the corium, and the Drüsenleiste. The various outlines and groupings of these structures and especially the two first, alone concern the subject of the sense of touch, from the present point of view.

FIG. 53.—DUCK-BILLED PLATYPUS. *Ornithorhynchus*. $\times 15$. Pes.

FIG. 54.—SPINY ANT-EATER. *Echidna*. $\times 15$. Manus.

FIG. 55.—AZARA'S OPOSSUM. *Didelphys azarae*. $\times 15$. Manus, D. 2. Terminal phalanx, long. section.

FIG. 57.—TASMANIAN WOLF. *Thylacinus cynocephalus*. $\times 15$. Manus. Large palmar pad.

FIG. 58.—VULPINE PHALANGER. *Trichosurus vulpecula*. $\times 15$. Pes, D. 5. Terminal phalanx, long. section. Papillary ridges transverse.

FIG. 59.—VULPINE PHALANGER. *Trichosurus vulpecula*. $\times 15$. Pes. Plantar surface section through rows of scales, long. section.

MONOTREMES. *Ornithorhynchus* (Fig. 53).—This section is taken from a piece of the skin of the hind foot, which had been kept in alcohol for a considerable time and perhaps on this account may show too little differentiation of the skin-structures, but it would seem to have a simple epidermis and papillæ of the corium poorly developed.

Echidna (Fig. 54).—Section from forefoot. Papillæ of the corium, numerous and well-pointed, irregular grooves on the epidermis resembling papillary ridges.

MARSUPIALS. *Didelphys Azaræ*.—Fig. 55 gives a longitudinal section of the terminal phalanx of a digit of the forefoot, and at the right-hand side or tip of the phalanx are seen some rudimentary papillary ridges on the epidermis and corresponding papillæ of the corium.

Fig. 56 is from the hind foot on the plantar surface through a whorl of papillary ridges situated on an interdigital pad. Well-developed ridges, bifurcated or double papillæ of the corium and large Drüsenleisten are seen. This is a development of the skin-structures in a low Marsupial much beyond that of many higher forms between this group and the Primates.

Thylacinus cynocephalus (Fig. 57).—Section from large palmar pad of forefoot. Presents a rough irregular surface of the epidermis, not unlike those of Carnivores, and papillæ of the corium pointed, and formed very much as those of many Carnivores.

Trichosurus vulpecula (Fig. 58).—Longitudinal section through transverse papillary ridges on terminal phalanx of a digit of the hind foot. Ridges a little irregular, papillæ of the corium and Drüsenleisten well-formed.

Fig. 59 from plantar surface of hind foot; section through rows of scales, not formed here into papillary ridges. Each separate scale except two in centre of section, shows papillæ of the corium bifurcated by a well-formed Drüsenleiste.

Fig. 60, forefoot, tip of digit, longitudinal section through large well-formed papillary ridges, bifurcated papillæ of the corium and large Drüsenleisten.

Fig. 61, a longitudinal section from the under-surface of the tail, through transverse rows of scales resembling coarse papillary

FIG. 60.—VULPINE PHALANGER. *Trichosurus vulpecula*. $\times 15$. Manus, D. 3. Terminal phalanx (tip) section longitudinal through papillary ridges at right angles.

FIG. 61.—VULPINE PHALANGER. *Trichosurus vulpecula*. $\times 15$. Tail, ventral surface, scales here arranged in transverse rows. Section longitudinal.

FIG. 62.—POTOROO. *Potorous tridactylus*. $\times 25$. Pes, D. 3. Terminal phalanx, section longitudinal.

ridges. Each scale possesses, like those of Fig. 59 its own Drüsenleisten (two each) and poorly developed papillæ of the corium.

Potorous tridactylus.—Figs. 62, 63, 64 show the variable nodules found on the epidermis mostly lying in rows on the hind foot, and very long, well-formed papillæ of the corium extending far up into these epidermis nodules. This is common among the members of the Marsupial order.

FIG. 63.—POTOROO. *Potorous tridactylus*. $\times 25$. Pes, central D. Terminal phalanx, proximal portion, section longitudinal.

FIG. 64.—POTOROO. *Potorous tridactylus*. $\times 15$. Pes, central D. Terminal phalanx, distal portion, section longitudinal.

FIG. 65.—POTOROO. *Potorous tridactylus*. $\times 15$. Pes. Plantar surface, eminence on heel, section longitudinal.

FIG. 67.—BRUSH-TAILED WALLABY. *Petrogale penicillata*. $\times 15$. Pes. Plantar surface, distal portion of median region, longitudinal section.

Fig. 65.—Longitudinal section from the plantar surface through an eminence over the heel. The epidermis is thickened and shows no nodules or scales and the papillæ of the corium are closely-set and pointed.

Petrogale penicillata.—Fig. 66 is a longitudinal section through tessellated scales covering the terminal phalanx of a digit of the

hind foot and exhibits a striking grouping of the skin-structures. The scales, or nodules, are situated in rough transverse rows and are separated from one another by marked broad depression or furrows. Each scale has its own group of small papillæ of the corium, and a varying number of dark pigmented bands the deeper terminations of which end in openings of ducts of sweat-glands.

Fig. 67, from the plantar surface and Fig. 68, from the same surface in front of the heel, show a similar but less-marked

FIG. 66.—BRUSH-TAILED WALLABY. *Petrogale penicillata*. $\times 20$. Pes, D. 4, terminal phalanx, longitudinal section through tessellated scales.

arrangement of these dark bands and Drüsenleisten. Fig. 69, in front of the heel, shows still less differentiation of the structures and Fig. 70, a smooth thickened epidermis and level corium without any papillæ of the corium, no tessellated scales being present in this region, which is one subject to great pressure and not needing much, if any, assistance from the sense of touch.

Figs. 71, 72 are from the small forefoot and in keeping with its subordinate use in the life of the Kangaroo, the scales of the epidermis and Drüsenleisten and papillæ of the corium, are ill-developed.

Fig. 73, a section from the hind foot of (*Epyprymnus rufescens*, epidermis little modified, but papillæ of the corium very large and projecting far up into the epidermis.

Macropus antilopinus (Fig. 74).—The hind foot has large and projecting nodules into which the papillary layer of

FIG. 68.—BRUSH-TAILED WALLABY. *Petrogale penicillata*. $\times 15$. Pes. Plantar surface in front of heel, longitudinal section.

FIG. 69.—BRUSH-TAILED WALLABY. *Petrogale penicillata*. $\times 15$. Pes. Plantar surface in front of heel, longitudinal section.

FIG. 70.—BRUSH-TAILED WALLABY. *Petrogale penicillata*. $\times 15$. Pes. Plantar surface over heel section from skin, where the epidermis is much thickened, and there are no tessellated scales or papillæ of the corium, longitudinal section.

FIG. 71.—BRUSH-TAILED WALLABY. *Petrogale penicillata*. $\times 15$. Manus, D. I. Terminal phalanx, longitudinal section.

FIG. 73.—RUFIOUS RAT KANGAROO. *Epyprymnus rufescens*. $\times 25$. Pes. Plantar surface in front of heel, scales here become indistinct, section longitudinal.

the corium extends towards the free surface. Numerous Drüsenleisten in each nodule, and papillæ of the corium small and compound. There are darker pigmented bands, like those of *Petrogale*, but less marked extending up to the free surface of the epidermis and most of them connected with Drüsenleisten.

Fig. 75, another species of *Macropus* (*derbianus*) very similar to that of *Lepyprymnus rufescens*. Section from plantar surface of the hind foot. Papillæ highly developed, pointed and extending far up towards the free surface of the epidermis.

EDENTATES.—*Myrmecophaga jubata* (Figs. 76, 77) are

FIG. 72.—BRUSH-TAILED WALLABY. *Petrogale penicillata*. $\times 15$. Manus, D. 2.
Terminal and middle phalanges, section longitudinal.

sections of the fore and hind foot, the former being from the dorsal surface of the forefoot which is habitually doubled under and thus rests on the ground when the animal walks. Both are covered with low, wide scales with a distal imbrication and in both the papillæ of the corium are long and pointed, extending near to the free surface of the epidermis, and they partake in the distal slanting direction of the epidermic scales.

UNGULATES.—*Hyrax capensis* (Fig. 78) is that of a section from the plantar surface of the hind foot and presents little differentiation of the epidermis, which is smooth on the surface, with numerous small sharp-pointed papillæ of the corium.

RODENTS.—*Sciurus vulgaris*. Fig. 79, epidermis roughened with no definite arrangement of nodules or scales. Papillæ of the corium well-developed and pointed, projecting far up to the free surface.

FIG. 74.—ANTILOPINE KANGAROO. *Macropus antilopinus*. $\times 25$. Pes, central D. Terminal phalanx, section longitudinal.

FIG. 75.—*Macropus derbianus*. $\times 25$. Pes. Plantar surface pad over distal portion, section longitudinal.

FIG. 76.—GREAT ANT-EATER. *Myrmecophaga jubata*. $\times 25$. Manus, D. 4. Section from extensor surface doubled under so as to rest on the ground, longitudinal.

Sciurus cinereus (Fig. 80).—Epidermis thrown more into folds forming rudimentary papillary ridges, Drüsenleisten and papillæ of the corium, well-developed.

FIG. 77.—GREAT ANT-EATER. *Myrmecophaga jubata*. $\times 15$. Pes. Plantar surface fibular border, at base of D. 5 skin here covered with thick scales, section longitudinal.

FIG. 78.—CAPE HYRAX. *Hyrax capensis*. $\times 15$. Pes. Plantar surface, pad on fibular side, skin smooth, section longitudinal.

FIG. 79.—COMMON SQUIRREL. *Sciurus vulgaris*. $\times 60$. Manus. Palmar surface, transverse section.

Xerus capensis (Fig. 81).—Epidermis nearly smooth, sudoriparous ducts well shown. Papillæ of the corium low and rudimentary.

Arctomys marmotta (Fig. 82).—Both epidermis and papillary layer of the corium are little developed.

Mus decumanus (Fig. 83).—Section from eminence on plantar surface of hind foot, shows epidermis simple and papillæ of the corium pointed and closely-set.

Myopotamus coypu (Fig. 84).—Section through thick epidermis scales, papillæ of the corium irregular, mostly low, a few pointed.

Hystrix cristatus (Fig. 85).—Epidermis smooth and very simple, papillæ of the corium low and broad, extending into the epidermis only a short distance and separated by thick Drüsenleisten.

Erethizon dorsatus (Fig. 86).—Section through large nodules

FIG. 82.—ALPINE MARMOT. *Arctomys marmotta*. $\times 30$. Pes. Plantar surface, pad at bases of D. 3, 4. Section longitudinal.

on the plantar surface, each nodule with its sudoriparous duct and small compound papillæ of the corium.

Calogenys paca (Fig. 87).—Epidermis divided into marked nodules, each with numerous Drüsenleisten and small papillæ of the corium.

Hydrochyrus capybara (Fig. 88).—Section from pad on palmar surface of fore foot, epidermis simple, papillæ of the corium very long and pointed.

Lepus cuniculus (Fig. 89).—Section from the terminal phalanx of a digit of the hind foot. Epidermis here thickly covered with fine hairs and modified into long rod-like extensions to which are attached the hairs. Papillæ of the corium little developed.

FIG. 80.—GREY SQUIRREL. *Sciurus cinereus*. $\times 15$. Pes. Plantar surface, pad at base of D. 3, longitudinal section.

FIG. 81.—SPINY SQUIRREL. *Xerus capensis*. $\times 15$. Pes. Plantar surface central pad, section longitudinal.

FIG. 83.—COMMON RAT. *Mus decumanus*. $\times 15$. Pes. Plantar eminence on fibular side, section longitudinal.

FIG. 84.—COYPU. *Myopotamus Coypu*. $\times 15$. Pes, D. 3. Terminal phalanx ; longitudinal section through thick epidermic scales.

CARNIVORES (Fig. 90).—Transverse section from the central pad of a specimen, *F. Leo*. born dead ; structures not well shown, but pointed papillæ, coiled sweat-glands and large Drüsen-leisten are visible.

Felis domestica (Fig. 91).—Longitudinal section from hind foot through central pad, magnified twenty-five times. Fig. 92, from central pad on forefoot magnified sixty times. Both sections show a corrugated surface of the epidermis and long pointed papillæ of the corium.

Arctigolidia trivergata (Fig. 93.)—Fore-foot, terminal phalanx of a digit, with bare epidermis, very marked Drüsenleisten and short but pointed papillæ of the corium.

FIG. 85.—COMMON PORCUPINE. *Hystrix cristatus*. $\times 50$. Pes. Plantar pad, fibular side, skin bare, no scales, section longitudinal.

Fig. 94.—Hind foot, longitudinal section through plantar surface. Epidermis shows rough nodules on its free surface and the papillæ of the corium are irregular but somewhat pointed.

Viverra civetta (Fig. 95).—Hind foot, section through interdigital pad. Epidermis simple and smooth. Papillæ of the corium at wide intervals and pointed.

Herpestes griseus (Figs. 96, 97).—Simple epidermis and irregular pointed papillæ on hind foot. Corrugated epidermis and irregular papillæ little pointed on forefoot.

FIG. 86.—CANADIAN PORCUPINE. *Erethizon dorsatus*. $\times 15$. Pes. Longitudinal section through large nodules.

FIG. 87.—PACA. *Cecogenys paca*. $\times 15$. Manus. Palmar surface, pad at bases of D. 2, D. 3, D. 4, section transverse.

FIG. 88.—CAPYBARA. *Hydrochaerus capybara*. $\times 15$. Manus. Palmar surface, pad at base of D. 3, longitudinal section.

FIG. 89.—RABBIT. *Lepus cuniculus*. $\times 15$. Pes, D. 3. Terminal phalanx thickly covered with short hairs, longitudinal section.

Suricata tetradactyla (Fig. 98).—From terminal phalanx of a digit, showing simple epidermis and highly pointed papillæ of the corium.

Crossarchus fasciatus (Fig. 99).—Oblique section through interdigital pad. Epidermis nodulated, each nodule possessing a group of low and pointed papillæ of the corium.

FIG. 90.—LION (born dead).—*Felis leo*. $\times 100$. Manus. Central pad, transverse.

FIG. 91.—DOMESTIC CAT. *Felis domestica*. $\times 25$. Pes. Plantar surface, central pad, longitudinal section.

FIG. 92.—DOMESTIC CAT. *Felis domestica*. $\times 60$. Manus. Central pad on palmar surface, longitudinal section.

FIG. 93.—THREE-BANDED CIVET. *Arcigolidia trivergata*. $\times 15$. Manus, D. 2. Terminal phalanx, longitudinal section through bare epidermis.

FIG. 94.—THREE-BANDED CIVET. *Arcigolidia trivergata*. $\times 15$. Pes. Plantar surface, longitudinal section through rough nodules.

FIG. 95.—AFRICAN CIVET. *Viverra civetta*. $\times 50$. Pes. Plantar surface, interdigital pad at bases of D. 3, D. 4. Section longitudinal.

FIG. 96.—GREY ICHNEUMON. *Herpestes griseus*. $\times 15$. Pes. Plantar surface, central pad, longitudinal section.

Proteles cristatus (Fig. 100).—Terminal phalanx of digit of hind foot. Epidermis is here very smooth on surface, papillæ of the corium closely-set and pointed with thick Drüsenleisten between them.

Canis familiaris (Fig. 101).—Section from plantar surface through a pad from forefoot of a Great Dane. Epidermis greatly thickened and divided into long rods separated from one another at the free surface. Papillæ of the corium very close and pointed. No Drüsenleisten to be seen.

FIG. 97.—GREY ICHNEUMON. *Herpestes griseus*. $\times 35$. Manus.
Palmar surface, central interdigital pad, longitudinal section.

FIG. 98.—SURICATE. *Suricata tetradactyla*. $\times 60$. Pes, D. I.
Terminal phalanx, longitudinal section.

FIG. 99.—BANDED MUNGOOSE. *Crossarchus fasciatus*. $\times 15$. Pes. Plantar surface, pad at base of D. 5, epidermis here granulated, oblique section.

FIG. 100.—AARD WOLF. *Proteles cristatus*. $\times 15$. Pes, D. 2. Terminal phalanx, epidermis bare, longitudinal section.

FIG. 101. GREAT DANE. *Canis familiaris*. $\times 20$. Manus. Pad on palmar surface, transverse section.

FIG. 102.—DACHSHUND. *Canis familiaris*. $\times 30$. Manus, D. 3.
Terminal phalanx, longitudinal section.

FIG. 103.—AMERICAN BLACK BEAR. *Ursus Americanus*. $\times 25$. Manus.
Pad on palmar surface.

Canis familiaris (Fig. 102).—Section from terminal phalanx of forefoot of a Dachshund. Very prominent rod-like extensions of the superficial layer of the epidermis arranged in a slanting direction. Papillæ of the corium extremely pointed and very well defined.

FIG. 104.—COMMON RACCOON. *Procyon lotor*. $\times 15$. Manus, D. 3. Terminal phalanx, section longitudinal through rudimentary papillary ridges.

FIG. 105.—KINKAJOU. *Cercoleptes caudivolvulus*. $\times 20$. Pes, D. 5. Terminal and middle phalanges, longitudinal section. Distal imbrication of papillary ridges and papillæ of corium.

Ursus Americanus (Fig. 103).—Section from a pad on the palmar surface of the forefoot. No defined arrangement of epidermis or free surface, and no Drüsenleisten seen. Papillæ of the corium at rather wide intervals, but well defined and pointed sharply.

Procyon lotor (Fig. 104).—Terminal phalanx of forefoot. Section made through a group of rudimentary papillary ridges. Coiled ducts of sweat-glands shown and pointed papillæ of the corium at wide intervals.

FIG. 106.—COMMON OTTER. *Lutra vulgaris*. $\times 30$. Manus, D. 2. Tip of terminal phalanx through rudimentary papillary ridges, which disappear on the proximal (left) side of section, longitudinal.

Cercoleptes caudivolvulus (Fig. 105).—Terminal and middle phalanges of the fifth digit of the hind foot : longitudinal section showing rudimentary papillary ridges on right of section, with a distal imbrication, and well-defined, blunt-pointed papillae of the corium also imbricated in a distal direction.

Lutra vulgaris (Fig. 106).—Longitudinal section through terminal phalanx of a digit of the forefoot. On the right is the tip of the phalanx and here the epidermis shows rudimentary papillary ridges, imbrication distal, and beneath each of these ridges a very long-pointed papilla extending nearly to the free surface of the epidermis. To the left or proximal end of the

phalanx the papillary ridges disappear and the papillæ of the corium become very small and less pointed, and reach much less near to the free surface.

Mellivora indica (Fig. 107).—Longitudinal section from palmar pad of forefoot, with a smooth surface to the epidermis and very long and pointed papillæ of the corium.

Mustela vulgaris (Fig. 108).—Terminal phalanx of a digit on

FIG. 107.—RATEL. *Mellivora indica*. $\times 50$. Manus, D. 2.
Pad on palmar surface, longitudinal section.

the forefoot with a rough and irregular surface on the epidermis and particularly long and pointed papillæ of the corium.

Mustela erminea.—Figs. 109, 110 show sections from terminal phalanges of different digits of the forefoot, the epidermis irregular and rough, the papillæ of the corium long and pointed and particularly so in Fig. 57 from the second digit.

Otaria pusilla (Fig. 111).—Transverse section from skin of plantar surface of hind foot. Epidermis covered with extremely fine longitudinal papillary ridges here shown cut across; each of

FIG. 108.—COMMON WEASEL. *Mustela vulgaris*. $\times 60$. Manus, D. 1. Terminal phalanx, longitudinal section.

FIG. 109.—STOAT. *Mustela erminea*. $\times 35$. Manus, D. 2. Terminal phalanx, longitudinal section.

these with groups of Drüsenleisten and low-pointed papillæ of the corium.

Otaria pusilla (Fig. 112).—Transverse section through thin skin at the free end of a digit of the hind foot. Papillary ridges on epidermis very well marked and closely set. Dorsal and ventral surfaces shown in section. Papillæ of the corium low and indefinite.

INSECTIVORES. *Talpa europæus* (Fig. 113).—Longitudinal section through palmar surface of forefoot. Epidermis here

FIG. 110.—STOAT. *Mustela erminea*.
× 15. Manus, D. 3. Terminal
phalanx, longitudinal section.

FIG. 111.—CAPE SEA LION. *Otaria
pusilla*. × 15. Pes. Plantar
surface at right angles to papil-
lary ridges; transverse section.

FIG. 112.—CAPE SEA LION. *Otaria pu-
silla*. × 15. Pes, D. 1. Tip,
transverse section through thin
terminal skin of flipper. Papil-
lary ridges very well-marked and
closely-set.

FIG. 113. COMMON MOLE. *Talpa
europæus*. × 15. Manus. Pal-
mar surface, longitudinal sec-
tion.

thrown into strong tough scales. Drüsenleisten shown, but at irregular intervals, and papillæ of the corium little defined.

Erinaceus europæus (Fig. 114).—Longitudinal section through ulnar side of palmar surface of forefoot. The epidermis is simple, Drüsenleisten shown, and the papillæ of the corium

FIG. 114.—HEDGEHOG. *Erinaceus europæus*. $\times 15$. Manus. Palmar surface, ulnar pad, longitudinal section.

FIG. 117.—BLACK-HEADED LEMUR. *Lemur brunneus*. $\times 15$. Manus, D. 1 terminal phalanx (tip), longitudinal section.

FIG. 115.—COMMON HEDGEHOG. *Erinaceus europæus*. $\times 35$. Manus, D. 1. Longitudinal section.

FIG. 116.—INDIAN FOX-BAT. *Pteropus medius*. $\times 50$. Pes, D. 5. Terminal phalanx, longitudinal section.

close and pointed, extending up near to the free surface of the epidermis.

Fig. 115.—From a terminal phalanx of a digit of the forefoot, and showing smooth epidermis and well-defined Drüsenleisten and papillæ of the corium especially on right-hand side of the section.

CHIROPTERA. *Pteropus medius* (Fig. 116).—Longitudinal section from a terminal phalanx of hind foot with smooth epidermis and fine-pointed papillæ of the corium, Drüsenleisten thick and well developed.

PRIMATES. *Lemur brunneus*.—Fig. 117 represents the skin-structures at the tip of the terminal phalanx of a digit of the forefoot. A longitudinal section commencing on the right hand of the drawing, close to the nail and passing through the pulp of the digit; about midway, the section is seen to be in the line of the papillary ridges which are here nearly longitudinally placed. The right-hand portion shows very marked papillary ridges, long and pointed Drüsenleisten, and papillæ of the corium bifurcated by the latter. The left-hand portion has a different relation, viz., a parallel one, to the papillary ridges and shows very little.

Fig. 118.—A longitudinal section from the palmar surface through an eminence on the radial side of the forefoot. The papillary ridges well marked and show a proximal imbrication. The Drüsenleisten are long and pointed and papillæ of the corium bifurcated.

Fig. 119 is a similar section from the ulnar side of the same forefoot.

Figs. 120, 121 show transverse and longitudinal sections of the terminal phalanx of the third digit of the hind foot—each has closely set papillæ of the corium, papillary ridges, and large Drüsenleisten, but the transverse section (Fig. 120) shows the papillæ of the corium more pointed and closely-set than the longitudinal.

Fig. 122 is a transverse section of the terminal phalanx of a digit of the hind foot. In this section the papillary ridges are marked and the papillæ of the corium particularly long

FIG. 118.—BLACK-HEADED LEMUR. *Lemur brunneus*. $\times 20$. Manus. Palmar surface; long pad on radial side, longitudinal section; imbrication proximal.

FIG. 119.—BLACK-HEADED LEMUR. *Lemur brunneus*. $\times 15$. Manus. Palmar surface, pad on ulnar side, longitudinal section.

FIG. 120.—BLACK-HEADED LEMUR. *Lemur brunneus*. $\times 15$. Pes, D. 3. Terminal phalanx, transverse section.

and pointed, running nearly up to the free surface of the epidermis.

Fig. 123 gives an oblique section from the plantar surface of the hind foot through an eminence and the ridged nodules (referred to in Part I. and figured), and Fig. 124 also shows a similar section from a pad at the base of the first digit. Both these show the groups of two, three or four Drüsenleisten belong-

FIG. 121.—BLACK-HEADED LEMUR. *Lemur brunneus*. $\times 15$. Pes. D. 3. Terminal phalanx, longitudinal section.

FIG. 123.—BLACK-HEADED LEMUR. *Lemur brunneus*. $\times 15$. Pes. Planar surface, at base of D. 1, through pad on tibial side and nodules, oblique section.

FIG. 122.—BLACK-HEADED LEMUR. *Lemur brunneus*. $\times 25$. Pes. D. 3. Terminal phalanx, transverse section.

ing to each nodule and the papillæ of the corium separated by the Drüsenleisten. The spaces between the separate nodules, show only furrows of the epidermis and folds of its deeper surface and no other structures.

Lemur mungoz (Fig. 125).—This is a very good illustration of the marked papillary ridges, below each of which is seen a long, pointed Drüsenleiste, and divided by these are papillæ of the corium also sharply pointed. This is a transverse section from

FIG. 124.—BLACK-HEADED LEMUR, *Lemur brunneus*. $\times 15$. Pes. Plan-
tar surface, distal portion of pad
at base of D. I, through nodules,
longitudinal section.

FIG. 126.—RING-TAILED LEMUR, *Lemur catta*. $\times 15$. Pes, D. I. Ter-
minal phalanx, transverse sec-
tion.

FIG. 125.—MUNGOOSE LEMU *Lemur mongoz*. $\times 30$. Pes, D. I.
Terminal phalanx at tip, transverse section.

the terminal phalanx of the third digit of the hind foot and is taken at right angles to the line of the papillary ridges, an arrangement which has in almost all other cases been observed.

Lemur catta (Fig. 126).—A transverse section from the terminal phalanx of the first digit of the hind foot, and it shows well the

FIG. 127.—GREAT GALAGO. *Galago crassicaudata*. $\times 30$. Manus, D, 4. Terminal phalanx, transverse section.

FIG. 128.—SLOW LORIS. *Nycticebus tardigradus*. $\times 30$. Pes, D, 2. Transverse section.

marked papillary ridges, close-pointed Drüsenleisten and small folds of epidermis between these, and pointed papillæ of the corium.

Galago crassicaudata (Fig. 127).—Transverse section through the terminal phalanx of a digit of the forefoot. Papillary ridges not well developed, but papillæ of the corium very

FIG. 129.—JAVAN LORIS. *Nycticebus javanicus*. $\times 25$. Pes, D. 2. Terminal phalanx, transverse section.

FIG. 130.—NEGRO TAMARIN. *Midas ursulus*. $\times 15$. Pes, D. 1. Terminal phalanx, transverse section.

FIG. 131.—NEGRO TAMARIN. *Midas ursulus*. $\times 15$. Manus. Palmar surface, pad at base of D. 1, longitudinal section.

close and pointed and approaching the free surface of the epidermis.

Nycticebus tardigradus (Fig. 128) and *Nycticebus javanicus* (Fig. 129) show transverse sections from the terminal phalanges of the hind foot, and has characters very much like those of *Galago crassicaudata* (Fig. 127).

FIG. 132.—MARMOSET. *Hapale jacchus*. $\times 25$. Manus. Palmar surface, hypothenar pad, longitudinal section.

FIG. 134.—SQUIRREL MONKEY. *Chrysotrrix sciurea*. $\times 25$. Pes. Plantar surface, pad at base of D. 5, longitudinal section.

FIG. 135.—CHACMA BABOON. *Papio porcarius*. $\times 15$. Manus. Palmar surface, central interdigital pad; longitudinal section through whorl; imbrication on each side of whorl directed to the apex.

FIG. 133.—SQUIRREL MONKEY. *Chrysothrix sciurea*. $\times 15$. Manus, D. 2. terminal phalanx (tip), longitudinal section.

FIG. 136.—CHACMA BABOON. *Papio porcarius*. $\times 15$. Pes. Plantar surface, fibular border, longitudinal section; distal imbrication.

Midas ursulus (Fig. 130).—A transverse section of a terminal phalanx of the hind foot showing irregular papillary ridges, long Drüsenleisten and long and pointed papillæ of the corium. (Fig. 131).—Longitudinal section through palmar pad at the base of a digit of the forefoot. Very marked and relatively large Drüsenleisten, low papillary ridges, and blunt, low papillæ of the corium.

Hapale jacchus (Fig. 132).—Longitudinal section from a pad on the palmar surface of the forefoot. Papillary ridges low, Drüsenleisten large and papillæ of the corium not highly developed.

Chrysothrix sciurea (Fig. 133).—Longitudinal section from the terminal phalanx of a digit of the forefoot, with low papillary ridges and highly developed Drüsenleisten and papillæ of the corium.

Chrysothrix sciurea (Fig. 134).—Longitudinal section from plantar surface of the hind foot, from a pad at the base of D. 5. Papillary ridges more definite than those of Fig. 81, Drüsenleisten less pointed and shorter, also papillæ of the corium shorter and wider.

Papio porcarius (Fig. 135).—Longitudinal section from an interdigital palmar pad of the forefoot through a whorl of papil-

FIG. 137.—YELLOW BABOON. *Papio babouini*. $\times 15$. Manus. Palmar surface, middle interdigital pad, transverse section.

FIG. 138.—MANDRILL. *Papio mormon*. $\times 25$. Manus. Palmar surface, ulnar border, longitudinal section; imbrication distal.

FIG. 139.—MANDRILL. *Papio mormon*. $\times 25$. Pes. Plantar surface, fibular border, in front of heel; slight imbrication of papillary ridges and of papillæ of corium; longitudinal section.

lary ridges. The apex of the whorl is in the centre and on either side of it are well-marked papillary ridges with an imbrication directed towards the apex. Drüsenleisten small, papillæ of the corium pointed.

Fig. 136.—Longitudinal section from the plantar surface of the hind foot, with marked papillary ridges imbricated in a distal direction, coiled sweat-duets passing down from each of these to the Drüsenleisten which are pointed and not very long, papillæ of the corium not well developed.

FIG. 140.—BLACK APE. *Cynopithecus niger*. $\times 15$. Pes, D. 4. Middle phalanx, imbrication distal, longitudinal section.

FIG. 141.—BLACK APE. *Cynopithecus niger*. $\times 15$. Pes, D. 5. Terminal phalanx, longitudinal section.

Papio babouini (Fig. 137).—Transverse section through an interdigital pad on the palmar surface of the forefoot, showing papillary ridges with imbrication directed away from the centre of the pad, and Drüsenleisten and papillæ of the corium not well marked.

Papio mormon (Fig. 138).—Longitudinal section from the ulnar border of the palmar surface of the forefoot, showing low papillary ridges, and these with a distal imbrication; blunt, short Drüsenleisten, and bifurcated papillæ of the corium.

Fig. 139.—Longitudinal section from plantar surface on the fibular side in front of the heel. Papillary ridges, low and

ill-defined, with a slight distal imbrication, thick, short Drüsenleisten, and papillæ of the corium somewhat indefinite.

Cynopithecus niger (Figs. 140, 141).—Longitudinal sections from middle and terminal phalanges of D. 4 and D. 5, the former with distal imbrication of the papillary ridges, coiled sweat-ducts extending from the free surface of the epidermis, and irregular Drüsenleisten and papillæ of the corium.

Macacus inuus (Fig. 142).—Longitudinal section from tip of terminal phalanx of a digit of the hind foot. Papillary ridges proximally imbricated and Drüsenleisten small, papillæ of the corium prominent and wide.

Ceercobus collaris (Fig. 144).—Longitudinal section through tip of terminal phalanx of a digit of the forefoot. Papillary ridges somewhat indefinite. Drüsenleisten and papillæ of the corium well developed.

Cercopithecus diana (Fig. 145).—Transverse section through terminal phalanx of a digit of the hind foot. Papillary ridges, Drüsenleisten, and papillæ of the corium well developed, especially the two former.

Cercopithecus callitrichus (Figs. 146, 147) are microphotograph and drawing of the same longitudinal section. Papillary ridges clear and large, and with proximal imbrication, the Drüsenleisten and papillæ of the corium moderately developed.

Fig. 148.—Longitudinal section through terminal phalanx of a digit of the hind foot. Papillary ridges large and slightly imbricated in a proximal direction, thick, large Drüsenleisten and pointed papillæ of the corium.

Fig. 149.—Longitudinal section through an interdigital pad on the plantar surface of the hind foot. Papillary ridges pointed and very much imbricated in a distal direction, Drüsenleisten small, papillæ of the corium low.

SIMIIDÆ. *Hylobates lar* (Fig. 150).—Longitudinal section through terminal phalanx at tip of a digit of the hind foot, and (Fig. 151) transverse section through plantar surface. Both show well-marked papillary ridges (Fig. 150), pointed Drüsenleisten and papillæ of the corium (Fig. 151), larger Drüsenleisten

FIG. 142.—BARBARY MACAQUE. *Macacus inuus*. $\times 25$. Pes D. 3. Terminal phalanx (tip). Imbrication proximal, longitudinal section.

FIG. 144.—WHITE-COLLARED MAN-GABEY. *Cercopithecus collaris*. $\times 15$. Manus D. 1. Terminal phalanx (tip), longitudinal section.

FIG. 145.—DIANA MONKEY. *Cercopithecus dianae*. $\times 15$. Pes D. 4. Terminal phalanx, transverse section.

FIG. 146.—GREEN MONKEY. *Cercopithecus callitrichus*. $\times 25$. Manus. Palmar surface, interdigital pad on ulnar side over carpus; imbrication proximal; longitudinal section.

FIG. 147.—GREEN MONKEY. *Cercopithecus callitrichus*. $\times 15$. Manus. Palmar surface, interdigital pad on ulnar side; imbrication proximal, longitudinal section.

FIG. 149.—GREEN MONKEY. *Cercopithecus callitrichus*. $\times 15$. Pes. Plantar surface, interdigital pad at base of D. 3 and D. 4, through a whorl; imbrication distal, longitudinal section.

FIG. 148.—GREEN MONKEY. *Cercopithecus callitrichus*. $\times 25$. Pes, D. 5. Terminal phalanx (tip); imbrication proximal, longitudinal section.

pointed papillæ of the corium, and folds of epidermis between them markedly developed.

Hylobates hoolock (Fig. 152).—An oblique section through interdigital pad on plantar surface of hind foot. Papillary ridges showing irregular proximal imbrication, Drüsenleisten and papillæ of the corium not well-defined.

Fig. 153.—Longitudinal section through skin over heel. On

FIG. 150.—LAR GIBBON. *Hylobates lar*. $\times 30$. Pes, D. 1. Terminal phalanx (tip), longitudinal section.

FIG. 151.—LAR GIBBON. *Hylobates lar*. $\times 35$. Pes. Plantar surface, base of D. 3, transverse section.

the left side of the section well-developed proximal imbrication of the papillæ of the corium, with very small Drüsenleisten, and on the right distal imbrication. No papillary ridges; epidermis thickened.

Simia satyrus (Fig. 154).—Longitudinal section from the aborted terminal phalanx of the first digit of the fore-

FIG. 152.—HOOLOCK GIBBON. *Hyllobates hoolock*. $\times 15$. Pes. Interdigital pad at base of D. I. Imbrication proximal; oblique section.

FIG. 153.—HOOLOCK GIBBON. *Hyllobates hoolock*. $\times 15$. Pes. Plantar surface over heel; imbrication of papillae of corium proximal on left of centre of section, distal on right, longitudinal section.

FIG. 154.—ORANG. *Simia satyrus*. $\times 25$. Manus, D. I (aborted). Terminal phalanx; imbrication proximal, longitudinal section.

foot. Papillary ridges low, but with marked proximal imbrication.

Fig. 155.—Longitudinal section from proximal phalanx of a digit of the forefoot. Papillary ridges highly developed, and showing distal imbrication. Drüsenleisten and papillae of the corium small and low.

FIG. 155.—ORANG. *Simia satyrus*. $\times 25$. Manus, D. 2. Proximal phalanx, ulnar side; imbrication distal, longitudinal section.

FIG. 156.—ORANG. *Simia satyrus*. $\times 15$. Pes. Plantar surface over heel, fibular side, oblique section; imbrication distal.

FIG. 157.—ORANG. *Simia satyrus*. Pes, D. 1. Terminal phalanx, dorsal surface. Transverse section across aberrant, longitudinally placed papillary ridges.

Fig. 156.—Longitudinal section from plantar surface, fibular side of heel, the papillary ridges low and compressed, but showing distal imbrication, some larger and some small Drüsenleisten, papillæ of the corium pointed.

Fig. 157.—An interesting section (transverse) from the dorsal surface of the terminal phalanx, near the nail, of the first digit

of the hind foot made across some aberrant longitudinally-placed papillary ridges. Under these are seen well-developed papillæ of the corium markedly larger and more prominent than are found in sections from skin where there are no papillary ridges.

Anthropopithecus troglodytes (Fig. 158).—Transverse section from an interdigital pad on the palmar surface of the forefoot, showing large clear, papillary ridges, low, thick Drüsenleisten, with bifurcated, low and pointed papillæ of the corium.

Fig. 159.—Transverse section from pad at the base of D. I on the palmar surface of the forefoot, shows long, close-set papillæ of the corium, and well-marked Drüsenleisten, free surface of the epidermis being little differentiated.

Fig. 160.—Longitudinal section from tip of terminal phalanx, showing low, papillary ridges of digit of hind foot, low papillæ of the corium, and small Drüsenleisten.

Man (Fig. 161).—Longitudinal section from the terminal phalanx of the fourth digit of the hand. Papillary ridges low and somewhat worn down and showing distal imbrication. Papillæ of the corium double and very marked with Drüsenleisten, moderately developed, dividing the papillæ. One group of these elements belongs to each papillary ridge.

Fig. 162.—Longitudinal section from fifth digit, terminal phalanx of hand, also showing distal imbrication, and papillæ of the corium more pointed and less clearly defined.

Fig. 163.—Transverse section (resembling Fig. 157 of *Simia satyrus*) across the dorsal surface of the terminal phalanx of the fourth digit taken near the root of the nail. This is made at right angles to certain aberrant longitudinally-placed papillary ridges. On the right side of the section are these ridges, and underneath them very numerous pointed, closely-set papillæ of the corium; on the left side are no papillary ridges and no papillæ of the corium are to be seen. This section shows particularly well the connection between papillary ridges and papillæ of the corium.

Fig. 164.—Longitudinal section through the pulp of the terminal phalanx of the second digit of the foot. Imbrication

FIG. 158. — CHIMPANZEE. *Anthropopithecus troglodytes*. $\times 30$. Manus. Palmar surface, interdigital pad at base of D. 3, transverse section; imbrication proximal.

FIG. 159. — CHIMPANZEE. *Anthropopithecus troglodytes*. $\times 15$. Manus. Palmar surface, pad at base of D. 3, transverse section.

FIG. 160. — CHIMPANZEE. *Anthropopithecus troglodytes*. $\times 15$. Pes, D. 1. Terminal phalanx (tip), longitudinal section.

FIG. 161. — MAN. $\times 25$. Manus, D. 4. Terminal phalanx; imbrication distal, longitudinal section.

FIG. 162.—MAN. (Young adult.) $\times 25$. Manus, D. 5. Terminal phalanx, radial side; imbrication distal.

of papillary ridges in a distal direction, and of the papillæ of the corium. Stratum corneum of the epidermis a little macerated.

Fig. 165.—Longitudinal section from the plantar surface of the heel on the fibular side, epidermis thickened, papillary ridges imbricated in a proximal direction, and papillæ of the corium taking the same course.

BIRDS. *Apteryx mantelli* (Fig. 166).—Longitudinal section from the terminal phalanx of a digit of the foot. Scales shown to take a distal slanting direction, and papillæ of the corium similarly slanted, these being wide, and each divided into numerous secondary papillæ.

Rhea Americana (Fig. 167).—Longitudinal section from plantar eminence of foot. Scales rough and thick. Papillæ of the corium very highly developed, and extending close up to the free surface of the epidermis.

Perdix cinerea (Fig. 168).—Longitudinal section from terminal phalanx of D. 3. Scales imbricated in a distal direction, papillæ of the corium large, and passing up near to the free surface of the epidermis, and divided into secondary papillæ.

Lagopus (Fig. 169).—Longitudinal section through terminal phalanx. Scales not imbricated. Papillæ wide, and extend close to free surface, not divided up into secondary papillæ.

Ciconia alba (Fig. 170).—Longitudinal section through proximal phalanx of a digit, scales very much imbricated in a

FIG. 163.—MAN. $\times 25$. Manus D. 4. Terminal phalanx, dorsal surface at root of nail; transverse section across aberrant longitudinally-placed, papillary ridges on the right half of section; on the left half no papillary ridges; and much aborted papillae of the corium.

FIG. 164.—MAN. $\times 25$. Pes, D. 2. Terminal phalanx through centre of pulp. Imbrication distal, longitudinal section.

FIG. 165.—MAN. $\times 15$. Pes. Plantar surface over heel, fibular side. Imbrication proximal, longitudinal section.

FIG. 166.—NORTH ISLAND KIWI. *Apteryx Mantelli*. $\times 25$. Pes, D. 2. Terminal phalanx. Imbrication distal, longitudinal section.

FIG. 167.—COMMON RHEA. *Rhea Americana* $\times 25$. Pes. Plantar pad between D. 3 and D. 4, longitudinal section.

proximal direction. Papillæ of the corium highly developed, long and pointed.

Aquila audax (Fig. 171).—Longitudinal section through terminal phalanx of a digit. Scales greatly elongated, and projecting almost like spines, and papillæ of the corium long, pointed, and reaching near to the free surface of each pointed scale.

FIG. 168.—PARTRIDGE. *Perdix cinerea*. $\times 25$. Pes, D. 3. Terminal phalanx, imbrication of scales distal, longitudinal section.

FIG. 169.—GROUSE. *Lagopus*. $\times 25$. Pes, D. 3. Terminal phalanx, longitudinal section.

Tinnunculus alaudarius (Fig. 172).—Longitudinal section from proximal phalanx of a digit. Scales rough and irregular, papillæ of the corium large and wide, and extending near to the free surface of the epidermis.

Corvus corax (Fig. 173).—Longitudinal section from pad at the bases of the digits. Scales thickened and projecting and showing a distal imbrication. Papillæ of the corium very long and pointed, and extending near to the free surface of the epidermis.

FIG. 170.—WHITE STORK. *Ciconia alba*. $\times 25$. Pes, D. 4. Proximal phalanx, imbrication proximal, longitudinal section.

FIG. 171.—WEDGE-TAILED EAGLE. *Aquila audax*. $\times 25$. Pes, D. 1. Terminal phalanx, longitudinal section.

FIG. 172.—COMMON KESTREL. *Tinnunculus alaudarius*. $\times 35$. Pes, D. 2. Proximal phalanx, longitudinal section.

FIG. 173.—RAVEN. *Corvus corax*. $\times 15$. Pes. Pad at base of D. 4. Scales well-marked and rough; imbrication distal, longitudinal section.

Summary.—The foregoing results and descriptions may be summed up briefly; the explanation of the numerous variations in the skin-structures will be left to the section which deals with the physiological side of the matter.

Of the three main elements of the skin here illustrated, *Drusenleisten*, *papillary ridges*, and *papilla of the corium*, the first are seen in the course of a study of the various sections

of skin to be very prominent, and in many of them more so than the papillary ridges or papillæ of the corium. But in considering the sense of touch which resides in the hand and foot of mammals, these structures can only be looked upon as of secondary importance, and their function and meaning will be discussed later. Most of the sections show that each of these ridges of the under-surface of the epidermis, which Blaschko and Miss Whipple have called Drüsenleisten, because of their relation to sweat-glands, corresponds to a papillary ridge, on which the duct opens, and they are very generally pigmented, from their close relation to the rete mucosum of the epidermis.

The following four general rules are illustrated from the cases brought forward :

(1) Differentiation of the papillary ridges, or their equivalents, and the papillæ of the corium, increases with the higher development of the species examined. (By the term "their equivalents" is meant the series of epidermic modifications, *scales*, *epidermic warts*, and *rods* which are functionally similar to the ridges, but of lower development.)

(2) The degrees of development of the papillary ridges and the papillæ of the corium are closely related to one another.

(3) The greatest development of the papillary ridges is shown by height, clearness of outline, and regularity of the ridges, and by the presence in certain areas of imbrication of the ridges, distal or proximal.

(4) The greatest development of the papillæ of the corium is shown by the acuteness of their angles, and their approximation to the free surface of the epidermis, and closeness to one another.

(1) Among the Monotremes and Marsupials the epidermic modifications are simple, as in Figs. 53, 54 of the former, and 57, 58, 59, 62, 63, 64, 66 to 72 of the latter. But the Tasmanian wolf, Fig. 57, has more highly developed papillæ of the corium than many higher forms. The two species of *Macropus*, Figs. 74, 75, and Fig. 73 of *Aepyprymnus rufescens*, have very highly developed papillæ of the corium, and marked epidermic nodules or warts. But of all the Marsupials (eight), only

two show true papillary ridges, viz., *Didelphys azarae* (Azara's Opossum), and *Trichosurus vulpecula*. *Petrogale penicillata* (the Brush-tailed Wallaby), Figs. 66 to 72, is interesting as showing much higher development both of the epidermic nodules or warts, and the papillæ of the corium on the hind foot than on the forefoot, and this is obviously correlated with the much greater importance to this animal of the functions of the former. Fig. 70 is instructive as showing the structure of the skin of the heel, in which no nodules are seen on the surface, the outer layer being much hardened, with entire absence of papillæ of the corium.

The Edentate examined shows a low organisation of the epidermis with flat scales, but a relatively high degree of development of the papillæ of the corium. Most of the eleven species of Rodents have all the skin-structures poorly developed, e.g., *Arctomys marmotta*, the Alpine Marmot (Fig. 82); *Xerus capensis* (Fig. 81); *Hystrix cristatus* (Fig. 85); *Erethizon dorsatus* (Fig. 86); *Myopotamus coypu* (Fig. 84); *Cælogenys paucæ* (Fig. 87).

One of the most singular of these epidermic modifications is that seen in Fig. 89, where a portion of the skin of the foot of a common rabbit is shown. The long, closely-set hairs are mixed with and attached to long rod-like extensions of the epidermis, and possess thus very good examples of "tactile hairs": the papillæ of the corium are not here very highly developed. The eighteen species of Carnivores examined are with few exceptions (e.g., *Arctigolidia trivergata*, Fig. 93; *Viverra civetta*, Fig. 95; *Herpestes griseus*, Figs. 96, 97; and *Proteles cristatus*, Fig. 100), notable for the acuteness of angle and closeness of the papillæ of the corium, e.g., *Felis domestica* Figs. 91, 92. *Suricata tetradactyla*, Fig. 98; *Canis familiaris*, Figs. 101, 102; *Ursus Americanus*, Fig. 103; *Cercoleptes candidivolvulus*, Fig. 105, and *Lutra vulgaris*, Fig. 106; *Mellivora*, Fig. 107; the *Mustelidae*, Figs. 108, 109, 110. The general differences between the differentiation of the skin-structures of the Rodents and Carnivores is consistent with the greater cerebral organisation and activity of habits of the latter group.

Among Insectivores the low development of the skin of the Mole, Fig. 113, is noteworthy, and is correlated with the rough digging-work required of the forefeet of this animal, and the special arrangements subserving the sense of touch which reside in the snout. The Hedgehog shows little differentiation of the elements of the skin (see Figs. 114, 115).

The only specimen from the *Chiroptera*, Fig. 116, is indicative of high development of the papillæ of the corium, and little modification of the epidermis. The *Lemuridæ*, *Lemur brunneus*, Figs. 117, 118, 119, 120, 121, 122; *Lemur mungoz*, Fig. 125; *Lemur catta*, Fig. 126; *Galago crassicaudata*, Fig. 127; *Nycticebus tardigradus* and *Javanicus*, Figs. 128, 129, are a striking group illustrating the fact that the lowest of the Primates are much above any of their known ancestors, or animals below them in the zoological scale. This group will be more particularly referred to in the physiological section. From this group onwards papillary ridges and papillæ of the corium become variously modified, but are always present in a high degree, as in *Hapalidæ*, Figs. 132, 131, 130; *Papio*, 135, 139; *Cercopithecidæ*, Figs. 142, 148; *Hylobatidæ*, Figs. 150 to 153; *Simia satyrus*, Figs. 154 to 157; *Antropopithecus troglodytes*, Figs. 158, 159, 160. In many of these special modifications and adaptations are seen. In Man the structures of the skin hardly show higher development than in many lower Primates, though the papillary ridges often imbricated in hand and foot, and the papillæ of the corium, as in Figs. 164, 161, 162, 165, are exceedingly well developed. Fig. 161 shows well the large compound papillæ of the corium at the tip of the fourth digit.

The eight birds shown have no elaborate epidermic modifications, but some very interesting arrangements of the papillæ of the corium, and imbrication of the scales (Figs. 166 to 173).

(2) This rule is illustrated throughout the series, even as low as *Didelphys*, Figs. 55, 54, where marked papillary ridges and papillæ of the corium go together, and obtains through the various groups, especially the Primates up to Man. The point may be best illustrated by referring to those cases where

low development of papillary ridges and papillæ of corium are associated, as in the hand of the Brush-tailed Wallaby, Figs. 71, 72 and the heel, Fig. 70; *Xerus capensis*, Fig. 81; *Hystrix cristatus*, Fig. 85; *Arctomys marmotta*, Fig. 82; *Myopotamus coypu*, Fig. 84; *Arctigolidia trivergata*, Figs. 93, 94; *Viverra civetta*, Fig. 95; *Herpestes griseus*, Figs. 96, 97; *Otaria pusilla*, Figs. 111, 112; *Talpa europæus*, Fig. 113; *Erinaceus europæus*, Figs. 114, 115.

(3) Illustrations of the greatest perfection of the papillary ridges are *Didelphys azarae*, Figs. 55, 54; the *Lemuridæ*, Figs. 117 to 129; *Papio*, 135 to 139; *Macacus inuus*, Fig. 142; *Cercopithecus callitrichus*, Figs. 146 to 149; *Hylobatidæ*, 150 to 153; *Simia satyrus*, Fig. 155; *Anthropithecus troglodytes*, Fig. 158; Man, Figs. 161, 161, 162, 165. Imbrication is shown in most of the Primates above the *Lemuridæ*.

(4) The papillæ of the corium are seen in the greatest perfection in most of the groups under Rule 3. and the particular cases do not need to be repeated here. The following exceptions may be mentioned, viz., *Cercopithecus callitrichus*, Figs. 146 and 149, 158, 143, 138, 133, 134, where the papillæ of the corium are relatively ill-developed, and exceptions in which the papillæ are better developed than the ridges or their equivalents are, Figs. 114, 115, 116, 107, 108, 109, 110, 105. All the Birds examined show papillæ of the corium strongly marked.

PART III
PHYSIOLOGICAL

CHAPTER I

THE PHYSIOLOGY OF THE SENSE OF TOUCH

THE bearing of the foregoing facts and observations, macroscopical and microscopical, on the Sense of Touch in Mammals and Birds must now be considered, but, before entering the region of interpretation, it is desirable to allude briefly to the history of the subject.

The sense of touch in animals below man has apparently been little investigated, though certain interesting studies of this sense have been made in isolated groups of the subject, notably those of Spallanzani on the tactile sense of bats, already referred to, and on the special minute anatomy of the nerve-endings of the snouts of moles, by Eimer, and in the snouts of pigs, where also peculiar branched axis-cylinders terminate in concavo-convex enlargements between the deeper epithelial cells (Quain). But beyond such occasional investigations of the sense of touch, and the well-known studies of Weber on that of man, there is little to record. The history of the subject resolves itself into the very extensive researches, which have been made by numerous investigators, into the papillary ridges of the hand of man, and of later years, into those of the hand and foot of lower animals. The amount of literature connected with these ridges is immense, and all that I have been able to collect from various sources is given in full in an Appendix. A long paper written in 1905 by Schlaginhaufen, gives an exhaustive list of the communications on the subject and this occupies four and a half pages. Altogether, not fewer than one hundred and twenty memoirs and books, bearing on this subject, have been collected by the industry of Schlaginhaufen and others.

The papillary ridges on the hand of man first attracted serious

attention in 1823, when Purkinge wrote a short memoir in Latin, reproduced and translated in Dr. Galton's work on Finger-Prints. In 1868, Alix published an important essay in the *Annales des Sciences Naturelles*, in which he described fully, the patterns and arrangements of ridges on the hand and foot of monkeys. Blaschko (1884 and 1887) and Kollmann (1883 and 1885) and Klaatsch (1888) have dealt with the gross and minute anatomy of the pads of the mammalian hand and foot. Ch. Féré has contributed numerous papers on the prints of the human fingers and toes and the relation of the papillary ridges to the sense of touch and the functions of the hand. Dr. Galton has done more than any other observer in his researches, which began before 1892, to systematise the study of human finger-prints and to apply his results to valuable biometrical studies. These have led to his well-known teachings on the subject of personal identification by means of human finger-prints. Dr. Hepburn (1893 and 1896) brought forward somewhat fresh views on the meaning and functions of the papillary ridges on the hands and feet of monkeys and men, maintaining that the primary function of these ridges, is a mechanical one, by which slipping in walking and prehension is prevented. E. R. Henry also published papers on the identification of criminals by finger-prints (1899 and 1900). The views of Dr. Hepburn were popularised and expounded in a paper by Mr. Lyd Dekker in 1903 on Monkey Hand-Prints, and Retzius, in 1904, wrote papers on the "tastballen," as he termed them, of the hand and foot of man. These are the most notable communications in the years preceding two recent and remarkable memoirs, the first, in 1904, by Miss Inez L. Whipple, who followed out certain researches and suggestions of Dr. H. H. Wilder, on the palm and sole prints of various mammals. Miss Whipple in a long paper, occupying more than one hundred pages, which was published in English in the *Zeitschrift für Morphologie und Anthropologie*, has dealt with the ventral surface of the hand and foot of mammals in a masterly and exhaustive manner. She introduces certain useful terms and takes up first, the description and meaning of the pads found in the hand and foot of mammals, and treats these as essentially walking-pads, tracing their

morphology in a very complete manner, and their homologies in numerous groups. It is impossible, briefly, to summarise so long a paper, but it may be stated here that she discards the term papillary ridges in favour of "epidermic ridges" and calls the skin on which these are found "friction-skin." She finds certain simple elements of which the developed ridges seem to be formed and calls them "epidermic warts" and "epidermic rings." These terms are in keeping with her main thesis, viz., that the ridges in question are not, as hitherto thought, primarily tactile structures, but that they are physiological adaptations, by which the walking-pads become covered with a surface calculated to prevent slipping either in walking or prehension, and that the ridges have only incidentally acquired an important tactile function. This paper of Miss Whipple's was published in the year before Schlaginhaufen wrote a still more elaborate memoir in Gegenbauer's *Morph. Jahrbuch* on the *Hautleisten system der Primaten-planta* which occupied about 220 pages and was largely illustrated. This paper was written by him in ignorance of the paper by Miss Whipple, and he deals with it in a short appendix, and does not controvert to any serious extent her views, except in the important point that he disagrees with her claim that the functions of the papillary ridges are primarily mechanical and only secondarily and incidentally tactile. Certain conclusions of a physiological nature which he makes, will be referred to later.

This brief account of a matter, which has reached such large proportions, will serve to show that the study of these minute ridges on the palm and sole of mammals is a not unimportant subject.

The physiology of the sense of touch does not of necessity mingle with the more controversial matters which Dr. Wilder, Miss Whipple, and Herr Schlaginhaufen have debated. It may be sound morphology, and probably is, to look upon the mammalian primary pads as essentially walking-pads, for they are found low down in the scale of mammals as in *Didelphys* and *Microtus agrestis*, where the act of prehension can hardly be fulfilled at all, also in *Cercoleptes caudivolvulus*, a very active

arboreal carnivore, but one which does not use its hand and foot for prehension. It is undoubtedly true that the skin which Miss Whipple terms "friction-skin" does derive great value from the roughened surface afforded by nodules, warts, rings, and ridges, and so far, the mechanical view of the ridges is well justified. But I cannot agree that it is possible or desirable to put one function before another in a matter so complex as a structure concerned in the evolution of the walking and prehensile powers of a large ascending series of animal forms. However, the study of the sense of touch is independent of these theoretical and controversial points, and may be followed on its own merits without any need to establish priority of origin for one function or another.

The chief points in connection with the anatomical facts previously described which bear on the physiology of the sense of touch are :

- (1) The functions of the papillary ridges.
- (2) The meaning of the patterns of the papillary ridges.
- (3) The functions of the papillæ of the corium.
- (4) The relation of the papillary ridges to the papillæ of the corium.

Functions of the papillary ridges.—(1) The interpretation of the patterns assumed by the papillary ridges in different animal forms is closely related to the question of the functions or uses of these ridges. Dr. Galton has paid great attention to the classification of the patterns on the human finger-tips, but has not gone further into the uses of the ridges, than to state that the primary use of the ridges is to raise the mouths of the ducts of the sudoriparous glands, so that the secretions may be more easily got rid of, and that the secondary use is to assist in some obscure way, the sense of touch. But Dr. Hepburn and Mr. Lyddekker have clearly shown that in addition to these two uses, the prehensile efficiency of the hand and foot of monkeys, and even of the prehensile tails of American monkeys and opossums, is increased by the ridges. The latter writer seems to be more correct than Dr. Galton, in assigning as the primary function of the ridges, the increased efficiency of prehension.

the raising of the mouths of the ducts of the sudoriparous glands being subservient to this by affording a necessary amount of moisture to make the hand or foot more adhesive, either to a cylindrical or spherical object. Dr. Hepburn draws attention to the fact that the ridges, though comparatively low, must cause a certain amount of friction and thereby prevent slipping, and refers also to the moist clammy state of the palm and sole of monkeys as of material value to their firmness of grasp. In view of the fact that prehension among these creatures is of two kinds, for cylindrical and spherical objects, it is clear that there is a reason for the opposite arrangements of transverse and longitudinal ridges which accommodate themselves to the two classes of objects.

The second use of the papillary ridges, given by Dr. Galton in a dubious manner, is the one to which attention is chiefly drawn in this work. He refers almost entirely to the patterns on the human finger-tips without reference to the more rudimentary plans and patterns exhibited in the lower Primates and certain still lower mammals. An endeavour will be made to show that in man as well as in most lower forms, the function of subserving the sense of touch is a much more important and certain use of the ridges than the above opinion would suggest.

It is necessary to refer again to the general and particular arrangements of the papillary ridges, and a sufficient number of species are shown in the present series to illustrate the chief features of these arrangements. The *oblique*, *longitudinal*, and *transverse* are the earliest and simplest types of arrangement, excepting the *radiating* pattern of squirrels, hedgehogs, and others which are probably accidental in the sense that they are determined by the shape of the eminences on which they lie. Departures from these three simple types begin to appear low down in the series, and may be classified as *arches*, *loops*, and *whorls*. This classification has been employed by Dr. Galton very extensively in his statistical studies, and is, for this purpose, of great value as an aid to biometrical investigation. He takes these phenomena as he finds them, but there is a further interest in them, if they are considered in the making, as the accompanying

drawings illustrate. It is here maintained that these three broad divisions of pattern are not fortuitous variations, and are not unconnected with function, but are adaptations subserving the sense of touch. The first change of arrangement of the ridges is that by which they become grouped in ellipses on the terminal phalanges of *Didelphys azaræ*, and this type is found throughout the Primates as far as the Anthropoid Apes, with an occasional appearance of a loop in certain digits, *e.g.*, in the *Chacma* baboon. The next type of departure from the longitudinal, oblique, and transverse arrangements shows an arched shape of the ridges, and the first species in which arches have been found are: *Cercoleptes caudivolvulus*, below Primates and *Chrysothrix sciurea* among them. From this form onwards to man, arches are found in various digits and palmar and plantar surfaces. A further development of the arch type takes place by which loops are formed, as in the footpads in *Lemur brunneus*, and are abundant in all the Primates above the Lemurs. The most highly developed of the departures from a simple type are whorls, which may be ovate or circular, the earliest instances being found in the hand of *Lemur catta* among Primates. It will be shown by illustrations from this series of drawings, that a loop is a further development of an arch, and a whorl a further development of a loop. A few species will be chosen for the purpose of demonstrating this point.

Lemur brunneus (Fig. 13) shows arches on the interdigital eminences of the hand, and no whorl.

Lemur catta (Fig. 15), arches and five marked whorls on the palm. *L. brunneus* arches on the sole. *L. catta*, a much more extensive series of arches on the sole, all the patterns of the former being simpler than those of the latter. This fact agrees with the generally higher development of the walking power and of the form of the hand and foot in *L. catta*.

Chrysothrix sciurea (Fig. 21) has on the phalanges good illustrations of arches on four digits and loops on one. The palmar surface presents well-marked loops on the distal and arches on the proximal portion of the thenar eminence, thus showing the transition from arch to loop on one area.

The foot shows on the phalanges, both arches and loops. In this species then, arches and loops appear, but no whorl.

Cebus fatuellus (Figs. 23, 24) shows an extensive development of whorls on the digits, palm and sole and loops, but only one group of arched ridges, on the hypothenar eminence.

The genus *Papio* (Figs. 25, 26, 27, 28) with powerful palmar and plantar portions of the hand and foot and small digits present numerous whorls, a few loops and no arches.

Cynopithecus niger (Figs. 29, 30), with a better development of digits than the Baboons and generally well-developed hand and foot, shows numerous arches and loops on the digits, with well-formed whorls on the palm and sole, similar to those of the Baboons.

The *Cercopithecidae* (Figs. 31, 32, 33, 34, 35, 36, 37, 38, 39, 40) examined, have increased numbers of arches and loops on the phalanges, and these are also freely interspersed with whorls on the palm and sole.

The *Hylobatidae* (Fig. 41) show numerous arches on the digits and on part of the palm, no whorls, and a few loops. This fact agrees with the powerful supporting action of the hands by which the animal swings from tree to tree, and indicates simplicity of function.

The *Simia satyrus* (Figs. 43, 44) has a considerable development of arches on the digits of the hand and loops on the terminal phalanges which accords with the fact of the great use made of its long, powerful arms and active digits in its arboreal life. The foot also has numerous arches as well as loops on the digits. The foot and hand of the Orang differ less from one another than do those of any other Anthropoid Ape.

Gorilla (Figs. 45, 46) has a hand and foot the digits of which are less relatively important than the Orang's; and present fewer loops and arches on the middle and proximal phalanges, but on the terminal phalanges loops, and on the palm at the clefts of the digits. The relatively small number of arches on the digits is in keeping with the higher and more complicated use to which the hand of the Gorilla is put, than that of the Orang.

The Chimpanzee's hand and foot (Figs. 47, 48) have numerous

arches, and the fourth and fifth digits have arches where the second and third digits have whorls. The hand is much more complex in pattern on the palmar portion than the plantar, which is singularly simple in pattern.

In the hand of man arches are found much less frequently than loops and whorls. Dr. Galton examined five thousand digits and found that 6·5 per cent. had arches, 67·5 loops, and 26·0 whorls, on the terminal phalanges. The palmar surface shows three groups of arches at the bases of the digits, but these are small and unimportant, and one or two small areas of loops, but with these exceptions, it is extremely simple in pattern, showing few departures from the transverse, longitudinal, and oblique arrangements. The foot of man normally presents whorls and loops on the terminal phalanges, but when these become distorted by pressure, arches often take their place. The arched arrangement of the ridges of the fifth digit, given in the drawing, agrees with the limited function of this digit. The hallux is far the most important of the digits as to function and presents much more complicated patterns of whorls, loops, or arches in different individuals. The plantar surface, except on the ball of the hallux, is exceedingly simple, and more so than any other palm or sole examined except the palm of the Gibbon and the sole of the Chimpanzee.

It would appear from the foregoing facts, that loops and whorls are higher developments of arches, and this view of them throws some light on the functions of the papillary ridges. If there be any meaning in the patterns of which arches, loops, and whorls are the highest forms, there must be more reason for the grouping of the ridges on the palm, sole, and digits, than would be supplied by the purely mechanical conditions involved in prehension. The complexity of the patterns which marks this series of hands and feet, shows that some other factor than adaptation to prehension is concerned in the development of the ridges. Dr. Hepburn says that "frictional sensibility or discriminating power do not account for the arrangement of the papillary ridges and the patterns produced." But the arches, loops, and whorls are clearly associated with an increasing acute-

ness of touch and cannot be explained at all on the prehension or friction theory. Dr. Hepburn's view of the various patterns is, that they are secondary to, or dependent on, the shape of the eminences on which they are situated, indeed, that in this respect, they are by-products. It is not intended here to attempt any proof that the individual patterns are physiological arrangements adapted to improving the sense of touch, though this view of them has been well shown by Ch. Féré,* but to prove that touch-sensation rather than prehension determines the changes of pattern exhibited by the Primates in the long course of their evolution. It is worthy of special note here, that the papillary ridges on the hand and foot of man display remarkable changes from their congeners, which agree with the growing complexity of the actions both of palm and digits of the hand and digits of the foot. Man no longer employs his hands only in the two simple modes of prehension, which are general in monkeys and apes, but in very varied ways he combines the functions of his opposable thumb and digits in handling objects of all sizes and shapes, and minutely applies his sensitive pulps to divers objects for the purpose of discrimination.

When the foot of man is compared with those of the Anthro-poid Apes, the most striking point is the extremely simple transverse arrangement of the ridges, except on the ball of the hallux and the pulps of the digits and occasional patterns on the inter-digital pads. This is significant of a great change of function and, from one point of view, in the direction of degradation of function. In the Monkeys we find the foot exercising support, progression, and simple prehension; in the Anthropoid Apes, support, progression, and more complicated prehension, in Man, support and progression alone. These facts as to the functions of Man's foot and the change of pattern of the ridges, prove that other functions than the simple one of prehension determine not only the degree of development of the individual ridges, but also their mode of arrangement. When it is taken into account that Man has not for many thousands of years employed his foot in prehension, and that when he did so employ it he must have

* See pp. 172 and 173 (Literature).

done so in a manner similar to that of the Anthropoid Apes, involving considerable lateral folding, and that these animals show a prevailing longitudinal direction of the ridges, instead of the prevailing transverse direction shown on the sole of man's foot, it becomes perfectly clear that prehension has nothing whatever to do with the present arrangement of the ridges on the greater part of the foot of Man.

Summary of argument.—The arguments in favour of the view that one of the primary uses of the papillary ridges in the Primates is that they subserve sensation, may be summed up as follows :

(1) The ridges are always associated with abundant papillæ, many of which contain touch-corpuscles, and the papillæ mostly project into or towards the ridges rather than the furrows.

(2) Arches, loops, and whorls represent degrees of departure from a primitive arrangement, and enable a larger area of ridge-covered surface to be exposed to contact, relatively to the size of the part.

(3) The sole of Man's foot, which is employed only in support and locomotion with sensation, and which has not been employed in prehension for a very long period of time, is highly endowed with ridges, and these are, in the main, placed transversely, thus differing from those of Monkeys and Anthropoid Apes.

(4) Papillary ridges develop in parts where they are not normally present on the hand and foot, when they have no relation to prehension. The following instances of these aberrant ridges may be mentioned.

Man.—(a) Ridges frequently appear on the radial side of the extensor surface of the index-finger to nearly the middle line of the finger, and more on the right than the left hand.

(b) The extensor surface of the fifth digit of the foot shows ridges when it is distorted by boots.

(c) In children who bite their nails badly, ridges develop on the extensor surfaces of the pulps down to the free edge of the nail, and in the case of a man whose nails were kept particularly short, because of rough mechanical work done by him, ridges were found well developed down to the free edges of the nails.

(d) On the heel of adult man ridges are found surrounding it, of the average depth of one inch from the plantar surface, and in one particular case of a woman aged forty-nine, the depth of this area on each foot measured was one and a half inches from the plantar surface.

Chimpanzee.—An instance of papillary ridges on the extensor surfaces of the digits of the hand, on the terminal phalanges, was brought forward at the Zoological Society* attributable to the habit of this Ape in walking, by which it supports its weight on the extensor surfaces of the digits; these were absent from the corresponding surfaces on the foot. A similar condition, with aberrant papillary ridges, has been found on the digits of the hand of the Orang.

Lemur brunneus.—Shows well-marked ridges on the extensor surfaces of the terminal phalanges extending to the lateral borders of the nail, and nearly to the middle line of the digit, where the ridges from the two sides are only separated by a narrow triangular space.

Hedgehog, Figs. 12, 13, and *Kinkajou*, Figs. 9, 10, show rudimentary ridges on their digits and palm and sole, these parts not being capable of use in prehension.

(5) The pulps of man's fingers have highly developed patterns, and these are more variable and complex than those of any other part of any of the Primates, and these are the most sensitive areas in any hand or foot. In this instance the connection between sensibility and complexity of pattern of ridges is intimate.

The pulps of the toes in man are less sensitive than those of the fingers, and the patterns of the second, third, fourth, and fifth digits simple, and these digits are relatively weak in function compared with the hallux.

In nearly all Monkeys and Anthropoid Apes simple ellipses are found on the pulps of the hand and foot, which accords with the lower function of these parts in the Primates below Man.

(6) The imbrication of the papillary ridges on the digits of man, and on the hallux and ball of the hallux, the former being

* "Proc. Zool. Soc." 1904, p. 263.

in a distal, and the latter in a proximal direction, is apparently an adaptation for the purpose of increasing the sensibility of the skin in these regions.

It is true that some of the instances here noted of the formation of aberrant papillary ridges on certain unusual areas of the hand and foot, are not incompatible with the broader view of Miss Whipple as to "friction-skin," but they are conclusive against the prehension-theory of Dr. Hepburn.

(7) The function or functions of the ridges themselves are intimately associated with the various directions or patterns which they assume, whether in the simple transverse, oblique, or longitudinal directions, or in the more complex directions which are called "patterns." The structure of a papillary ridge is altogether too highly developed and peculiar to the ventral surfaces of the hand and foot, to be separated from some elements of the acts of walking and prehension, and when it is seen on reviewing a large series of mammalian forms, that there is a growing complexity of the grouping of these ridges up to those of man, the conclusion is forced upon one that there is an important meaning in the variations of pattern.

Dr. Hepburn dismisses the patterns of the human and Simian hand and foot as secondary results of the shape of the eminences on which they are found, whereas Miss Whipple attaches to them a great importance as being arrangements by which the ridges are so placed as to be at right angles to the force which tends to cause slipping in walking or prehension, or to the resultant of several forces therein concerned. This theory of Miss Whipple's is exceedingly difficult to work out in a review of a large series of hands and feet. This is seen in the case of the ellipses of papillary ridges which are so common on the terminal phalanges of the digits, both of hand and foot, of many Primates, or even lower mammals, such as *Didelphys azaræ*, Figs. 3, 4; *Petaurus sciurea*, Figs. 5, 6; *Lemur brunneus*, Figs. 13, 14; or *Lemur catta*, Figs. 15, 16; *Nycticebus tardigradus*, Figs. 17, 18. It is not necessary to mention more than these few cases, but similar ellipses are seen in nearly all Monkeys. Such elliptically arranged ridges could not, by any

possibility, tend to prevent slipping in walking, and only very rarely in prehension, when a spherical object is grasped. But when this elliptical pattern is regarded as a means of presenting as many as possible of these delicate tactile structures to any opposing surface which requires discrimination, it is seen that there is a meaning in the arrangement. Again, in the hand and foot of the Kinkajou, Figs. 9 and 10, the terminal phalanges present concentric ridges under the cover of the long-pointed nails, a position in which prevention of slipping is necessarily excluded, but which affords a delicately, sensitive area on that part of the pulp which may often be called upon to discriminate in a very important manner, as to different surfaces with which this active arboreal animal is concerned. In Figs. 12, 13, the Hedgehog shows a similar rudimentary arrangement of ridges on three digits of the hand, and three (D. 2, 3, 4) of the foot in situations where any connection with slipping is excluded. The remarkably modified hand and foot of the Slow Loris (*Nycticebus tardigradus*), Figs. 17, 18, is not less opposed to the friction-theory of Miss Whipple when the pads and their patterns are considered. The extreme tips of the digits in hand and foot are furnished with a radiating arrangement of ridges, such as is illustrated on Fig. 19. The ridges of this area, of which a small portion in the centre is bare, are well calculated to expose a very sensitive surface to any object, but for preventing slipping they would be obviously useless. The tip of the singular second digit of the hind foot is covered with a highly developed whorl-like pattern under the cover of the long, curved nail, where no opportunity of preventing slipping is possible. All the palmar and plantar surface of this creature, when quite fresh, is of a remarkable softness, and is very moist. The latter quality is of great use in assisting prehension in its deliberate slow movements along the branches of trees, but the soft, moist character of the skin is altogether opposed to the theory that the ridges, by their complicated patterns, can prevent slipping. Of course if such a skin be examined only when hardened in alcohol, this peculiar quality of moisture and softness, which it shares to some extent with *galago lemur* and certain Monkeys,

such as the various forms of *Papio*, is not noticed, but it militates strongly against the anti-slipping theory of Miss Whipple. Further, the interdigital pads, though prominent, are so soft that a very little pressure squeezes them flat, thus eliminating any possible effect the ridges might have in preventing slipping. *Cebus fatuellus*, Figs. 23, 24, again has on the proximal phalanges of D. 3, 4 of both fore and hind foot a curious bilateral whorl which is too highly developed to be connected with any imagined need for preventing slipping in this surface, largely covered as it is by the adjoining fleshy interdigital pads, but which may well be supposed to be of use in conferring an especial degree of tactile sensibility. The short and not very efficient digits of the hand of *Macacus cynomologus*, Figs. 35, 36, show on the proximal phalanges of D. 2, 3, 4, 5 well-formed ellipses in an unusual position, and under the cover of the interdigital pads, where they would be quite incapable of preventing slipping, but would be useful tactile structures supplementing the three well-developed whorls on the interdigital pads. The hand and foot of *Hylobates hainanus*, Figs. 41, 42, show an interesting change from most of the Monkeys in the much more longitudinally-placed palmar and plantar ridges, and transverse ridges of the digits, which are more regularly and accurately arranged than is usual in lower forms. These two arrangements are in keeping with the immense use made by Gibbons of the long digits for support and swinging from branch to branch, and of the palm and sole for the grasping of spherical objects, such as fruits. A similar grouping of the ridges is seen in the Orang, but the foot shows more transverse ridges than that of the Gibbon, and the patterns of the digits are still more highly developed. The clumsy shorter hand and foot of the Gorilla, Figs. 45, 46, suggest greater power, but less delicacy of touch than either the Orang or Gibbon. The Chimpanzee, Figs. 47, 48, hand and foot again show much more simplicity of pattern on the digits than the Gibbon, as might be expected from the shorter and less efficient digits of the former, and the difference of their habits. In the case of the human hand and foot it has been pointed out before that the characteristic human arrangements are: first,

that the patterns of the palmar surface are much more simple than those of the terminal phalanges, and that the latter are more complicated in pattern than in any group below man; secondly, that the human foot is markedly more simple in its patterns than the hand, and here again, the plantar surface is more simple than the digits. The complex patterns of arches, loops, and whorls on the tips of the human fingers are developed in a region, and in a part of that region where the need for not slipping is reduced to a minimum, and in the palmar and plantar surfaces, where the patterns are of the simplest, there is, at any rate, some need for the prevention of slipping in prehension and walking.

It is necessary to enter a little into the controversial aspect of the functions of the patterns of the papillary ridges, and to point out the important fact that the theory of the ridges and their patterns being adapted to minister to the sense of touch, applies more consistently to all the special areas which may be chosen for study, than the theory of Miss Whipple that they are arranged so as to be at right angles to the forces which tend to produce slipping, or the resultant of those forces. In any critical area of the palm or sole or digits where it is important to avoid slipping, it is obviously more necessary still that an accurate intimation should be conveyed to the central nervous system by means of these delicate projecting tactile ridges as to the direction and degree of muscular force required, than that a mere mechanical contrivance, such as the string on the handle of a cricket bat, should mechanically prevent slipping. We see thus that complexity of pattern either on palm, sole, or digits has an endless *raison-d'être* in connection with varying tactile needs, whereas the mechanical theory of Miss Whipple finds itself in all manner of difficulties as indicated in certain special cases, pp. 152, 153, and as can be gathered in many more, if the whole series of hands and feet be studied from this point of view.

The position here adopted with regard to the meaning of the patterns on the Mammalian palmar and plantar surfaces is that they are adaptations, with a variability as great as the

variability of the needs and lives of the animals presenting them, calculated to subserve, in an important degree, the sense of touch residing in the hand and foot. The areas of ridge-covered skin between the primary pads before-mentioned, are mostly covered with ridges of a simple transverse, oblique, or longitudinal direction, but the pads (apical, interdigital, and proximal) being primarily "buffers" in function, become more and more important as sensitive areas in walking and prehension, and on these arches, loops and whorls of the papillary ridges become grouped with increasing complexity of pattern until the hand of Man is reached. Here the highest development is found, and in association with it the highest degree of discriminative sensibility. The view here maintained, and supported by the evidence of a large series of Mammalian hands and feet, that whorls are a further development of loops, and loops of arches, is unfortunately in direct contradiction to the view of these patterns which Miss Whipple holds. She says that the arrangement of ridges into a whorl (as it is here called), constitutes the "typical pattern," and she finds this low down among the Primates, as in *Galago* and *Lemur*, and on p. 339 she gives a series of impressions from human finger-tips, in which she endeavours to show the process of degeneration from this typical pattern, the next stage being a loop, the next a tented arch, and the final stage a simple arch. There is an objection to this view of the degeneration of patterns from the whorl to the loop, and the loop to the arch, which Miss Whipple's own study of the Mammalian pads brings out with fatal clearness, but which her own limited series of drawings of the whole hand and foot fails to show. As before stated, Miss Whipple lays much stress on the division of pads into primary and secondary pads, the former group being apical, interdigital, and proximal. She and Dr. Wilder trace certain lines either of ridges or rows of epidermic warts round these primary pads in a certain constant form, and they point out that each typical pad has its three *triradii*. In lower Mammals which have no epidermic warts or ridges, such as *Microtus agrestis*, these are foreshadowed by triradiating arrangements

of the skin-folds surrounding the pads. Great morphological importance is attached by Miss Whipple to these ridge-triradii bordering the primary pads, and they form a leading point in her classification of ridge patterns. By the presence or absence of these triradii round a pad in their full number, or by their more or less complete development, she would determine the perfection or degeneration of the pad and its ridges, and she is then led to the view of the human finger-prints in which whorls, loops, and arches are shown, that these two last represent successive stages of degradation.

But if one looks at certain of the secondary pads or eminences, one finds on these a precisely similar series of changes of pattern to which Miss Whipple refers (without giving many drawings of them) as secondary patterns, thus distinguishing them from typical patterns. A few illustrations of the secondary patterns are the proximal phalanges of *Chrysothrix sciurea*, Figs. 21, 22, in which well-marked arches are seen, the proximal phalanges of *Cebus fatuellus*, Figs. 23, 24, with fully formed whorls, which Miss Whipple would call "typical patterns," if formed on a primary pad. Then in *Papio porcarius*, Figs. 22, 28, the proximal phalanges show arches and loops, but no whorls, as also Figs. 29, 30 of *Cynopithecus niger*, and Figs. 31, 32 of *Cercocebus*, also the proximal and middle phalanges of *Macacus nemistrinus*, Figs. 33, 34, both showing loops and arches, but no whorls, and *Macacus cynomologus*, Fig. 35, with well-formed ellipses on the proximal phalanges; *Macacus silenus*, Figs. 37, 38, with arches and loops on both middle and proximal phalanges, and *Cercopithecus patas*, Figs. 39, 40, with arches and loops on the proximal phalanges, and similar patterns are seen on all the Anthropoid Apes which are illustrated. Now Miss Whipple cannot possibly contend that these are degenerated "typical patterns," for such patterns are not found in the ancestors of these forms; indeed, the further down the scale of mammals one goes, the simpler are the patterns on these secondary pads, and the ridges are usually either transverse, oblique, or longitudinal. These secondary patterns then, are very inconvenient witnesses for Miss Whipple's case,

for they directly contradict the view they would be supposed to support. They should, on Miss Whipple's view of their origin, be traceable to some more highly developed patterns in ancestral forms. But they are mere "foundlings," no recorded patterns being recognised by which they are found to be the degenerate descendants. It is, indeed, a case of "Japhet in search of a father," and no success in the search. Miss Whipple admits as much of these secondary patterns when she speaks of them as having "greater physiological than morphological importance." This is a true bill, and applies in my opinion, to the whole series of patterns, primary and secondary, and they are, in that view, essentially physiological modifications, their ancestry being a matter of minor and doubtful importance. A similar difficulty is felt in the case of the complex apical patterns in man, for according to the theory under discussion, these are the descendants of more perfect typical patterns. Now, I venture to say of the highest of these patterns, the whorls, that they are another group of "foundlings," and can find no pedigree among the whole mammalian series examined either by Miss Whipple, Schlaginhaufen, or myself. The nearest approach to a whorl, as it is here called, or "typical pattern," as Miss Whipple calls it, in lower mammals, is in the elliptical patterns in numerous Monkeys and in the Anthropoid Apes, which, in certain digits, become more broadened out than in others. Miss Whipple's figure of *Macacus*, p. 273, is only a diagram, and not a print or drawing, but even this gives no such pattern as could be the ancestral type of the perfectly shaped whorls so common in man's digits. In the Kinkajou, and some of the Anthropoids, there are arches on the apical pads, and in the Anthropoid well-marked loops, but nowhere a properly formed *whorl*. The interdigital patterns have too much been taken as typical and primitive, to the exclusion of the careful consideration of the apical patterns. But if the secondary patterns are looked upon as adaptations of differing value, arches the lowest, loops the next, and whorls the highest, for increasing the acuteness of the sense of touch, there is no difficulty of

accounting for their development on secondary pads where they are needed in their measure, just as the corresponding arches, loops, and whorls are on the primary pads. It would seem that in reference to this particular matter, Miss Whipple led astray from a useful physiological view of the patterns in her earnest search for morphological consistency and homologies, has read the series of patterns backwards.

At this point there is apparently a divergence of paths, and reconciliation of the two views does not seem possible.

This digression into controversial matters is justified by the fact that if the view here put forward as to the connection of the patterns with the sense of touch be correct, and the opposing theory that they are mechanical contrivances to prevent slipping be incorrect, the whole field of the complex and varying patterns on the hand and foot of man and the lower mammals is opened up to a fruitful study. In this case, researches such as those of Ch. Féré, on the functions of the human hand and foot in connection with the patterns of the papillary ridges are abundantly justified. It may be useful here to refer to some observations made by Schlaginhaufen, and summarised in his paper* referred to before. He has examined the tactile sensibility of the human finger-tips in a way similar to that of Weber. He applied the two points of a pair of compasses at a fixed distance from one another to the finger-tips in different directions, and came to the following conclusions :

(1) That they are distinguished better as two points when their line of junction is at right angles to the direction of the ridges, than when this is parallel with them or lies on them. Thus the two points, *c* and *d*, are better distinguished than *c* and *b*.

(2) That they are distinguished better when they lie on the pattern in such a manner that their line of junction, *cd*, representing part of a large curve, *cbad*, is at right angles to the direction of the ridges, than when they are so placed that their line of junction is along a rectilinear portion of ridge.

(3) That they are distinguished better when they lie so on the ridges that their line of junction joins two points of the

* See p. 143.

same curved ridge, as *cd*, than when they lie so that it joins two different ridges, as *ef*.

This illustration of experiment made on the patterns of man's hand will serve to show that the sense of touch is most usefully assisted by the arrangement of the papillary ridges into patterns, and it is to be hoped many further such researches will be made.

Functions of Papillæ of the Corium.—Whatever different views may be held as to the primary, secondary, or even tertiary

FIG. 174.—Diagram copied from memoir by Schlaginhaufen, illustrating certain points in connection with the sense of touch.

functions of the ridges, there can be no doubt of the fact that the essential organ of touch of mammals resides in the papillary layer of the corium. Though among the papillæ some are vascular only, this does not alter the fact that this layer of the skin is primarily tactile, and the numerous sections of skin which have been shown are sufficient to indicate a great variability in the elaboration of the papillæ in different animals. It is in these papillæ of the hand and foot of man that the special tactile corpuscles of Meissner are found, though they also occur in some other regions of the human body, as the bed of the nails, the flexor surface of the forearm, the skin of the nipple, the conjunctiva at the edges of the lids, and in the mucous membrane of the tip of the tongue. All of these are regions with a delicate tactile sense highly valuable to its possessor.

They are also found in monkeys (Quain). The distribution of these touch corpuscles is significant; thus, there have been found on the ventral surface of the index-finger as many as twenty-one to the square centimetre, whereas in other parts of the palm and sole they vary from two to eight to the square centimetre. This is in keeping with the well-known sensitiveness of the pulps of the index-finger. It may be well to quote here the observations of Weber as to the delicacy of discrimination in different regions of the human body.

He examined the skin with a pair of compasses, noting the distances between their points, when they were still felt as two points in such regions as the tongue and different parts of the limbs. Some of his results were :

Tip of tongue, $\frac{1}{24}$ in. or 1 mm.

Palmar surface of terminal phalanx of forefinger, $\frac{1}{12}$ in. or 2 mm.

Palmar surface of middle phalanges of fingers, $\frac{1}{6}$ in. or 4 mm.

Palm of hand, $\frac{5}{12}$ in. or 10 mm.

Dorsal surface of first phalanges of fingers, $\frac{7}{12}$ in. or 14 mm.

Dorsum of hand, $1\frac{1}{6}$ in. or 25 mm.

Upper and lower parts of forearm, $1\frac{1}{2}$ in. or 37 mm.

Middle of thigh and back, $2\frac{1}{2}$ in. or 62 mm.

He also found that the points of the compasses had to be separated further so as to be felt as two, in the limbs, when the line joining the points was in the long axis of the limbs, than when placed transversely.

Relations between the Papillary Ridges and Papillæ of the Corium.—The foregoing drawings and photographs show clearly a close connection between these two structures, and little needs to be added to what has been said before. Wherever ridges are clearly cut and well formed, there is always a corresponding development of the papillæ of the corium, and this is particularly noticeable in the Carnivores, the Lemnuriæ and Monkeys, and most of all in Man. The relation is so close and so seldom departed from, that I venture to affirm that the old term papillary ridges, with the meaning it connotes, ought to be retained as indicating a constant relation between two great structures of the skin, and a sound physiological theory.

CHAPTER II

SUMMARY

AN extensive series of facts has here been brought together in connection with the skin-structures of the ventral surface of the mammalian hand and foot. There is found on this surface a specialised form of skin, not only in the character of the epidermis, but also of the corium, and in both cases, extreme variability has been shown to occur in the different groups of mammals, and the variability of the corium in a few birds examined has also been shown to be considerable. The seven coarser modifications of the outer layers of the epidermis have been shortly described and sub-varieties of these also mentioned, but the chief interest of the free epidermic surface lies in the highest development of these modifications in the form of papillary ridges. Remarkable and complex patterns are shown to be formed of these ridges, the complexity increasing very closely according to the higher organisation of the animals in question. There are differences of view as to the nomenclature suitable for the various epidermic structures, especially the ridges, and these differences of view of course depend upon the main function, or functions, which are attributed to the ridges, but it seems difficult to resist the large mass of evidence in favour of the intimate and essential connection of these ridges with the papillary layer of the corium, and consequently with the sense of touch. They are, therefore, frankly associated with their function and still called papillary ridges. This is not to underrate or ignore such secondary uses as they may have in affording a roughened surface for the hand and foot in prehension and walking and in raising the mouths of the sudoriparous ducts so rendering the flow of moisture over the surface more free. In the corium

quite as much as the epidermis, as shown by the drawings and photographs of sections of the mammalian skin, it is shown that there is a structure which is, to a great extent, peculiar to the ventral surface of the hand and foot. This highly specialised form of papillary layer of the corium can have no *raison d'être*, but that of increasing the delicacy of the sense of touch. As before stated there are certain other regions, such as the nipples, edges of eyelids, and on the tip of the tongue where the papillæ are highly developed; but in the greater part of the skin of the body these are little developed and the peculiar distribution of Meissner's tactile corpuscles on the human hand is significant of the great importance of the skin of this region as the organ of touch. The very fact that the above three or four regions are all that can be enumerated where the papillæ are highly developed, makes the high degree of development of the papillary layer of the corium of the hand and foot, all the more striking.

There are certain established principles concerning the sense of touch in man, to which reference should be made and which will serve as indications of similar principles in the lower animals, though as yet these have not been demonstrated at all fully.

It has been well said that the skin is a mosaic of tiny sensorial areas, for minute examination of its surface shows that there are small but definite intervals between sensory spots, where no sensation is produced by a fine stimulus. Sensory spots of at least four kinds have been distinguished; touch-spots, cold-spots, warmth-spots, and pain-spots, and it is probable that the difference between these separate classes of sensory areas depend upon the distribution in them of the five or six kinds of end-organs of the skin and subcutaneous tissue which have been identified. In the root-sheaths of hairs there is a fine network of nerve-fibrils and also in the epidermis among the epithelial cells, a plexus of non-medullated nerve-fibrils. The loss of the tactile function of the hairs on the hairless palmar and plantar surfaces of the hand and foot is more than compensated by the still more delicate papillary ridges and highly developed papillæ of the corium. It is held, also, that in order to produce the necessary stimulus for the organs of touch, there must be a deformation of

the surface of the skin, to which papillary ridges and their equivalents in lower forms easily lend themselves. An important manifestation of the tactile sense is that by which it supplies to the cerebellum, one of the four afferent impressions necessary for "keeping it informed of the position of the body in space." Further reference to this function will be made shortly.

Uses of the Sense of Touch.—It remains to be asked of what use to the animal in the course of its life are these tactile structures and the tactile sense? To answer this question, one must first consider the tactile sense of the hand and foot of man as known better to us than those of any lower animal, thus proceeding from the well known to the less known.

The Hand of Man.—From the days of eolithic man, up to a comparatively recent period, the basal element of his progress in civilisation has been an increasing skill in the use of implements. This is so much so, that the early epochs of his long reign over the earth have derived their titles from the nature of his implements; as the Stone Age, old and new, the Iron Age and the Age of Bronze. It is easy to understand that in such a development of mechanical appliances as these titles indicate, the sense of touch has played an extremely important part.

This making of implements constituted a large part of his armoury in early times which equipped him in his struggle for mastery with the lower animals, and of itself, it divided him by a great gulf from these his enemies or rivals. Little imagination is needed to enable one to understand how his acute sense of touch became a useful servant to his developing brain, as he learned to distinguish between such substances as stone of various kinds, wood of different structures, and metals, and to handle both the tools he made from them as well as the raw materials. Implements employed for the purpose of war against the lower animals became, in due time, supplemented by those belonging to the peaceful arts. In the construction of the implements of the chase, of agriculture, of domestic arts and finally of scientific apparatus, an immense field is opened to the more or less skilful application of the sense of touch. Between the tactile structures in the skin of early man, who chipped rough

flints for the construction of his tools, and those of the modern watchmaker or scientific instrument-maker, there may have been little anatomical difference. In the application of the sense of touch by a growing intelligence, the difference would be immense.

That the sense of touch can be highly cultivated by practice, is shown in the rapid and skilful way in which blind persons can distinguish the different letters of their raised type, when the ordinary person of intelligence cannot find any distinction. Another small development of the tactile sense in man is in the imbrication of the papillary ridges referred to on the terminal phalanges of the hand in certain human subjects. This arrangement has the effect of increasing the "discriminative sensibility" of the skin for the texture of various substances of which a person may desire to make a judgment. If a surface, roughened equally all over, such as the cover of a book, be examined, it is found that the instinctive action which one makes in forming this judgment, is to pass the tips of the fingers in a distal direction or away from the body, and in a slightly slanting direction. This has the effect of bringing the imbricated ridges of this region more definitely against the grain of the rough surface. If the fingers be drawn with equal pressure towards the body or in a proximal direction, the surface in question is felt to be markedly smoother than when passed in a distal direction. This application of the sense of touch must have some analogous action in the lower animals, for the phenomenon of imbrication is common also in them.

It were wearisome even to enumerate the multifarious mechanical arts in which the sense of touch is of extreme importance. All one need say further is, that such use of this sense in man must have contributed greatly to his better equipment for the struggle of his life and thus, in a broad way, have been governed by a slow, remorseless process of selection. This first use of the tactile sense is of course connected only with the hand.

The Foot of Man.—The great importance of cutaneous impressions in the maintenance of equilibrium has been referred to, and in this use of the tactile sense, the foot of man derives its main value, the prehensile function of this organ having long

ceased to operate. It is known that in a disease such as that called locomotor ataxy, or tabes dorsalis, the sensory tracts of the spinal cord are damaged and this contributes the main cause of the inability felt by the sufferer to stand firm when his eyes are shut, two of the four great afferent impressions to the cerebellum being thus for the time cut off. Such persons also find greater difficulty in walking at night than in a good light. It has also been shown in the case of brainless frogs, that if the skin of the hind legs be stripped off, they are unable to ascend an inclined plane in a reflex manner, which they can do when the skin is intact. This use, then, of the tactile sense in the preservation of man's balance in walking and standing is of fundamental importance to his well-being and success in the struggle of life.

The value of the roughened surface of the foot with its papillary ridges can hardly have been great, even in the days when the foot of man was naked; for these low, soft ridges could do little to prevent slipping on such surfaces as grass, sand, rock, wet or dry, and from the time when he began to protect his feet with coverings, this small value would be still further reduced. Whereas the increased delicacy of the tactile sense conveyed by the ridges would be most useful in intimating to his higher centres the important varieties of surface injurious or otherwise, with which his foot would be in contact.

These two main uses to which the tactile sense in man is put are then :

- (1) *Discriminative sensibility.*
- (2) *Maintenance of equilibrium.*

(1) The first is the only one which the human hand exercises, the second that which the human foot alone exercises.

In the lower Primates and still lower Mammals, the hand and foot both exercise the first of these, though in a lower degree than man, whereas the second is exercised by the hand and foot in a nearly equal degree.

The discriminative sensibility of the hand and foot becomes of necessity less important to lower Mammals than it is to man, the varieties of surfaces touched and judgments concerning them

being less complex as the life and habits of the animal become simpler. The most complex problem which a monkey's sense of touch will have to solve will hardly go beyond the need to distinguish between the size and kind of surface of such fruits and nuts and other articles of food as it may require; there can be no such interpretation of details and careful estimation and comparison of surfaces as man's organs of touch are concerned with. And so down the scale of Mammals this use of the tactile sense must become simpler until it becomes limited to the discrimination of the very few kinds of surface which enter into its humble life. It may even be that this use entirely vanishes in the lowest groups and is replaced by sensations of pain alone.

(2) It is otherwise with the second use, viz., the maintenance of equilibrium. This reflex act is common to all mammals and in most of them the tactile sense of the hand and foot, and in birds the tactile sense of the foot is of the utmost importance to them. It is probably more highly developed in the arboreal animals and especially those that are nocturnal also than in any others. At any rate the illustrations of the skin-structures of the group of Lemuroids given in Figs. 126, 127, 128, 129 suggests very strongly that they are more than any group endowed with a high degree of this reflex power of maintaining equilibrium. The marked development of the papillæ of the corium in this group, has been sufficiently considered before, and no further description is required here. The well-known Slow Loris (*Nycticebus tardigradus*) may be taken as a typical and marked example of these Lemuroids. Its habits are most instructive from the present point of view. It is an animal of about the size of a cat and of strictly nocturnal and arboreal habits. In the daytime it will sleep in the hollows of trees curled up into a ball, and at night-time it commences its more active life, climbing along the branches of trees in search of its prey, such as fruits, birds, insects, eggs. Its method of climbing and moving along the branches has been carefully observed, and in Lyddekker's "Natural History" the following account is given.

"He is extraordinarily slow in his motions and his trivial name, *Eardigradus*, well marks his habit in that particular. When he

climbs he first lays hold of the branch with one of his hands, and then with the other. When he has obtained a firm hold with both hands, he moves one of his hind paws, and, after firmly grasping the branches with it, he moves the other. He never quits his hold with his hind paws until he has obtained a secure grasp with his hands. When he walks he moves his limbs in the same methodical manner as when he climbs."

This description of the nocturnal arboreal life of the Slow Loris gives one a vivid idea of the extreme importance to its life, of an accurate and delicate sense of touch, so that when visual impressions are much diminished or absent, their place should be taken by very efficient tactile impressions. The other five Lemuroids examined, Galago, Javan Loris, Lemurs of three species, depend nearly as much for their safety and success in life upon a delicate tactile sense; and the illustrations of their papillæ of the corium show a very similar high degree of development. In the case of many birds also, there is present a great need for similar effective maintenance of equilibrium in the large part of their lives and in this group also, we have seen a highly developed papillary layer of the corium. One may easily read in terms of the development of the papillary layer of the corium, and often of the papillary ridges or their equivalents, the degree of importance to the animal of this use of the tactile sense. The effect of this study is to show that it is possible to read this record very closely in the series of illustrations of sections of the skin in the various groups examined.

APPENDIX

IMBRICATION OF PAPILLARY RIDGES OF HUMAN HAND AND FOOT EXAMINED

Terms and abbreviations.

Digits —D. 1, 2, 3, 4, 5.

Imbn.—Imbrication.

Indiff.—Indifferent.

Proxl.—Proximal.

D.—Distal.

P.R.—Papillary Ridges.

CASE I.

W.K.—*Left Hand.*

Digits 1. *Terminal Phalanx.* P. R. worn down at tip. Indiff. At both sides of pulp and centre. P. R. mostly Indiff. and worn down. Imbn. D. faintly shown on both sides.

Proxl. Phalanx. Imbn. D. marked on both radial and ulnar borders. Central region Indiff.

D. 2. *Terminal Phalanx.* Tip worn down. Indiff. Pulp radial side Imbn. D. Pulp ulnar side Indiff. Pulp central region Imbn. D.

Middle Phalanx. Radial side Imbn. D., especially at base. Central region and ulnar side Indiff.

Proximal Phalanx. Radial side Imbn. D. faint. Ulnar side and central region Indiff.

D. 3. *Terminal Phalanx.* Tip worn down Indiff. Pulp radial side Imbn. D. faint. Pulp ulnar side and central region Imbn. D. marked.

Middle Phalanx. Radial side Imbn. D. faint. Ulnar side and central region Imbn. D. marked.

Proximal Phalanx. Central region Imbn. D. faint, mostly visible over prominence of first phalangeal joint. Indiff. elsewhere.

D. 4. *Terminal Phalanx.* Pulp—tip worn down. Indiff. Radial and ulnar border Imbn. D. faint.

Middle Phalanx. Imbn. D. marked in central region.

Proximal Phalanx. Central region over prominent phalangeal joint Imbn. D. marked. Elsewhere Indiff.

W.K.—*Left Hand.*

D. 5. *Terminal Phalanx.* Pulp, radial and ulnar sides Imbn. D. Central region Indiff.

Middle Phalanx. Radial and ulnar sides Imbn. D. Central region Imbn. D. faint.

Proximal Phalanx. Ulnar side Imbn. D. faint. Elsewhere Indiff.

W.K.—*Right Hand.*

D. 1. *Terminal Phalanx.* Worn down at tip Indiff. Pulp, radial side Imbn. D. Ulnar side Imbn. D. fainter. Central region worn down and Indiff.

Proximal Phalanx. Radial side Imbn. D. Ulnar and central region Indiff.

D. 2. *Terminal Phalanx.* Tip worn down. Indiff. Pulp, radial side Imbn. D. Ulnar side and central region Indiff.

Middle Phalanx. Radial and ulnar sides Imbn. D. Central region Imbn. D.

Proximal Phalanx. Radial and ulnar sides Indiff. Central region Imbn. D.

D. 3. *Terminal Phalanx.* Radial side and central region Imbn. D. Ulnar side worn down and Indiff.

Middle Phalanx. Indiff.

Proximal Phalanx. Indiff., except on prominence over first phalangeal joint, here D. Imbn.

D. 4. *Terminal Phalanx.* Tip and pulp worn down and Indiff. on both sides.

Middle Phalanx. Radial and ulnar sides Imbn. D. and on central region close to first phalangeal joint. Over second phalangeal joint a few P. R. with Imbn. P.

Proximal Phalanx. Radial and ulnar side Imbn. D. Central region Indiff.

D. 5. *Terminal Phalanx.* Tip. Indiff. and P. R. worn down. Radial and ulnar sides D. Imbn. Ulnar much worn down.

Middle Phalanx. Indiff.

Proximal Phalanx. A few P. R. with Imbn. D. on ulnar side, elsewhere Indiff.

Palmar Surface—Left Hand. Thenar and hypothenar surfaces show P. R. worn down and level. All the rest of the surface of palm Imbn. absent, except on small eminences at bases of D. 2, 3 and 4, where Imbn. is D. No Imbn. on eminence at base of D. 5.

Right Hand. Resembles the left hand, except that the eminence at bases of D. 5 shows Imbn. D.

CASE 2.

H.K.—*Right Hand.*

D. 1. *Terminal Phalanx.* Imbn. Indiff. except on radial border, where it is D.

H.K.—*Right Hand.*

D. 2. *Terminal Phalanx.* Part of ulnar side Imbn. D., elsewhere Indiff.

D. 3. *Terminal Phalanx.* Imbn. D.

Middle Phalanx. Imbn. D.

D. 4. *Terminal Phalanx.* Imbn. D. radial side.

D. 5. *Terminal Phalanx.* Imbn. D.

Middle Phalanx. Ulnar side Imbn. D.

Palmar Surface. Eminences at bases of D. 3 and 4 Imbn. D.

Proximal parts of thenar and hypothenar eminences Imbn. D.

Left Foot.

D. 1. *Terminal Phalanx.* Tibial side Imbn. D. Fibular side Indiff.

D. 2. *Terminal Phalanx.* Indiff.

D. 3. *Terminal Phalanx.* Indiff.

D. 4. *Terminal Phalanx.* Indiff.

D. 5. Tip of Terminal Phalanx Imbn. P. (this segment considerably bent in a flexed position).

Ball of D. 1 Imbn. P.

Fibular border of metatarsophalangeal joint Imbn. P.

Heel. Imbn. P.

CASE 3.

E.K.—*Right Foot.*

D. 1. *Terminal Phalanx.* Imbn. P. on tibial and fibular sides of pulp.

D. 2. Indiff.

D. 3. Indiff.

D. 4. Indiff.

D. 5. Imbn. D.

Plantar Surface.

D. 1. Ball Imbn. P.

Fifth metatarso-phalangeal joint Imbn. P.

Fifth tarso-metatarsal Imbn. P.

Heel. Tibial border Indiff. Fibular border Imbn. P.

Left Foot.

D. 1. *Terminal Phalanx.* Tibial side Imbn. P. Fibular side Imbn. P. faint.

D. 2. *Terminal Phalanx.* Imbn. D. faint.

D. 3. *Terminal Phalanx.* Imbn. D. faint.

D. 4. *Terminal Phalanx.* Imbn. D. faint.

D. 5. *Terminal Phalanx.* Imbn. D. faint.

Plantar Surface. Ball of D. 1 Imbn. D. faint on tibial side. Indiff. on fibular side.

5th Metatarso-phalangeal joint Indiff.

5th Tarso-metatarsal joint Indiff.

Heel. Indiff. on both sides.

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The sense of touch in mammals and birds