AN INTERPRETATION OF THE RECORDED ARTERIAL ANOMALIES OF THE HUMAN LEG AND FOOT[1]

By H. D. SENIOR, M.D., F.R.C.S.,

Temporary Civil Surgeon, Middlesex War Hospital, Napsbury, Professor of Anatomy, New York University

During the course of an investigation into the development of the arteries of the human lower extremity, I became very much interested in the study of such published figures of arterial anomalies as happened to be available at the time. Some of these figures revealed the presence in the adult limb of vessels which, from their course and connections, were clearly recognisable as persisting embryonic arteries.

The occasional persistence of such arteries in adult life suggested that a more thorough study of the literature relating to anomalies might well be used for controlling the conclusions already reached by purely embryological means.

Since the direct study of human embryology is so closely dependent upon the accessibility of suitable material, the value of any method, however indirect it may be, which is capable of furnishing evidence bearing upon the nature of developmental process, is too great to be ignored.

In many cases a conception of the type of arterial distribution characteristic of any given stage of development must, of necessity, be founded upon the study of a single embryo. Under the most favourable conditions the data gathered from one specimen may be supplemented by comparison with other embryos representing an approximately identical stage of development. Generally speaking, however, the total number of embryos examined is far too small to provide unequivocal evidence upon the nature of the numerous changes occurring throughout the course of development.

The examination of the literature from which the present paper has resulted was primarily directed towards the recognition of the specific deviation from the course of normal development underlying the production of the particular anomaly investigated. It consists, to a large extent, of an analysis of the many excellent figures which have been published between the year 1743 and the present day. Unillustrated descriptions have been used also, but to a much more limited extent, since the intelligibility of many of the records belonging to this class is vitiated by errors of interpretation and by the omission of essential details.

[1] An essay, substantially identical with the portion of this paper relating to the leg, was accepted by Durham University in partial fulfilment of the requirements for the degree of Doctor of Medicine.

The system of interpretation is based entirely upon the results of the embryological investigation, previously mentioned, which will be published elsewhere[1]. It may be added that the examination of the rather long series of recorded anomalies which forms the basis of this study has not led to the essential modification of any of the opinions expressed in the paper dealing with the process of development.

The sources from which the anomalies examined were taken are noted in the text, but reproductions of line drawings, prepared by means of tracings taken from photographs of the originals, have been added for convenience of reference.

Since it is impossible to name anomalous arteries according to the nomenclature ordinarily applied to the normal adult, *a system has been employed of labelling the normal embryonic components of the abnormal vessels in Roman type.* Persisting embryonic arteries regarded as foreign to normal development, normal adult arteries and other adult structures have been labelled in *Italics.* As a key to the system used, the popliteal and posterior crural regions of a normal leg have been labelled on similar principles and reproduced as fig. 31 (p. 161).

The majority of the figures used have been taken from the following publications[2]:

TIEDMANN, F. *Tabulae Arteriarum.* Carlsruhe, 1822.

BOURGERY ET JACOB. *Traité Complet de l'Anatomie de l'Homme,* tome IV. Paris, 1835.

QUAIN, R. *The Anatomy of the Arteries of the Human Body.* London, 1844.

DUBRUEIL, J. M. *Des Anomalies Artérielles.* Paris, 1847.

HYRTL, J. "Ueber normal und abnorme Verhältnisse der Schlagadern des Unterschenkels," *Denkschriften der Mathematische-Naturwissenschaftliche Classe der K. Akademie der Wissenschaften.* Wien, 1864.

BARKOW, H. C. L. "Erlaüterungen Zur Schlag—und Blutader—Lehre des Menschen," *Comparative Morphologie des Menschen und Menschenähnlichen Thiere,* Theil VI. Breslau, 1868.

Of the three sections into which the following paper is divided, the second is devoted to the interpretation of the anomalies forming the basis of this study. The shorter section which precedes it reviews the principal changes occurring during the course of normal development. The final section deals with the share taken by each of the embryonic arteries in the composition of the adult arterial system, whether normal or abnormal, and serves as a summary of the other two.

I take this opportunity of acknowledging my obligation to Professor Howden, and to Doctors R. J. Gladstone and Stuart Tidey for their kindness in reading the manuscript and for their helpful criticism.

[1] "On the Development of the Arteries of the Human Lower Extremity," by H. D. Senior, *Am. Journ. Anat.* On account of the large amount of material which has been awaiting publication this paper is not yet in type.

[2] Siebold, R., *Ueber den anomalen Ursprung und Verlauf der in chirurgischer Beziehung wichtigen Schlagaderäste,* Würsburg, 1837, is inaccessible. The sources of anomalies cited from journals and other publications are noted elsewhere.

A BRIEF SKETCH OF DEVELOPMENT

A description of the arterial system of the human lower extremity in progressive stages of its development is to be found in the paper upon development to which reference has been made in the Introduction. The same paper also contains a brief account of each of the embryonic arteries as far as its history has been investigated.

For convenience of reference the main features of the developmental processes involved in the production of the adult arterial system of the leg and foot have been recapitulated here. Further details bearing upon the developmental changes concerned in the production of a few special anomalies are to be found in the section dealing with the region to which the anomaly in question belongs.

The *primitive axial artery*, which arises from the dorsal (secondary) root of the *a. umbilicalis*, already traverses the axis of the limb at an extremely early stage of development. So early, indeed, that the lumbo-sacral nerves have not yet emerged from the spinal medulla, and the limb-bud itself is still indistinctly circumscribed upon the surface. The artery terminates in the region of the foot by dividing into the stem branches of the plantar arterial rete, and into two or three arteries which later blend to form the *r. perforans tarsi*. The latter vessels traverse the sinus tarsi to enter into the formation of the dorsal arterial rete of the foot. Up to *the stage of* 12 *mm.* (fig. 1) the arterial system of the leg retains, in an essentially unaltered condition, the form it presents at 6 mm., the earliest stage at which it has been carefully studied.

During the earlier stages of development there are no means of determining the exact relations borne by the axial artery to the, as yet undifferentiated, skeletal and muscular structures of the part. Throughout the period occupied by its gradual differentiation, the skeletal core of the limb is enveloped by an ill-defined condensation of mesenchyme representing the developing musculature. It is not until a stage of about 18 mm. that differentiation is sufficiently advanced for the identification of the mesenchymal territories which, up to that time, have but virtually represented the individual muscles. Owing to the fortunate circumstance that all the nerves and supporting structures of the limb are clearly recognisable before any part of the axial artery has disappeared, the course of that vessel can be accurately ascertained. It is as follows:

Leaving the pelvis at the distal margin of the m. pyriformis the axial artery follows the n. tibialis as far as the proximal margin of the m. popliteus. Having passed between the m. popliteus and the tibia, it runs between the m. tibialis posterior and the interosseous membrane (figs. 1, 2 and 3). A short distance above the malleoli the artery emerges upon the lateral side of the m. tibialis posterior and closely follows the lateral side of the tendon of that muscle in its course around the medial malleolus. It finally passes into the sole and ends at the plantar orifice of the sinus tarsi.

Before the *stage of* 14 *mm.* (fig. 2), two arterial landmarks have been established which may be used for the convenient subdivision of the axial artery into three sections. These landmarks are the termination of the a. femoralis and the origin of a vessel which represents the first step in the development of the adult a. tibialis anterior, namely, the *r. perforans cruris.*

The section of the axial artery included between the points above indicated will be referred to henceforth as the a. poplitea profunda, while the sections proximal and distal to the a. poplitea profunda will be called the a. ischiadica, and the a. interossea, respectively.

The *a. ischiadica* having previously relinquished the chief blood supply of the limb in favour of the a. femoralis, is represented at the stage of 22 mm. by the *a. glutea inferior*, and by the anastomosing ramifications of the *aa. perforantes* upon the posterior aspect of the m. adductor magnus.

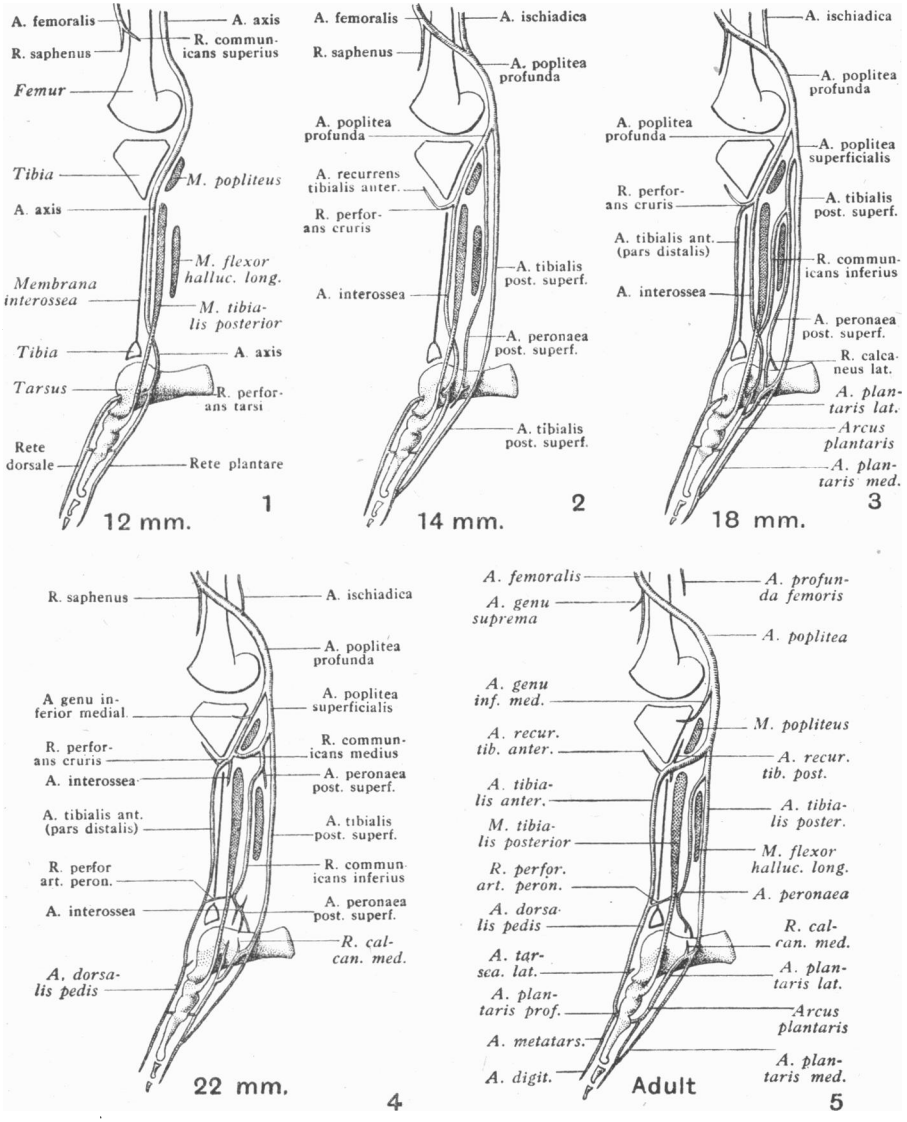
The *a. poplitea profunda* is the most permanent section of the axial artery. The portion of this vessel extending from the hiatus tendineus to the proximal border of the m. popliteus persists unchanged in the adult. The distal portion of the artery, which extends from the proximal border of the m. popliteus to the proximal end of the tibio-fibular interspace and passes anterior to the m. popliteus, has been supplanted at the stage of 22 mm. by the a. poplitea superficialis, which lies upon the posterior surface of that muscle.

The *a. interossea* disappears almost entirely before the completion of development. A short section of it participates, however, in the formation of the supramalleolar portion of the a. peronaea of the adult. The persisting section of the a. interossea gives origin to two important branches which, persisting with it, are taken over branches of the portion of the adult artery. One of the two branches of the a. interossea, the r. coronarius malleolaris, is present at the stage of 18 mm.; the other, the r. perforans, has not been observed until the stage of 22 mm.

At *the stage of* 18 *mm.* the presence of the a. femoralis in the thigh, and the addition of four longitudinal arteries in the leg (making five in the latter situation), has given rise to an arterial arrangement of much greater complexity than that found in the embyro of 14 millimetres.

One of the five arteries which pursue a longitudinal course through the leg at the stage of 18 mm. is the a. interossea, already described. The other four are the a. tibialis posterior superficialis, the a. peronaea posterior superficialis, the r. communicans inferior and the a. tibialis anterior, pars distalis.

The *a. tibialis posterior superficialis* and the *a. peronaea posterior superficialis* are already present at the stage of 14 mm. (fig. 2), at which stage they take independent origin from the a. poplitea profunda. The former artery traverses the leg upon the posterior aspect of the n. tibialis and enters the foot as the *a. plantaris medialis*, while the latter courses to the medial malleolus upon the posterior aspect of the m. flexor hallucis. The a. peronaea posterior superficialis terminates by dividing into two branches which end blindly at the stage of 14 mm. By the stage of 18 mm. (fig. 3) the terminal



Figs. 1–5. Diagrams indicating the distribution of the main arteries of the right leg and foot at four stages of development and in the adult. A sagittal section is represented as having passed through the femur and through the interosseous membrane and adjacent parts of the extremities of the tibia. The section does not involve the skeleton of the foot, which is shown entire. The muscles remain indifferentiated prior to the stage of 18 mm. The positions of the muscles shown in the earlier stages are, therefore, virtual only and not actual.

Labels in Roman type refer to embryonic arteries; italics are used for adult arteries and for all other structures.

branches of this artery have formed a continuous channel which unites the a. tibialis posterior superficialis with the lateral region of the plantar arterial rete. This channel is the *a. plantaris lateralis.*

The a. peronaea posterior superficialis gives origin, at the stage of 18 mm., to a branch which eventually becomes the terminal portion of the a. peronaea, it is the *r. calcaneus lateralis.*

The *r. communicans inferius,* which is a vessel of recent origin at the stage of 18 mm. (fig. 3), eventually takes a large share in the formation of the a. peronaea. Leaving the a. peronaea posterior superficialis on a level with the proximal end of the m. flexor hallucis longus, it passes anterior to the muscle and joins the a. interossea in the supramalleolar region.

The *a. tibialis anterior, pars distalis* arises at a stage of 15–16 mm. from the *r. perforans cruris* which itself appears shortly before the stage of 14 mm. Having followed a course through the anterior crural region identical with that taken by the adult a. tibialis anterior, it joins the dorsal arterial rete of the foot (fig. 3).

At *the stage of* 22 *mm.* two of the arteries of the leg, the a. tibialis anterior and the a. peronaea, have begun to assume their adult form.

The *a. tibialis anterior* has reached completion through the appearance of the *r. communicans medius,* which becomes its definitive root. The embryonic components of the a. tibialis anterior are: The r. communicans medius, a short section of the a. poplitea profunda, the r. perforans cruris, and the pars distalis (see figs. 1—5).

From the time of the appearance of the r. communicans medius, which receives its blood from the developing a. peronaea, the distal end of the a. poplitea profunda begins to undergo retrogression. The a. recurrens tibialis posterior and the root of the a. genu inferior medialis are its representatives in the adult.

The *a. peronaea* has become recognisable mainly by reason of the disappearance of the transient portions of the a. peronaea posterior superficialis and a. interossea. Through extensive degeneration the two latter vessels have relinquished their original connection with the arterial retia of the foot. These are now supplied by the aa. tibialis anterior and posterior.

The embryonic components of the a. peronaea are: The a. peronaea posterior superficialis, the r. communicans inferior, a short section of the a. interossea and the r. calcaneus lateralis of the a. peronaea posterior superficialis. More detailed information regarding the composition of the a. peronaea is given on p. 150.

At this stage of development the a. peronaea arises from the a. poplitea superficialis and gives origin to the a. tibialis anterior.

The *arterial arrangement of the adult leg* differs from that encountered at the stage of 22 mm. mainly in the completion of the a. poplitea, and in the origin from that vessel of the a. tibialis anterior.

The formation of the *adult a. poplitea* has been accomplished by the blending

of the proximal part of the a. poplitea profunda with the *a. poplitea superficialis*. The latter vessel, which arises through the gradual union of the proximal part of the a. peronaea posterior superficialis with that of the a. tibialis posterior superficialis, lies upon the posterior surface of the m. popliteus. By the time the a. poplitea has reached completion it has taken over the a. tibialis anterior as one of its terminal branches.

The progressive union between the a. peronaea posterior superficialis and the a. tibialis posterior superficialis does not stop at the termination of the a. poplitea. It is continued as far as the point at which the adult a. peronaea takes origin from the *a. tibialis posterior*.

The part of the a. tibialis posterior distal to the origin of the a. peronaea is derived directly from the a. tibialis posterior superficialis. It differs from its embryonic precursor, however, in the relation it bears to the n. tibialis.

ANOMALIES IN THEIR RELATION TO ARTERIAL DEVELOPMENT

It is questionable whether even the most local deviation from the course of normal arterial development manifests itself entirely within the limits of a single adult artery. Cases characterised by absence, or other gross variation, of one of the adult arteries are commonly classified as anomalies of the particular vessel most obviously affected. In consequence, however, of the very intimate interdependence of the alternative arterial routes which successively become available during the progress of development, it happens that arterial anomalies affect general arterial regions rather than individual vessels.

The classification used in this paper depends upon the selection of three general regions in the leg, and the treatment of the foot as a whole. The leg regions (particularly the first and third) are somewhat arbitrarily separated, but have been found convenient in practice. They are the popliteal, the anterior crural and the posterior crural.

In analysing cases in which the anomaly depends upon the absence of one of the embryonic arteries it has been assumed, unless there is evidence to the contrary, that the absence is primary, and not due to the disappearance of a vessel once present. In cases in which neither alternative is subject to verification the first, and perhaps the more probable of the two, has been taken for granted in order to obviate the necessity of repeating the possibilities of each case.

A. THE POPLITEAL REGION

The only section of the embryonic axial artery which normally persists as a main adult trunk is that represented by the part of the a. poplitea profunda which furnishes the part of the adult a. profunda extending from the hiatus tendineus to the origin of the a. genu medialis inferior. The section of the adult a. poplitea in question seems to be invariable even though its proximal and distal connections may be quite abnormal. The portion of the

embryonic a. poplitea profunda which lies anterior to the m. popliteus, normally abandons its original function as part of the main arterial channel into the leg, and is superseded by the a. poplitea superficialis which passes posterior to that muscle.

The recorded anomalies of this region are as follows:

1. HIGH DIVISION OF THE POPLITEAL ARTERY INTO THE POSTERIOR TIBIAL AND PERONEAL, THE LATTER GIVING OFF THE ANTERIOR TIBIAL: fig. 6, from Quain (pl. 79, fig. 5). Examples of an exactly similar anomaly have been given by Haller (*Icones Anatomicae*, Göttingen, 1743, pl. 5) and Tiedmann (pl. 51, fig. 3). Others, by Barkow and Hyrtl, are reproduced here as figs. 25 and 26.

The a. poplitea superficialis is absent, the embryonic a. tibialis posterior superficialis and a. peronaea posterior superficialis having failed to unite in the normal manner.

Failure in the union of the roots of these two embryonic arteries has produced a further anomaly which affects the aa. tibialis posterior, peronaea, and tibialis anterior. The first of these arteries is necessarily smaller than usual above the point at which a. peronaea should normally arise. The a. peronaea, instead of arising from the a. tibialis posterior, takes origin from the a. poplitea, while the a. tibialis anterior arises from the a. peronaea.

2. HIGH ORIGIN OF THE PERONAEAL ARTERY, THE POPLITEAL BEING NORMAL: fig. 7, from Quain (pl. 79, fig. 6). This anomaly, though slighter in degree, is of precisely the same nature as the preceding. Union between the aa. peronaea posterior superficialis and tibialis posterior superficialis has failed to extend as far as usual. The failure has resulted in diminution of the calibre of the proximal part of the a. tibialis posterior. The proximal part of the a. tibialis anterior (r. communicans medius) arises from the a. peronaea, as in the embryo of 22 mm. (fig. 4).

3. HIGH DIVISION OF THE POPLITEAL ARTERY INTO POSTERIOR AND ANTERIOR TIBIAL: fig. 8, from Quain (pl. 79, fig. 3). This anomaly would appear to depend upon a series of events more complicated than that underlying the two preceding cases. Union between the embryonic aa. peronaea posterior superficialis and tibialis posterior superficialis, instead of being complete as far as the site of origin of the future a. peronaea, seems to have occurred in the region near the distal margin of the m. popliteus only.

The greater part of the blood entering the proximal part of the a. peronaea posterior superficialis would, under such circumstances, have passed through the r. communicans medius which ordinarily forms the root of the a. tibialis anterior. The greater part of the blood entering the proximal part of the a. tibialis posterior superficialis would, similarly, have passed into the distal part of the vessel. A smaller proportion of the blood entering the proximal part of each vessel would be free to enter the distal part of the a. peronaea posterior superficialis.

The transition from such an arrangement to the condition of affairs repre-

sented in fig. 8 could be readily explained by assuming the subsequent disappearance of the part of the a. peronaea posterior superficialis which originally intervened between the origin of the r. communicans medius and its junction with the a. tibialis posterior superficialis. The disappearance of the part of the vessel in question would leave the r. communicans medius attached to the proximal part of the a. peronaea posterior superficialis. The distal part of the latter artery would remain attached to the a. tibialis posterior superficialis and become the root of the adult a. peronaea.

4. HIGH DIVISION OF THE POPLITEAL ARTERY, THE ANTERIOR TIBIAL ARTERY PASSING ANTERIOR TO THE POPLITEUS MUSCLE: fig. 9, from Quain (pl. 79, fig. 4). This anomaly depends upon absence of the embryonic r. communicans medius, which, in normal cases, forms the root of the adult a. tibialis anterior. The deficiency has been rectified by the maintenance of the connections normally found at the embryonic stage of 18 mm. The distal part of the a. poplitea profunda has retained its integrity and supplies the anterior crural region by transmitting blood directly into the r. perforans cruris.

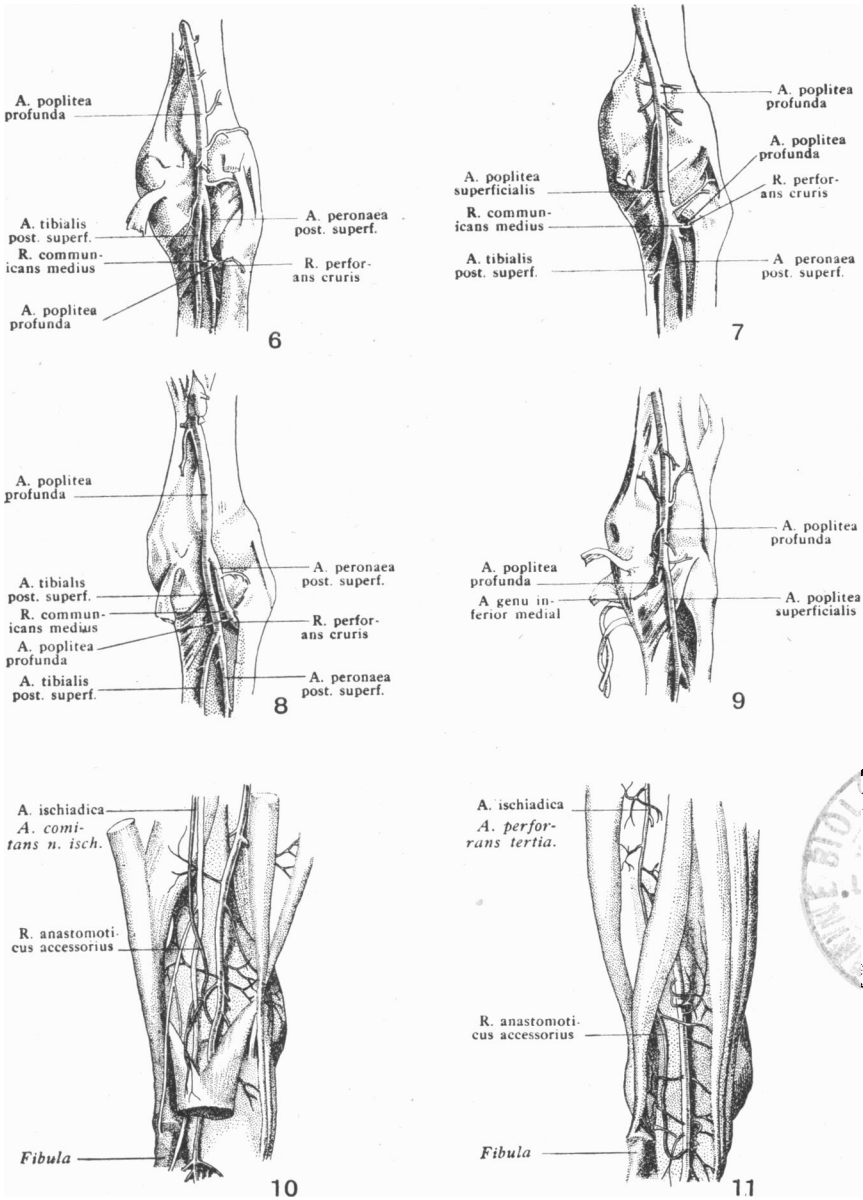
5. DIVISION OF THE POPLITEAL ARTERY INTO ANTERIOR TIBIAL AND "GREAT" PERONAEAL, OR AN ARTERY DERIVED FROM KINDRED ANTECEDENTS, THE POSTERIOR TIBIAL BEING ABSENT: figs. 21, 22, 23 and 24. Further examples of the anomaly represented in fig. 21 are recorded by Quain (pl. 84, fig. 3), Tiedmann (pl. 36, fig. 3) and Hyrtl (pl. 3, figs. 1 and 2). All these cases are characterised by absence of the embryonic a. tibialis posterior superficialis as will be discussed later. The proximal portion of the a. poplitea has been formed, in the usual way, from the a. poplitea profunda, while the distal portion may be regarded approximately as a direct survival of the root of the embryonic a. peronaea posterior superficialis.

6. FIGURES OF TWO SO-CALLED ANOMALIES OF THE POPLITEAL ARTERY, WHICH SEEM TO BELONG ONLY SECONDARILY TO THIS VASCULAR REGION, ARE REPRODUCED AS FIGS. 10 AND 11, from Hyrtl (pl. 1, figs. 1 and 2).

In each there is an artery which, lying upon the lateral side of the a. poplitea, inosculates with that vessel near the back of the knee joint. The proximal part of the artery in question (a. commitans nervi ischiadici in the first case, and the a. perforans tertia in the second) is clearly a persisting part of the a. ischiadica.

The embryonic a. ischiadica normally terminates at the hiatus tendineus by becoming the a. poplitea profunda. The distal portion of the anomalous artery in both of Hyrtl's cases is, therefore, not a part of the a. ischiadica. It appears to be merely an anastomosing muscular ramus of the a. poplitea. If these cases are to be regarded as anomalies of the a. poplitea at all, they should be classed as secondary rather than primary anomalies of that vessel.

The primary nature of another case published by Hyrtl, and cited by Krause as an anomaly of the a. poplitea (Henle's *Gefässlehre*, p. 305) may also be regarded as somewhat questionable. In the case in question the a. suralis



Figs. 6–11. The anomalies shown in figs. 6, 8 and 9 affect the popliteal, peronaeal and anterior and posterior tibial arteries. In the case of fig. 7 the same arteries, with the exception of the popliteal, are involved. Figs. 10 and 11 represent a persisting ischiadic artery, the original termination of which has been supplanted by a new, and more distal, connection with the popliteal.

Labels in Roman type refer to the normal embryonic predecessors of the adult arteries shown; italics are used for all other structures. Figs. 6–9 from Quain, pl. 79, figs. 5, 6, 3 and 4 respectively: 10 and 11 from Hyrtl, pl. 1, figs. 1 and 2 respectively.

magna arises from the a. poplitea. Hyrtl's figure (pl. 3, fig. 3), which has been reproduced here as fig. 29, will be referred to again in the section devoted to the anomalies of the posterior crural region.

The embryonic elements entering into the composition of the a. tibialis anterior in the cases reproduced as figs. 6, 7, 8 and 9, are reviewed, together with those found in other anomalies affecting that vessel, on the next page.

B. THE ANTERIOR CRURAL REGION

The portion of the a. tibialis anterior situated in this region of the leg is the product of two embryonic vessels, namely, the r. perforans cruris and the a. tibialis anterior, pars distalis. Of these, the former appears to be absolutely constant, while the latter is not infrequently too small for the complete arterial supply of the dorsum of the foot, and may be altogether absent. Very occasionally the anomalous a. saphena magna appears as an accessory vessel in this region and reaches the malleoli. It may even be large enough to assist materially in the arterial supply of the foot.

The graphically recorded anomalies of the anterior crural region are as follows:

7. THE DISTAL PART OF THE ANTERIOR TIBIAL ARTERY IS ABSENT: fig. 12, from Hyrtl (pl. 8, fig. 2). In this case arterial blood is conveyed to the dorsum of the foot by a branch of the a. tibialis posterior which perforates the interosseous membrane at the junction of the middle and lower thirds of the leg.

From the large size of the a. dorsalis pedis, as compared with the perforating branch, it is obvious that the former vessel receives the greater proportion of its blood from the arcus plantaris by way of the r. plantaris profundus. The r. perforans cruris, and its continuation the a. recurrens tibialis anterior, have retained the relations normally found in the embryo of 14 mm. (fig. 2).

The a. tibialis anterior, pars distalis, which should have been developed later (fig. 3), has failed to appear, or, having appeared, has undergone partial degeneration. The large recurrent branch which passes from the perforating ramus towards the r. perforans cruris suggests the probability of the latter alternative. No other figures of this anomaly have been found in the literature. Similar cases, however, have been recorded by Burns (*Diseases of the Heart*, 1809), Ryan (*Diss. Inaug. de quarundam Arteriarum in Corpore Humano Distributione*, 1812), and Otto (*Pathol. Anat.* 1829).

8. THE DISTAL PART OF THE ANTERIOR TIBIAL ARTERY IS SMALL: fig. 13, from Quain (pl. 85, fig. 5). In this example the a. tibialis anterior ends, without inosculation, among the extensor muscles of the leg. The a. dorsalis pedis arises from a large r. perforans arteriae peronaeae. Dubrueil, also, figures a somewhat similar case (pl. 17, fig. 2).

Cases in which a small a. tibialis anterior is sufficiently long to inosculate with, and be reinforced by, the r. perforans have been figured by Tiedmann (pl. 36, fig. 2), Quain (pl. 85, fig. 4), Hyrtl (pl. 8, fig. 1), Barkow (pl. 9, figs. 1, 2 and 3; pl. 10, figs. 1 and 2) and others. Numerous unillustrated instances

in which the r. perforans (with or without inosculation with an a. tibialis anterior of small size) had provided the main arterial supply of the dorsum of the foot, are scattered throughout the literature. The anomaly is of common occurrence.

Anomalies affecting the anterior tibial artery occur not only in the anterior crural, but in the popliteal region also.

The a. tibialis anterior is the product of four embryonic arteries which arise at different stages of development. The part of the adult artery which takes origin from each of the embryonic vessels concerned can be identified with approximate accuracy, as follows:

Part I extends from the origin of the artery to a point immediately proximal to the origin of the a. recurrens tibialis posterior. It corresponds to the whole of the embryonic r. communicans medius.

Part II is the part of the artery which gives origin to the a. recurrens tibialis posterior, and, occasionally, to a short descending branch which represents a persisting part of the a. interossea. This part of the artery is derived from a very small section of the embryonic a. poplitea profunda.

Part III extends from a point immediately distal to the origin of the a. recurrens tibialis posterior to the origin of the a. recurrens tibialis anterior. It is derived from the embryonic r. perforans cruris.

Part IV extends from the distal side of the origin of the a. recurrens tibialis anterior to the front of the ankle joint. It corresponds to the entire a. tibialis anterior, pars distalis, of the embryo.

In the anomaly shown in fig. 6, the embryonic elements which enter into the formation of the a. tibialis anterior are five in all, viz. the a. peronaea posterior superficialis, r. communicans medius, a. poplitea profunda, r. perforans cruris, and the pars distalis. The same elements appear in the anomalies shown in figs. 7 and 8, but in the former case the part contributed by the a. peronaea posterior superficialis is much shorter than that found in the cases which form the subjects of figs. 6 and 8.

In the anomalies shown in fig. 9 the embryonic components of the a. tibialis anterior are: the a. poplitea profunda, r. perforans cruris, and the pars distalis; in that of fig. 12, they are the r. communicans medius, a. poplitea profunda (presumably), and the r. perforans cruris; three in each case. In the case of fig. 13, the embryonic components are normal in number and order, but the fourth has failed to reach its usual goal, namely the rete dorsale pedis.

An anomaly of the anterior tibial artery, apparently unique but much quoted in the literature, is that of Velpeau (*Eléments de Médicine Opératoire*, 1839) of which no figure is given. In this case the artery is recorded as having reached the anterior crural region by passing laterally around the neck of the fibula, following the course of the n. peronaeus communis. Such an artery is not of normal occurrence in the embryo, and must be regarded as peculiar to the individual in which it occurred. The embryonic elements entering into

the formation of the a. tibialis anterior in Velpeau's case may be supposed (in the absence of a figure showing the exact conditions) to have been as follows: a. comitans n. peronaei, a. recurrens tibialis anterior, r. perforans cruris, and the pars distalis. It may be supposed, further, that the r. communicans medius, the portion of the r. perforans cruris posterior to the interosseous membrane, and the portion of the a. poplitea profunda which normally unites them, were absent. The two latter components of the anomalous vessel, which must have been present in their respective stages of development, were presumably lost in consequence of usurpation of function. The former (not necessarily present at all) may have failed to develop as in the case illustrated in fig. 9.

9. A. SAPHENA MAGNA: fig. 14, from Zagorski (*Mémoires de l'Académie Impériale des Sciences de St Pétersbourg*, T. I. 1809).

Two figures have been published which very closely resemble Zagorski's, namely, those of Barkow (pl. 56, fig. 1) and Manners-Smith (*Journ. Anat. and Physiol.* vol. XLV. pl. 20). In all three the origin of the a. saphena is independent of that of the common trunk of the musculo-anastomotic rami, a condition found in the embryo prior to the stage of 22 mm.

Unillustrated instances have been reported by Broca (*Bulletin de la Soc. Anat.*, Paris, 1849), Rug, and Popowski. Rug's case occurred in association with persistence of the embryonic a. ischiadica (*Würzburger Medicinische Zeitsch.*, Bd. IV. 1863). The thigh only appears in the figure, which, however, shows the root of an unusually large a. genu suprema.

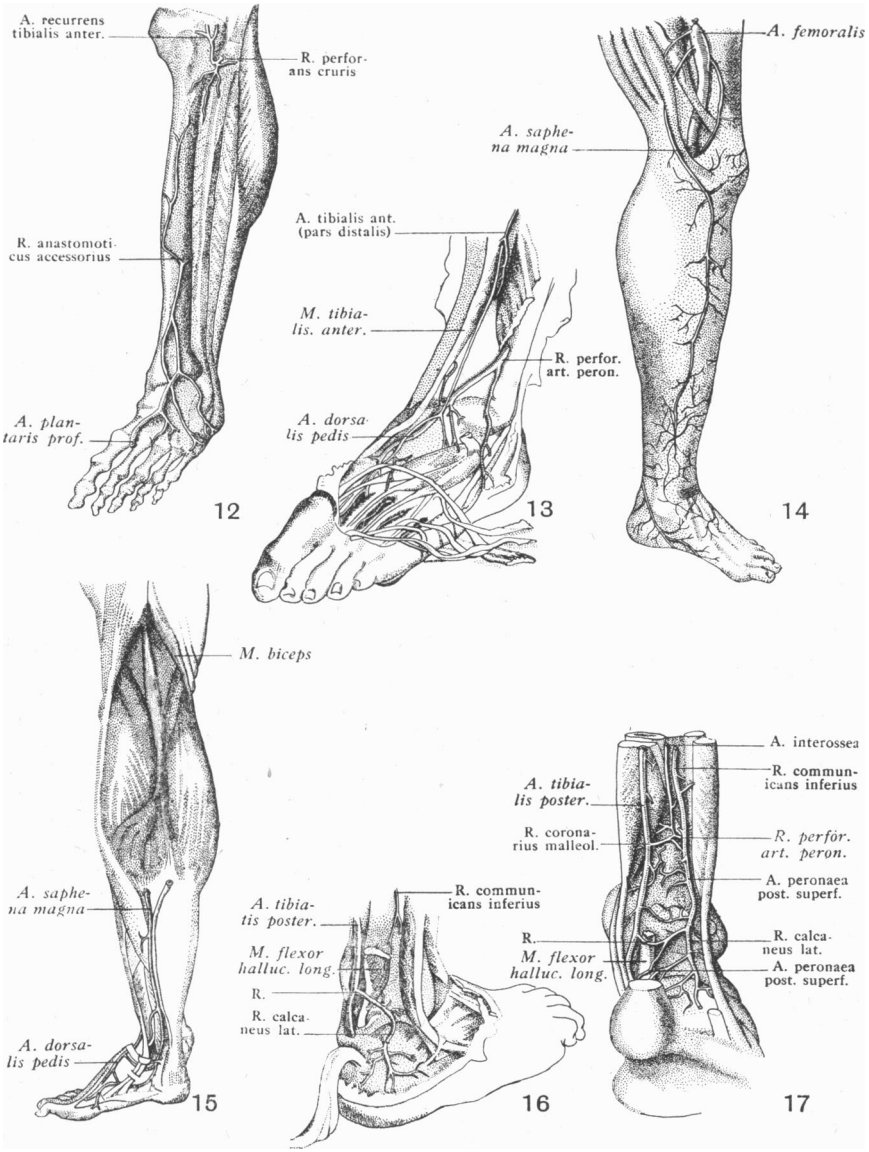
Judging from Rug's description the ultimate distribution of the main trunk of the vessel resembled the a. saphena magna of Zagorski's example.

In Popowski's case (*Anatomischer Anzeiger*, Bd. VIII. 1893) the artery, of which the root is as large as the a. poplitea, has a very much more extensive distribution. It divides into an anterior and a posterior branch, the former of which extends to the foot to supply the medial side of the great toe and reinforce the a. dorsalis pedis, while the posterior branch passes beneath the calf muscles to reinforce the a. tibialis posterior.

Fig. 15, from Hyrtl (pl. 3, fig. 3), represents an interesting case of a. saphena magna occurring in the right leg of a new-born infant. In this instance the vessel does not arise from the a. femoralis, but from the a. tibialis posterior.

Hyrtl's case would admit of a relatively simple explanation, and not improbably the true one, if it were assumed that the a. saphena magna originally resembled the large vessel described by Popowski. The posterior branch of such an artery, if it should have transmitted blood from the a. tibialis posterior into the anomalous artery, rather than in the contrary direction, might well have usurped the function of the original root of the a. saphena magna. It is unfortunate that the limb was not posed, for the purpose of reproduction, in such a way as to display the region of the a. femoralis from which the a. genu suprema usually takes origin.

The small branch of the a. saphena magna shown in fig. 15, which passes



Figs. 12–17. The chief anomaly in figs. 12 and 13 is of the anterior tibial artery. Subsidiary anomalies affect the posterior tibial and dorsalis pedis in the former, and the peronaeal in the latter. Figs. 14 and 15 are examples of a. saphena magna. The peronaeal and posterior tibial arteries are anomalous in fig. 16, and the peronaeal in fig. 17.

Labels in Roman type refer to the normal embryonic predecessors of the adult arteries shown; italics are used for all other structures. Figs. 12 and 15 from Hyrtl, pl. 8, fig. 2, and pl. 4, fig. 2 respectively; fig. 14 from Zagorski; figs. 13 and 16 from Quain, pl. 85, fig. 5, and pl. 84, fig. 4 respectively; fig. 17 from Tiedmann, pl. 36, fig. 4.

anterior to the malleolus, represents, no doubt, the true termination of the artery. Nevertheless, the behaviour of the termination of the main trunk in Hyrtl's case bears a very striking resemblance to that of the anterior branch in Popowski's. It divides into two branches, one of which supplies the medial border of the great toe, while the other passes laterally beneath the tendons of the mm. tibialis anterior and flexor hallucis longus to join the a. dorsalis pedis.

It would appear, on the whole, that what may be regarded as the fully developed termination of the a. saphena magna finds exemplification in the case of Popowski and Hyrtl rather than in those of Zagorski and Barkow and Manners-Smith. In the three latter cases the vessel loses its individuality before it reaches the medial malleolus.

Although the anomalous a. saphena magna appears in the anterior crural region, the circumstances bearing upon its origin and proportions form a part of the developmental history of the arteries of the thigh. The *a. iliaca externa*, which arises from the a. umbilicalis before the stage of 8·5 mm., ends blindly until after the stage of 11 mm. It then divides into the *a. epigastrica inferior* and the *a. femoralis*, which grow rapidly into their respective territories. The growing extremity of the a. femoralis is, from the very first, bifurcated into the *r. communicans superius* and *r. saphenus*. The former branch joins the axial artery at the hiatus tendineus shortly after the developmental stage of 12 mm., while the latter, growing into the anterior crural region, extends less than half way down the leg. The musculo-anastomotic ramus of the *a. genu suprema* arises originally from the a. femoralis, but is taken over by the r. saphenus (the root of which thus becomes common to all branches) at the stage of 22 mm.

In Rug's case of a. saphena magna it does not seem unreasonable to suspect correlation between abnormal overgrowth of the r. saphenus and absence of the r. communicans superius. The other examples of this anomaly do not seem to admit of a definite embryological explanation.

Out of a relatively large number of human embryos examined by the writer, in which the a. femoralis had tapped the axial trunk in the normal way, not one was found in which the importance of the r. saphenus approached that of the a. saphena of Popowski, or even those of Zagorski, Barkow and Manners-Smith. The opinion has been expressed by some comparative anatomists[1] that the a. genu suprema and r. saphenus of the human adult probably represent a vestige of a much larger embryonic vessel. A large r. saphenus, appearing at any stage of development, would seem, on the contrary, to be almost as rare an anomaly in the embryo as is the occurrence of an a. saphena magna in the adult.

The arterial supply of the sole by means of the a. saphena occurs throughout

[1] Notably Zuckerkandl, 1895, "Zur Anat. u. Entwickelunges des Unterschenkels u. des Füsses," *Anat. Hefte*, B. 5, H. 2, 207, and Popowski, 1893, "Ueberbleibsel der Arteria saphena beim Menschen," *Anat. Anz.*, B. 8, 580.

the mammalian series with sufficient constancy as to suggest, on purely theoretical grounds, the likelihood of compensation for anomalous absence of the human a. tibialis posterior through the agency of the a. saphena magna. The information yielded by an examination of the graphically recorded instances of the anomaly in question, however, is entirely negative in this regard. It is found, firstly, that compensation has been accomplished in all such cases through the abnormal persistence of the distal part of the embryonic a. peronaea posterior superficialis. Secondly, that persistence of the a. saphena magna in association with absence of the a. tibialis posterior has not hitherto been recorded.

A closer comparison between the part of the a. saphena which normally supplies the aa. plantares in the great majority of mammals, upon the one hand, and the part of the a. peronaea posterior superficialis which supplies the sole in the human anomaly characterised by absence of the a. tibialis posterior, upon the other, may prove to be exceedingly interesting. More accurate information than is now available regarding the course usually followed by the posterior branch of the well-developed mammalian a. saphena magna in its passage through the malleolar region would be necessary for purposes of comparison. It is not improbable that the morphological affinity between the malleolar section of the two arteries may be greater than the nature of their more proximal connections would suggest.

In the cases of Popowski and Hyrtl cited above, the share taken by the a. saphena magna in the dorsal arterial supply of the foot recalls that encountered normally in many other primates. As has been noted above, however, deficient development of the distal part of the human a. tibialis anterior usually receives compensation through proportional enlargement of the a. perforans arteriae peronaeae.

C. THE POSTERIOR CRURAL REGION

Many cases are recorded in the literature in which but one large artery traverses the posterior crural region and supplies the sole. The single artery has been interpreted as the a. peronaea in some such cases and as the a. tibialis posterior in others. The latter interpretation, where made, would seem to have been founded upon the fact of its being the chief artery of the region and supplying the sole, rather than upon information which might have been gained from the study of its relations.

Hyrtl, in commenting (in 1864) upon the great rarity of absence of the a. peronaea, refers to No. 2093 in the Breslau Anatomical Museum as the only undoubted example of this anomaly with which he is acquainted. Krause also, in Henle's *Gefässlehre* (Braunschweig, 1868) cites No. 2095 G in the Breslau Museum, as having the endorsement of Hyrtl, and refers, in addition to No. 2113 of the Göttingen collection.

Barkow's review of the evidence bearing upon the nature of the single large artery which occasionally traverses the posterior crural region and

supplies the sole, is most instructive. It is founded upon an examination of nine examples of this anomaly contained in the Breslau Museum, including those cited by Hyrtl and Krause. Although Barkow's views upon the subject are most guardedly expressed, his evidence does not favour the view that a case has ever been recorded in which the a. tibialis posterior supplied the posterior crural region and sole, in the absence of the a. peronaea[1].

In view of the fact that reliably recorded instances of absence of the a. peronaea do not appear to be available, it is extremely desirable that a good reproduction of any case which appears to be an example of this anomaly should be placed upon record.

That the a. tibialis posterior is not essential for the adequate supply of the foot is indicated by the comparative frequency of its absence from the adult leg. In all cases in which the a. tibialis posterior is absent in adult life, and in some in which it is small, the distal part of the embryonic a. peronaea posterior superficialis, instead of undergoing retrogression, has retained its primitive connection with the a. plantaris lateralis.

In the absence of the a. tibialis posterior, the artery which performs the function of the missing vessel is invariably derived from the embryonic arteries which take part in the formation of the normal adult a. peronaea. In the cases in which the persisting elements of the embryonic vessels in question are identical with those entering into the composition of the a. peronaea, and arranged in a similar order, the main artery of the posterior crural region takes the form of a large peronaeal artery which, instead of ending in the leg, is continued into the sole. Some cases occur, however, in which the persisting portions of the embryonic arteries in question differ somewhat from those

[1] Barkow thinks it probable that the cases cited by Hyrtl and Krause, and those described by Otto and Lauth as examples of absence of the a. peronaea, belong to a single group which includes also the recorded examples of absence of the a. tibialis posterior. In his opinion there is a great general resemblance between all the cases belonging to the Breslau Collection, notwithstanding the fact that the single artery of the posterior crural region has been labelled a. peronaea in some of them, and a. tibialis posterior in others.

The eight Breslau preparations are all dried specimens and bear the numbers XLIX. 14, 15, 16, 17 and 18, and L. 4, 9 and 10 respectively. Hyrtl's case, originally No. XLIX. 16, was renumbered 2093 by Otto. It is somewhat damaged, but, judging from Barkow's description, does not appear to differ materially from the others. The Breslau case cited by Krause as having Hyrtl's endorsement is not really the same as that to which Hyrtl referred; Krause, having evidently transposed the 5 and 9, appears to have been misled by the similarity of numbers. No. 2059 G (Krause's specimen) is a more recent acquisition, and was numbered by Barkow, who described the case as "absence of the peronaeal in which the posterior tibial takes the course of the missing vessel."

Barkow concludes that Krause's Göttingen specimen conforms to the same general type as those belonging to the Breslau collection. This conclusion appears to me to be borne out by Krause's statement (p. 310) that the a. perforans arteriae peronaeae arises, in his specimen, from the a. tibialis posterior. The r. perforans is developmentally a branch of the part of the a. interossea which becomes the third portion of the normal a. peronaea. If Krause's perforating branch is really the vessel he takes it for, the artery from which it arises is certainly not the a. tibialis posterior.

See Barkow, H. C. L., *Die Angiologische Sammlung im Anatomischen Museum der Königlicher Universität zu Breslau*, Breslau, 1869.

which enter into the formation of the normal a. peronaea. The embryonic structure of the artery which traverses the posterior crural region, in cases of this kind, to supply the sole, may vary very considerably in detail.

In spite of variations occurring in the embryonic composition of the artery which may replace the a. tibialis posterior as the chief artery of the posterior crural region, one part of it remains invariable. The part in question is that which traverses the malleolar region upon the lateral side of the tendon of the m. flexor hallucis longus and passes, anteriorly to that tendon, into the sole. It is the portion of the embryonic a. peronaea posterior superficialis which lies distal to the origin of its r. calcaneus lateralis.

Persistence of the distal part of the a. peronaea posterior superficialis and absence of the adult a. tibialis posterior seem to depend, alike, upon absence of the embryonic a. tibialis posterior superficialis. This point is evident from the developmental history of the connections between the arteries of the leg and those of the foot:

The deeper arteries of the sole, including the arcus plantaris, are derivatives of the original plantar rete, which dates from the developmental period during which the sole is supplied by the a. interossea. The a. plantaris medialis represents the terminal portion of the embryonic a. tibialis posterior superficialis. The a. plantaris lateralis represents the connection between the a. tibialis posterior superficialis and the lateral region of the rete plantare which is effected at the stage of 18 mm., through the agency of the two terminal branches of the a. peronaea posterior superficialis.

In cases in which the a. tibialis posterior superficialis is normally developed, the a. plantaris lateralis conducts some of the blood which issues from the a. tibialis posterior into the rete plantare, the remainder passing into the a. plantaris medialis. In cases, however, in which the a. tibialis posterior superficialis fails to appear, or is too small to reach the sole, the medial terminal branch of the a. peronaea posterior superficialis is unable to form its usual connection. In such cases blood might pass from the leg to the rete plantare either by way of the a. interossea or through the lateral terminal branch of the a. peronaea posterior superficialis.

The distal portion of the first named artery normally disappears shortly after the lateral branch of the a. peronaea posterior superficialis has reached the rete plantare. No case of persistence of the a. interossea in adult life has been recorded. The artery which supplies the sole in all recorded cases of absence of the a. tibialis posterior, is the persisting distal portion of the embryonic a. peronaea posterior superficialis.

It can be readily understood how a vessel formed from persisting sections of the embryonic a. interossea and peronaea posterior superficialis (whether combined as the normal a. peronaea or in some other manner) which, traversing the posterior crural region, might supply the sole in the absence of the a. tibialis posterior. It would be so difficult, however, to account for the presence of the a. tibialis posterior in association with absence of the

a. peronaea, or an artery derived from similar antecedents, that there is little wonder that examples of such an anomaly do not seem to have been recorded.

In order to explain the formation of the arcus plantaris and the a. plantaris lateralis, it is necessary to assume the presence (at their respective stages of development) of the a. interossea and of the a. peronaea posterior superficialis. In order to account for the production of an anomaly in which the sole is supplied by the a. tibialis posterior, in the absence of the a. peronaea (or a vessel derived from its normal embryonic antecedents), it would still be necessary to make a further assumption. It would be necessary, in fact, to assume that the aa. interossea and peronaea posterior superficialis had disappeared at a stage of development subsequent to that in which the material for the development of the chief arteries of the sole had been provided by their branches.

The anomalies graphically recorded as having occurred in the posterior crural region are the following:

10. THE PERONAEAL ARTERY IS SMALLER THAN USUAL, THE POSTERIOR TIBIAL BEING PRESENT: fig. 16, from Quain (pl. 84, fig. 4).

In this case the r. communicans inferius forms the termination of the a. peronaea. The embryonic vessel which normally forms the termination of this adult artery, namely, the r. calcaneus lateralis of the a. peronaea posterior superficialis, figures as a branch of the a. tibialis posterior.

The production of this anomaly appears to depend upon disappearance of the portion of the embryonic a. interossea, which usually persists to form the part of the a. peronaea immediately succeeding the part derived from the r. communicans inferius. The portion of the a. interossea in question, together with the r. coronarius malleolaris and the r. perforans, to which it normally gives origin, is entirely absent.

Fig. 17 from Tiedmann (pl. 36, fig. 4) represents another anomaly characterised by failure of the a. interossea to enter into the formation of the a. peronaea. This case seems to throw light upon the nature of the changes which transform the embryonic pattern of the supramalleolar region into that which characterises the adult. The changes in question are so numerous, and so nearly simultaneous in their occurrence, that they are difficult to follow satisfactorily in the embryo.

In Tiedmann's anomaly the a. interossea is not absent, as in Quain's case, but lies upon the medial side of the a. peronaea. It not only gives off the r. coronarius malleolaris and the r. perforans but effects its normal junction with the distal part of the a. peronaea posterior superficialis. How the a. peronaea has been completed without the interpolation of the usual short section of the a. interossea between the parts contributed by the r. communicans inferius and the a. peronaea posterior superficialis, it does not seem possible to determine with certainty. The main importance of the case lies in the independent co-existence of a persisting section of the a. interossea and of the portion of the a. peronaea which it normally forms.

Another interesting feature of this case is the persistence, although diminished in size, of the portion of the embryonic a. peronaea posterior superficialis which lies beyond the origin of the r. calcaneus lateralis. The part of the embryonic artery in question is connected with the a. tibialis posterior by a branch which effects an indirect communication between that vessel and the a. peronaea.

The persistence of the distal part of the embryonic a. peronaea posterior superficialis and its connection with the a. tibialis posterior clearly explains the mechanism of the transference of the r. calcaneus lateralis to the a. tibialis posterior which has occurred in Quain's case of fig. 16. It seems also to throw light upon the nature of the unnamed branch, so frequently to be seen upon the posterior surface of the m. flexor hallucis longus, which connects the a. tibialis posterior and the a. peronaea. This superficial communicating branch, of which the primitive relations are revealed in fig. 17, has been labelled *R* in figs. 16, 17 and 31.

The superficial connection between the a. peronaea and a. tibialis posterior mentioned above is entirely distinct from the deeper connection between these two vessels known as the r. communicans.

The nature of the r. communicans has been deduced by Hyrtl from an exhaustive examination of its relations in the adult leg. According to Hyrtl (*Schlagadern des Unterschenkels*, 1864, p. 21) the r. coronarius malleolaris of the a. peronaea originally passes across the posterior and medial surfaces of the tibia to join the a. tibialis anterior. Its union with the a. tibialis posterior, which subsequently occurs through anastomosis, divides the r. coronarius into two parts. Of these, the part intervening between the a. peronaea and the a. tibialis posterior becomes the r. communicans, while that extending from the a. tibialis posterior to the a. tibialis anterior is transformed into the aa. malleolares mediales and the rete malleolare mediale.

While the blending of the a. tibialis posterior with the r. coronarius has not been observed in the human embryo, the latter vessel, from the time of its first appearance as a branch of the a. interossea (the a. peronaea not having been formed), follows the course which Hyrtl ascribes to it. At the stage of 22 mm. the a. tibialis posterior is widely separated from the r. coronarius by the n. tibialis. The separation of the two arteries, however, is subsequently so greatly reduced by the assumption of the adult relations between the n. tibialis and the a. tibialis posterior, that there can be little doubt as to the substantial correctness of Hrytl's interpretation.

For the purpose of forming comparisons between the various *anomalies affecting the peronaeal artery* it will be convenient to review the composition of the normally developed artery in terms of its embryonic antecedents. The distinctive relations taken by the adult a. peronaea in the successive stages of its course through the leg provide a basis for the division of this vessel into four parts. The parts in question are derived respectively from the four distinct embryonic elements from which the adult artery has arisen.

The parts of the adult a. peronaea, and the embryonic elements which precede them are as follows:

Part I extends from the origin of the artery to the proximal margin of the m. flexor hallucis longus. It is derived from a persisting section of the embryonic a. peronaea posterior superficialis.

Part II lies between the mm. flexor hallucis longus and tibialis posterior. It corresponds to the whole of embryonic r. communicans inferius.

Part III lies upon the interosseous membrane and gives origin to the rr. communicans and perforans. It is derived from a short persisting section of the embryonic a. interossea.

Part IV passes behind the lateral malleolus to the calcaneus. With the exception of a short section derived from the trunk of the embryonic a. peronaea posterior superficialis, it consists of the r. calcaneus lateralis of that embryonic artery.

In the case reproduced here as fig. 16, the first and second parts of the a. peronaea seem to be normally formed. The fourth part has been taken over by the a. tibialis posterior, while the third part is altogether absent.

In Tiedmann's case, reproduced as fig. 17, the third part of the a. peronaea seems to have been formed by an unusually long r. communicans inferius. The fourth is the only other part of the artery shown; it is of normal composition. The part of the main trunk of the a. peronaea posterior superficialis beyond the origin of its r. calcaneus lateralis, is here represented by a branch of the a. peronaea sufficiently long to clearly indicate its developmental origin.

11. THE PERONAEAL ARTERY IS LARGER THAN USUAL, AND SUPPLIES THE SOLE, THE POSTERIOR TIBIAL BEING PRESENT BUT VERY SMALL. Three examples of this anomaly, differing somewhat in detail, are reproduced as figs. 18, 19 and 20 respectively.

Fig. 18, from Bourgery and Jacob (pl. 50, fig. 2) shows an arrangement of the a. peronaea commonly found in cases of complete absence of the a. tibialis posterior (compare fig. 21). In it the portion of the a. peronaea posterior superficialis beyond the origin of its r. calcaneus lateralis has retained its embryonic connection with the lateral plantar artery. The former vessel can be identified with certainty by its relation to the tendon of the m. flexor hallucis longus. The a. tibialis posterior ends in the supramalleolar region by dividing into a pair of small branches which contribute indirectly to the blood supply of the sole.

Fig. 19, from Tiedmann (pl. 51, fig. 4), represents a case in which the a. tibialis posterior, slender throughout the greater part of its extent, seems to have been reinforced by the embryonic r. coronarius malleolaris above the ankle.

The artery passing distally from the place of reinforcement to the sole follows a course which resembles that of the a. tibialis posterior rather than that of the embryonic a. peronaea posterior superficialis. The absence of any

indication of the positions occupied by the flexor tendons, however, renders the point somewhat doubtful.

In this case the r. coronarius malleolaris seems to have retained its primitive relations, and is continued above the medial malleolus as the a. malleolaris posterior medialis. It is the large branch of communication between the r. coronarius and the a. tibialis posterior which reinforces the latter artery.

An interesting feature of this case is the presence of the persisting proximal end of the embryonic a. interossea, which, arising from the root of the a. tibialis anterior, runs distally posterior to the interosseous membrane. This little vessel, which is frequently present in the adult, marks with certainty the portion of the a. tibialis anterior derived from the embryonic a. poplitea profunda. The a. recurrens tibialis posterior (a remnant of the latter vessel) is not present, unless it is represented by the small medial branch arising from the r. fibularis.

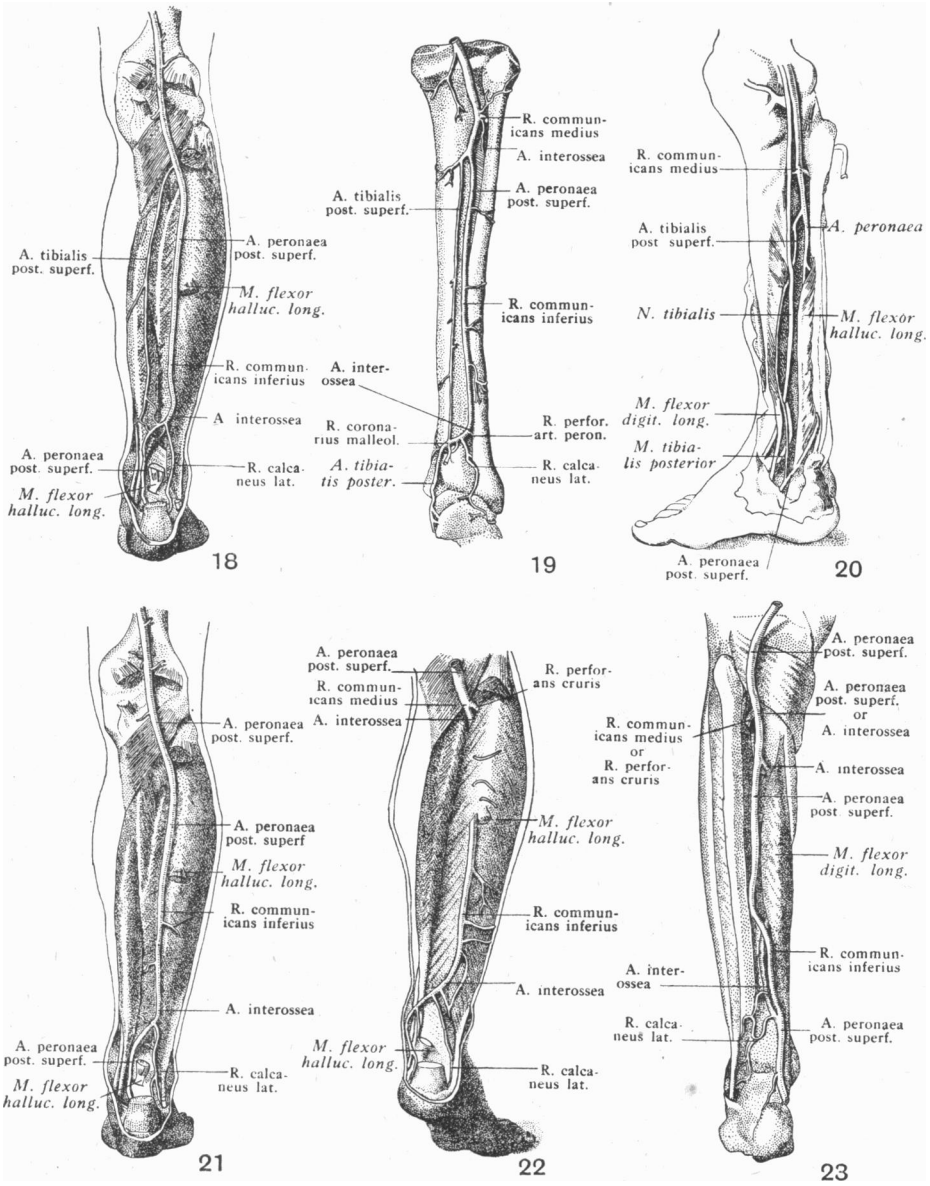
Fig. 20, from Quain (pl. 84, fig. 2), represents an anomaly closely resembling that shown in fig. 18. The distal end of the a. peronaea posterior superficialis has persisted, but joins the small a. tibialis posterior much beyond the point at which the junction has occurred in the case published by Bourgery and Jacob. Whether the trunk formed by the junction of the a. tibialis posterior and the a. peronaea posterior superficialis is to be regarded as a continuation of the former or of the latter artery it seems impossible to determine. The relations of the structures behind the medial malleolus of the original preparation appear to have been purposely disturbed in order to secure a clear reproduction.

In the anomaly reproduced as fig. 19, the a. peronaea retains its normal form. The peronaeal artery in the cases represented in figs. 18 and 20, conforms with the type to which the term "a. peronaea magna" has been given. The composition of the latter vessel is given on p. 138.

12. THE PERONAEAL ARTERY IS LARGER THAN USUAL, AND SUPPLIES THE SOLE, THE POSTERIOR TIBIAL BEING ABSENT: fig. 21, from Bourgery and Jacob (pl. 50, fig. 3). This case has been selected from several published examples of this anomaly. The cases published by Tiedmann (pl. 36, fig. 3), Quain (pl. 84, fig. 3) and Hyrtl (pl. 3, figs. 1 and 2), have not been reproduced here.

All of the cases mentioned above bear a very striking resemblance to one another. The example reproduced differs from all the others in the absence of a small muscular branch which, from its position and direction, seems to represent an imperfect a. tibialis posterior.

In this form of anomaly the a. peronaea, in spite of its great size, is normally constituted except for the fact that the branch which usually arises from the medial side of its fourth part is very large and passes into the sole. The branch which thus connects the a. peronaea with the a. plantaris lateralis takes the form of a continuation of the main trunk of the former artery and represents the persisting distal part of the embryonic a. peronaea posterior superficialis.



Figs. 18–23. In figs. 18, 19 and 20 the posterior tibial artery is small, in 21, 22 and 23 it is absent.

Labels in Roman type refer to the normal embryonic predecessors of the adult arteries shown; italics are used for all other structures. Figs. 18 and 21 from Bourgery and Jacob, pl. 50, figs. 2 and 3 respectively; 19 from Tiedmann, pl. 51, fig. 4; 20 from Quain, pl. 84, fig. 2; 22 from Dubrueil, pl. 17, fig. 1; 23 from Hyrtl, pl. 5, fig. 3.

In Dubrueil's case (fig. 22) the venae comitantes (shown in the original) have been omitted.

The mechanism of the retention of the distal part of the latter artery in cases of absence of the a. tibialis posterior has been reviewed upon p. 140.

The arterial supply of the sole is so frequently effected by means of a modification of the normal a. peronaea that it will be convenient to apply a name to the anomalous vessel which performs this function. It may be called the *a. peronaea magna.*

The a. peronaea magna differs so little, except in size, from the a. peronaea of normal adult anatomy, that a description of the latter artery will apply equally well to the former if the following description of the fourth part be substituted for that given on p. 150:

Part IV. Passes, from a point above and medial to the lateral malleolus, obliquely across the m. flexor hallucis longus, anteriorly to the tendon of which it passes into the sole. Its proximal part gives origin to the r. calcaneus lateralis, which follows the course of the termination of the normal a. peronaea. The fourth part of the artery represents the persisting terminal portion of the embryonic a. peronaea posterior superficialis.

It is unfortunate that none of the cases in which the plantar region is supplied, in the absence of the a. tibialis posterior, by the a. peronaea magna have been posed for reproduction in such a way as to display the distribution of the arteries of the sole. In view of the developmental history of the plantar arteries (reviewed upon p. 163), the absence of the a. plantaris medialis and of the proximal section of the a. plantaris lateralis may be taken for granted.

It is quite possible that in some cases in which the a. tibialis posterior is absent, an artery somewhat resembling the normal a. plantaris medialis may have been produced by unusual elongation of the medial terminal branch of the embryonic a. peronaea posterior superficialis. Something of this nature seems to have occurred in Barkow's case which forms the subject of figs. 24 and 28 of this paper.

Barkow illustrates a sole (*Die Angiologische Sammlung, u.s.w.*, Breslau, 1869, Tab. 9, fig. 2) in which the arterial supply of the area usually occupied by the a. plantaris medialis has been taken over by a supplementary branch of the a. dorsalis pedis. The a. plantaris lateralis in this case is irregular, but the stem from which it arises (labelled a. tibialis posterior) both from its lateral position, and from the fact that it gives origin to typical r. calcaneus lateralis, almost certainly represents a persisting embryonic a. peronaea posterior superficialis.

A case which throws a certain amount of light upon the effect of failure upon the part of the medial terminal branch of the a. peronaea posterior superficialis to join a poorly developed a. tibialis posterior has been reproduced here as fig. 25.

The abnormal composition of the distal portion of the popliteal artery in all cases of anomalous absence of the a. tibialis posterior is referred to under category 5 (p. 138).

13. EMBRYONIC ANTECEDENTS OF THE PERONAEAL PERSIST IN THE FORM OF A SINGLE LARGE ARTERY WHICH SUPPLIES THE SOLE, THE POSTERIOR TIBIAL BEING ABSENT: fig. 22 from Dubrueil (pl. 17, fig. 1). In this case the a. poplitea divides, at the distal border of the m. popliteus, into the a. tibialis anterior and the chief artery of the posterior crural region. The latter at first passes anteriorly to the m. tibialis posterior and then, having pierced that muscle, runs between it and the m. flexor hallucis longus until it turns medially to reach the malleolus.

The portion of the artery beyond the proximal end of the m. flexor hallucis longus corresponds exactly, in embryonic structure, with the second, third and fourth parts of the a. peronaea magna (see pp. 138 and 150). The portion proximal to the point in question, however, differs radically from the first part of that artery.

The course followed by the proximal part of the vessel is not that of the embryonic a. peronaea posterior superficialis but that of the a. interossea. It would seem that, at some stage of development, a branch must have pierced the m. tibialis posterior to effect a connection between the a. interossea and the proximal end of the r. communicans inferius. The alternative blood-channel thus formed would seem to have superseded the collateral section of the a. peronaea posterior superficialis which has been lost.

In such a case as Dubrueil's the composition of the a. poplitea and that of a. tibialis anterior would be involved in the anomaly. The a. tibialis anterior of the case represented in fig. 22 should consist of three parts only, namely, the a. poplitea profunda, the r. perforans cruris and the pars distalis (compare with the composition of the normal artery, p. 141). The part of the a. tibialis anterior derived from the embryonic r. communicans medius is not missing, as in the case represented in fig. 9, but has been added to the distal end of the a. poplitea. This point will be made clear by reference to fig. 4.

14. EMBRYONIC ANTECEDENTS OF THE PERONAEAL PERSIST IN THE FORM OF TWO ARTERIES, ONE OF WHICH SUPPLIES THE SOLE; THE POSTERIOR TIBIAL BEING ABSENT. Two types of anomaly, differing widely in their nature, belong to this category.

Fig. 23, from Hyrtl (pl. 5, fig. 3), represents a case in which the main artery of the posterior crural region gives origin to an aberrant vessel, which rejoins it after having traversed the middle two-fourths of the leg.

It seems impossible, in the absence of the mm. flexor hallucis longus and tibialis posterior, to arrive at a complete determination of the nature of this anomaly. It is probable that the muscles were removed from the original preparation in order to reveal, as fully as possible, the course taken by the arteries. For this purpose also, or by accident, the main artery has been evidently displaced towards the medial side of the leg.

If Hyrtl's figure is not so instructive as it might be, his description is still less so. Employing a criterion which has commonly been used as a basis of interpretation, namely, the relative size of the arteries rather than their

relations to the adjacent structures, Hyrtl merely notes that the a. peronaea follows the medial side of the a. tibialis posterior and rejoins it above the malleolus[1].

Judging from the relations of the vessels the aberrant artery represents a persisting a. interossea. The main arterial trunk is either an a. peronaea magna of normal constitution or one in which the usual first part has been replaced by a component derived from the embryonic a. interossea.

It is the absence of the m. tibialis posterior that prevents the exact determination of the embryonic origin of the part of the main arterial trunk above the aberrant vessel. If this part of the main trunk was originally situated upon the posterior surface of the muscle in question, it would represent the first part of a normally formed a. peronaea magna. If, upon the other hand, it passed anteriorly to the muscle, it would represent a persisting section of the embryonic a. interossea. In the latter case the vessel must have pierced the muscle immediately below the origin of the a. aberrans; the constitution of the main artery of the posterior crural region would be identical with that of the single main occupying the posterior crural region of the preceding case (see fig. 22).

The steps followed in arriving at a conclusion regarding the nature of the aberrant artery and of the part of the main trunk which lies distal to the origin of that vessel, are briefly as follows:

(1) Since there is no embryonic artery which passes between the m. digitorum longus and the tibia, or between that muscle and the m. tibialis posterior, the aberrant artery of this case can be identified as the a. interossea which passes anterior to the latter muscle.

(2) In the formation of the a. peronaea magna the distal end of the part of the a. interossea which becomes the third part of that vessel, ends by joining the part of the a. peronaea posterior superficialis which persists to become the fourth. The origin of the r. calcaneus lateralis from the vessel which, in this case, supplies the sole, forms a sufficient means of identification.

(3) The part of the main vessel, which, in this case, intervenes between the origin and termination of the a. aberrans, ends by joining the a. interossea. It can thus be identified as the r. communicans inferius, which lies between the m. flexor hallucis longus and the m. tibialis posterior and forms the second part of the a. peronaea magna.

The shortness of the part of the a. interossea which, in this case, intervenes between the r. communicans inferius and the distal end of the a. peronaea posterior superficialis and corresponds with the third part of the a. peronaea magna, recalls the relations of the case represented in fig. 17, in which it is absent altogether.

[1] "Streng genommen, fehlte die Arteria peronea nicht. Sie entsprang vielmehr an gewöhnlicher Stelle aus der Tibialis postica. Aber sie bog in der Mitte des Unterschenkels zur Tibialis postica hinüber, lagerte sich an die innere Seite derselben, begleitete sie bis zum inneren Knöchel, und mündete, etwas über diesem, in die Tibialis ein." Hyrtl, *Schlagadern des Unterschenkels*, 1864, p. 265.

Ryan has published a case which must have resembled Hyrtl's very closely, and may even have been a duplicate of it. Ryan's brief description offers no clue as to the nature of the proximal part of the main trunk, which he, like Hyrtl, regarded as the a. tibialis posterior. It leaves no doubt, however, as to the relation borne by the aberrant artery (which he regards as the a. peronaea) to the m. tibialis posterior[1].

Fig. 24, from Barkow (pl. 56, fig. 2), represents a case in which the single arterial trunk of the posterior crural region is the a. peronaea magna. The vessel, however, differs slightly, in its composition, from what may be called the normal type, and gives origin to a large vessel composed of a persisting part of the embryonic a. peronaea posterior superficialis.

The appearance of fig. 24 suggests that the m. flexor hallucis longus has been displaced laterally in order to uncover the distal part of the a. peronaea magna. That this has actually occurred is clearly indicated in fig. 28, which illustrates an earlier stage in the dissection of the same limb.

The peculiar form assumed by the a. peronaea magna in this case appears to have resulted from the unusual position of the connection between the third and fourth parts of that artery.

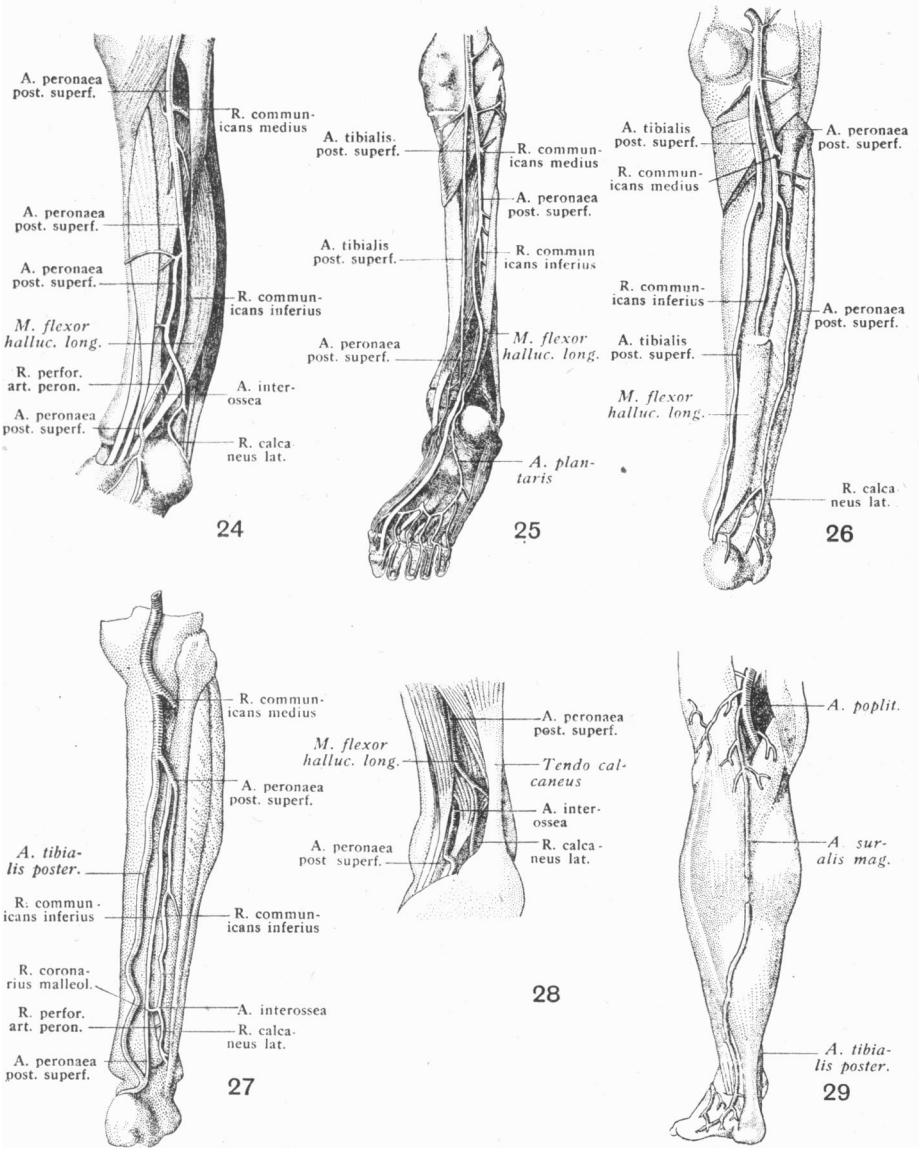
The relations usually borne by the third and fourth parts of the a. peronaea magna to the m. flexor hallucis longus are clearly indicated in figs. 17 and 20. The expectation is that figs. 18, 21, 22 and 23 would have presented a similar picture if the muscle had been retained in the preparations from which they were drawn.

The course of the distal part of the a. peronaea magna shown in figs. 24 and 28 suggests that the connection between the a. interossea and the a. peronaea posterior superficialis occurred near the medial, instead of the lateral, margin of the m. flexor hallucis longus. The connection of the two embryonic vessels in this situation appears to account for the fact that, in Barkow's anomaly, the a. peronaea magna crosses the anterior, instead of the posterior, surface of the m. flexor hallucis longus.

The abnormal persistence of a part of the embryonic a. peronaea posterior superficialis, in the form of a branch of the a. peronaea magna, may also depend upon the site of the connection referred to above. The connecting branch from the a. interossea appears to have joined the a. peronaea superficialis beyond the origin of the r. calcaneus lateralis. The latter branch, although lost to the a. peronaea magna, has been retained by the part of the embryonic a. peronaea posterior superficialis, which has persisted in the form of a branch of the adult artery.

It is interesting to note that Barkow refers to the main artery of the posterior crural region in this case as "the a. tibialis posterior taking the

[1] "Inter arterias maxime irregulares quoad originem et distributionem fibularis enumeranda est....Aliquando superficiei proxima ante tibialem posticam et flexorem pollicis propriam currit, et posticae tibiali conjungitur supra calcem...." Ryan, *Dissertatio inauguralis de quarundam Arteriarum in Corpore Humano Distributione*, 1809, p. 27.



Figs. 24–29. In figs. 24–28 two vessels represent the embryonic predecessors of the peronaeal artery, the posterior tibial being present in all but the first. Fig. 28 shows the correct relations of the arteries of fig. 24 before these were disturbed by further dissection. Fig. 29 is an example of the a. suralis magna.

Labels in Roman type refer to the normal embryonic predecessors of the anomalous adult arteries shown; italics are used for all other structures. Figs. 24, 25 and 28 from Barkow, pl. 56, fig. 2, pl. 8, fig. 2, and pl. 55, fig. 1 respectively; 26, 27 and 29 from Hyrtl, pl. 5, figs. 1 and 2, and pl. 3, fig. 3 respectively.

course of the a. peronaea." Since one or more of the cases in the group belonging to the Breslau collection (see footnote on p. 146) has been described in similar terms, it would seem that this case resembles the supposed examples of absence of the a. peronaea. It may even be one of them.

The a. peronaea magna ends by dividing into the a. plantaris lateralis and a vessel which Barkow labelled as a. plantaris medialis in the original figure. The reason for doubting the correctness of his identification is indicated in the review of developmental history of the plantar arteries given on p. 163.

15. EMBRYONIC ANTECEDENTS OF THE A. PERONAEA PERSIST IN THE FORM OF TWO ARTERIES, THE POSTERIOR TIBIAL BEING PRESENT.

Two types of anomaly have been published which belong to this category. The first type is characterised by the co-existence of the embryonic a. peronaea posterior superficialis and an artery largely composed of the r. communicans inferior. The second type has resulted from the reduplication of the latter vessel.

Fig. 25, from Barkow (pl. 8, fig. 2), and fig. 26, from Hyrtl (pl. 5, fig. 1), are representatives of the first type.

In both these cases the proximal ends of the embryonic aa. peronaea posterior superficialis and tibialis posterior superficialis, by remaining separate, have failed (as in the case represented in fig. 6) to complete the distal end of the a. poplitea. In both cases also the a. peronaea posterior superficialis, which has retained its individuality throughout the leg, gives origin to the a. tibialis anterior.

In Barkow's case of fig. 25, the m. flexor hallucis longus has been displaced laterally for the display of the r. communicans inferius, but not sufficiently to materially alter the primitive relations of the a. peronaea posterior superficialis to that muscle. In Hyrtl's, of fig. 26, the artery has been shifted on to the m. peronaeus longus. In both cases the termination of the r. communicans medius is hidden by the m. flexor hallucis longus, so that it cannot be determined whether it has formed the usual connection with the neighbouring section of the a. interossea or not.

The a. tibialis posterior, which is a much more important vessel in Hyrtl's case than in Barkow's, probably bifurcates normally into the plantar arteries. In the latter case the vessel is extremely small and has failed to produce an a. plantaris medialis or to take over the a. plantaris lateralis in the usual way.

The connection shown in fig. 25 between the termination of the a. peronaea posterior superficialis and the a. plantaris lateralis is quite in accordance with the views I have already expressed.

Fig. 27, from Hyrtl (pl. 5, fig. 2), differs from the two preceding cases in that both the arteries in the peronaeal region lie deep to the m. flexor hallucis longus. Although the muscle is not represented in the figure, Hyrtl makes a perfectly clear statement regarding this point: "Die beiden peronaeae sind dann profundae, und liegen im canalis musculo-peroneus hart nebeneinander."

Since the proximal parts of the two arteries of the peronaeal region occupy the position normally held by the second part of the a. peronaea, it is difficult to escape the conclusion that they have resulted from a reduplication of the embryonic vessel from which that artery arises, namely, the r. communicans inferius.

The distal part of the more lateral of the two arteries gives origin to the r. communicans and r. perforans and ends as the r. calcaneus lateralis. It seems, therefore, to have been derived from the embryonic precursors of the third and fourth parts of the a. peronaea (see p. 150).

The origin of the distal part of the more medial of the two trunks can scarcely be determined with certainty in the absence of any indication of its relation to the tendon of the m. flexor hallucis longus. Comparison with fig. 26, however, suggests the probability of its derivation from the terminal part of the main trunk of the a. peronaea posterior superficialis.

The short stem of the double artery, since it arises from the a. tibialis posterior at the usual site of origin of the a. peronaea, probably represents the first part of that vessel. It is to be presumed, therefore, that it rests upon the posterior surface of the m. tibialis posterior and represents a persisting section of the a. peronaea posterior superficialis.

Green has described and figured an example of so-called double a. tibialis posterior (*An Account of the Varieties of the Arterial System*, Dublin, 1820, pl. 6, fig. 1) which very probably represents an example of one of the two types of anomaly under consideration. His exceedingly diagrammatic figure indicates the contour of the leg and shows the a. poplitea giving off three branches which course longitudinally through the posterior crural region. From the absence of any indication of the relations of the arteries it is impossible to form an opinion as to the essential nature of the case. The evidence, however, afforded by the study of development and of figures of kindred anomalies does not favour the acceptance of Green's interpretation.

16. A. SURALIS MAGNA: fig. 29, from Hyrtl (pl. 3, fig. 3), represents a case in which a large artery accompanies the v. saphena parva through the leg to the dorsal aspect of the foot. An almost identical case has been figured by Oesterreicher (*Anatomischer Atlas oder bildliche Darstellung des menschlichen Körpers neu bearbeitet von M. Erdl*, München, 1845, pl. 93, fig. 2). Another case in which the distribution of the artery is not so extensive has been published by Haller (*Icones Anatomicae*, Fasic. 8, pl. 2).

The a. suralis magna, which occurs occasionally in the adult limb, can scarcely be regarded as having resulted from the persistence of a normal embryonic vessel, for its presence in the embryo has not yet been recorded. The artery, no doubt, arises during the development of the limb, but it must occur almost as rarely in the embryo as in the adult.

The fact that the a. suralis magna has taken origin from the a. poplitea in all the cases hitherto published as examples of this anomaly, would lead, rather naturally, to the supposition that the appearance of this anomalous

vessel had depended upon the excessive development of one of the a. surales superficiales. Such a supposition may eventually prove to be well founded, but a review of the conditions associated with the appearance of other anomalous arteries cannot be regarded as supporting it.

The occurrence of supernumerary arteries in the adult lower limb depends usually upon the anomalous persistence of embryonic channels which normally disappear during the later stages of development. The case of the a. saphena magna, however, forms an exception to the general rule. The occasional appearance of this artery in the adult may perhaps be taken as the manifestation of a tendency towards excessive growth which might be inherent in a terminal branch of such a rapidly growing artery as the embryonic a. femoralis. No anomalous artery has yet been recorded which appears to owe its existence to the fortuitous enlargement of a minor offshoot of one of the regular vessels of the lower limb.

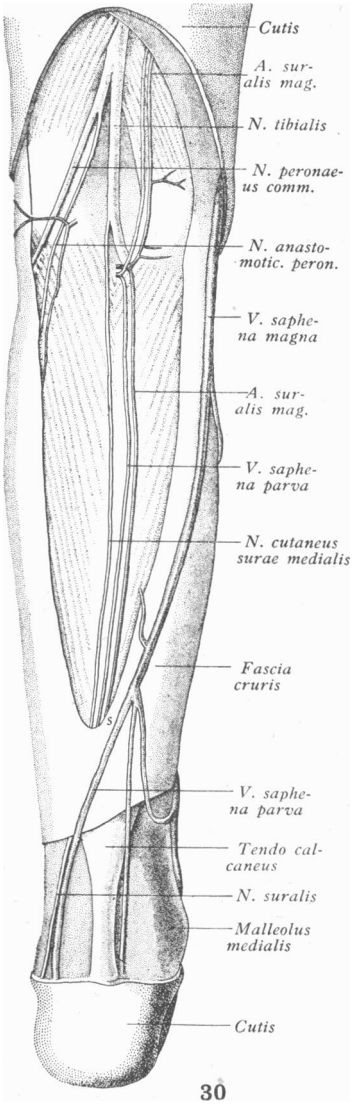
Barkow has published a figure which suggests the possibility that the a. suralis magna may not arise in the first place from the a. poplitea at all, but that it may have been taken over by that vessel by means of a secondary anastomosis. Barkow's figure was primarily intended to record an anomaly affecting the v. saphena parva. The connections of the small artery which accompanies this vein and its continuation through the leg and thigh, probably on that account, are not fully displayed. The figure however taken in conjunction with the embryological possibilities, if not entirely conclusive, may be regarded as extremely suggestive.

Fig. 30, from Barkow (pl. 57, fig. 1), represents a left leg in which the distal part of the v. saphena parva is drained, above the malleoli by a tributary of the v. saphena magna. Following the course usually taken by the v. saphena parva upon the back of the leg is a small vein which communicates with the v. poplitea behind the knee. Above the knee the vein pursues a course which identifies it as the further continuation of the embryonic v. ischiadica.

Traversing the leg upon the medial side of the small v. saphena parva, is a slender artery, which, according to the author's explanation, terminates below, at the point marked *S*, deep to the fascia. The artery appears to arise from a branch of the a. poplitea to the gastrocnemius muscle, and is unquestionably an imperfect example of the a. suralis magna. Extending upwards from the apparent origin of vessel is a small artery which can be traced through the lower part of the thigh to the point at which it disappears beneath the fascia lata. Barkow gives no information whatever regarding the latter part of the artery. It is quite possible, however, that it may represent a prolongation of the a. glutaea inferior.

The possibility just referred to is suggested by the nature of the changes undergone by the more proximal of the two parts into which the a. ischiadica divides when its original continuity has suffered interruption.

At the stage of 18 mm. the a. ischiadica is a continuous vessel which, following the course of the n. tibialis through the thigh, gives origin to no extra-



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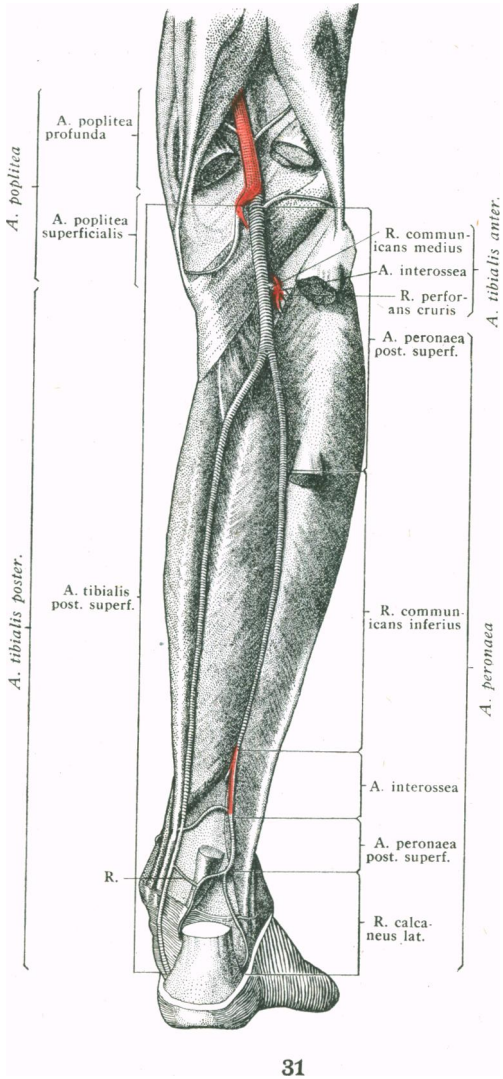

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Fig. 30 represents a superficial dissection of the left leg copied, with negligible modification, from Barkow's pl. 57, fig. 1.

The case was originally published to record an anomaly of the v. saphena parva, but is reproduced for the sake of the light it appears to throw upon the origin of the a. suralis magna.

Fig. 31 represents a right leg from which the superficial calf muscles, and the flexor hallucis longus have been removed to show the normal distribution of the arteries of the popliteal and posterior crural regions.

The main arteries of the adult are labelled in terms of the embryonic vessels which enter into their composition; italics being used for the names of the adult, and Roman type for the embryonic vessels. The adult arteries representing persisting portions of the primitive axial artery are coloured red.

pelvic branches. At the stage of 22 mm. the continuity of the artery has been broken near the site of origin of the n. tibialis from the lumbo-sacral plexus. The distal portion of the vessel has become engaged in the formation of an extensive anastomosis upon the posterior aspect of the m. adductor magnus. The extremity of the proximal portion of the a. ischiadica has left the position formerly occupied by the original vessel upon the n. tibialis to accompany the n. femoris cutaneus posterior and the v. ischiadica to the surface of the limb.

The proximal part of the a. ischiadica persists in adult life as the a. glutaea inferior. Its termination, no doubt, normally furnishes the muscular and cutaneous branches of the lower glutaeal region.

The fact that the a. glutaea inferior follows the embryonic v. ischiadica for a short distance in the upper part of the thigh would seem to give but slight support to the theory that it may occasionally follow it as far as the foot. Barkow's figure, however, suggests that this may be the case, in spite of the fact that the continuity between the artery upon the back of the thigh has not been demonstrated.

If the artery which, in Barkow's case, follows the v. ischiadica, should have proved, upon examination, to be continuous with the a. glutaea inferior, the evidence would have been conclusive. It would have been scarcely less so if the artery had ended blindly upon the posterior surface of the thigh. In the event of the artery in question having been found to join one of the aa. perforantes the evidence would have been merely negative.

An a. glutaea magna long enough to extend throughout the length of the limb (in the event of an undoubted example of this anomaly being found) might well be regarded as forming a common basis of the two variants of the a. suralis magna which have been published. A long and probably slender artery of this character would almost certainly communicate with the a. poplitea behind the knee. Such an anastomosis would not be unlikely to lead to the secondary degeneration of the proximal part of the artery; it might produce, in fact, a condition similar to that shown in fig. 29.

It is extremely probable that the shortening of the a. saphena magna, indicated in fig. 15, has been accomplished through the agency of a secondary anastomosis similar to that which might have produced the shortening of the a. suralis magna. It is not unlikely, also, that the condition of the arteries of the anterior crural region shown in fig. 12 has resulted from the partial suppression of an originally complete a. tibialis anterior depending upon a secondary anastomosis between that artery and the a. tibialis posterior.

The identity of the a. suralis magna and the a. glutaea inferior cannot, by any means, be regarded as definitely established. The publication of cases throwing light upon the origin of the vessel known as the a. suralis magna, or as the a. saphena parva, is very much to be desired.

D. THE FOOT

The main arterial channel of the foot consists of a continuous loop of which the component parts are known, in adult anatomy, as the a. plantaris lateralis, the arcus plantaris, the r. plantaris profundus and the a. dorsalis pedis. From an embryological standpoint, however, it is convenient to divide the loop into two parts only. One of these consists of the a. plantaris lateralis, while the other embraces the part formed from the three remaining vessels.

The embryological distinction is based upon the fact that the a. plantaris lateralis is derived from the terminal bifurcation of an artery of the leg, namely, the a. peronaea posterior superficialis, while the other part of the loop arises from the embryonic arterial retia of the foot.

During the earlier period of development the plantar and dorsal arterial retia of the foot retain their primitive form and communicate with one another around the borders of the foot and between the digits. The plantar rete receives its blood from the a. interossea and the dorsal through the r. perforans tarsi.

At the stage of 18 mm. the appearance of the arterial retia has been modified by the development of three new arterial channels in the leg which have extended into the foot.

The three arterial channels in question are the a. tibialis posterior superficialis, the a. peronaea posterior superficialis and the a. tibialis anterior, pars distalis. Soon after these vessels have formed their definitive connections, the distal part of the a. interossea and its perforating tarsal branch undergo degeneration.

The distal ends of the arteries extending from the leg into the foot are disposed in the following way:

The terminal part of the a. tibialis posterior superficialis extends along the medial side of the sole, but is very slightly connected with the rete plantare. It becomes the *a. plantaris medialis.*

The a. peronaea posterior superficialis bifurcates, upon entering the sole, into medial and lateral terminal branches. The medial branch joins the a. tibialis posterior superficialis and thus marks the point at which the adult a. tibialis posterior bifurcates into the aa. plantares. The lateral branch crosses the developing muscles of the sole to join the rete plantare near the base of the fifth metatarsal. The medial and lateral branches together form a direct channel which becomes the *a. plantaris lateralis.*

The a. tibialis anterior, pars distalis, ends by joining the rete dorsale in front of the ankle joint.

The consequence of the alteration in the site at which the retia of the foot receive the entering blood-stream is clearly to be distinguished at the stage of 22 mm. At that period of development a very definite main arterial track is outlined by the enlargement of the elements of the original retia which intervene between the termination of the a. plantaris lateralis and that of

a. tibialis anterior. The course taken by the track in question marks it as forming the part of the main arterial loop of the adult foot which is formed by the *arcus plantaris*, the *r. plantaris profundus* and the *a. dorsalis pedis*.

As already pointed out, absence of the a. plantaris medialis results from the absence, or imperfect development, of the embryonic a. tibialis posterior superficialis. It is associated with absence of the medial section of the a. plantaris lateralis and with the supply of the sole by the a. peronaea magna or an artery of kindred embryonic antecedents. Fig. 25 is an example of this form of anomaly.

With the exception of the anomaly just mentioned and of Hyrtl's unique case of persistence of the r. perforans tarsi, the more important anomalies of the foot may be divided into two general categories. The first of these comprises the recorded examples of absence of one or more of the elements of the arterial loop of the foot which have been derived from the embryonic retia. The second comprises the cases in which the loop, although fully formed, is characterised by a more or less localised irregularity of calibre.

17. EXAMPLES OF INCOMPLETE LOOP: fig. 32, from Hyrtl (pl. 10, fig. 1), represents a case in which the distal end of the a. tibialis anterior breaks up into an arterial plexus which has probably preserved the main features of the embryonic rete dorsale. Apart from the aa. metatarsae dorsales none of the arteries usually found upon the dorsum of the foot are recognisable. Hyrtl states that the rr. perforantes are lacking but gives no information regarding the arterial supply of the sole.

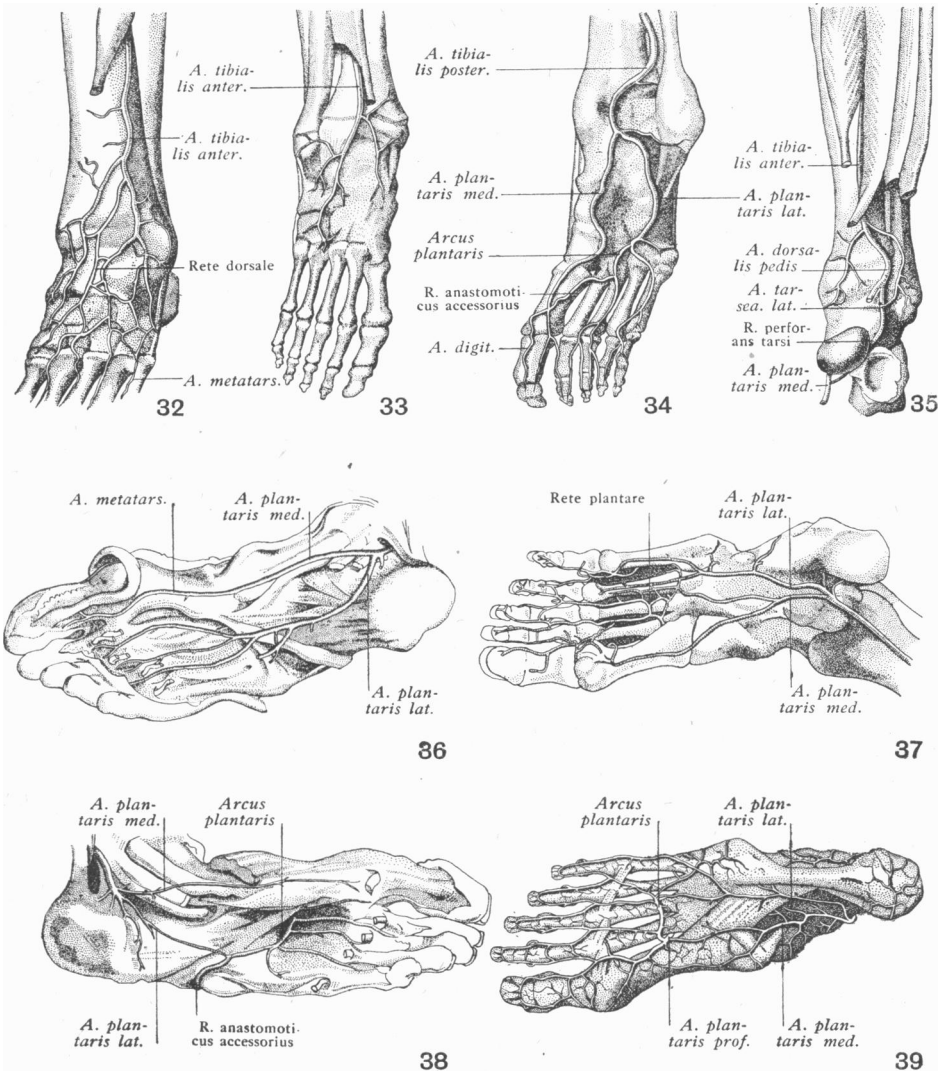
Figs. 33 and 34, from Hyrtl (pl. 9, figs. 1 and 2 respectively), represent the dorsal and plantar surfaces of the same right foot. The a. dorsalis pedis is incomplete, and the r. plantaris profundus absent; there are no aa. metatarsae dorsales. In the sole, the arcus plantaris, which is small and irregular, is completed by a connection between the first and second plantar metatarsal arteries. The a. plantaris medialis is unusually large and ends as the first plantar metatarsal artery.

Fig. 36, from Quain (pl. 86, fig. 4), represents a sole which, in its arterial distribution, somewhat resembles the case represented in fig. 34. The arcus plantaris ends, however, as the second plantar metatarsal artery, and does not join the first plantar metatarsal which forms the termination of the large a. plantaris medialis.

In all the cases cited above, the absent section of the arterial loop of the foot belongs to the part derived from the embryonic retia. Absence of the part of the loop formed by the a. plantaris lateralis, which is derived from the embryonic a. peronaea posterior superficialis, has not been recorded.

The site of the initial departure from the normal course of arterial development upon which the production of anomalies of this class depends is difficult to localise. Figs. 32, 33, 34 and 36 would seem to favour its localisation in retia of the foot.

18. EXAMPLES OF IRREGULAR LOOP. Fig. 37, from Barkow (pl. 10, fig. 4),



Figs. 32–39. The arterial loop of the foot is incomplete in figs. 32, 33, 34 and 37, irregular in 38 and 39. Fig. 35 is an example of persistence of the r. perforans tarsi.

Labels in Roman type refer to the normal embryonic predecessors of the anomalous adult arteries shown; italics are used for all other structures. Figs. 32–35 from Hyrtl, pl. 10, fig. 1; pl. 9, figs. 1 and 2, and pl. 10, fig. 3 respectively; 36 and 38 from Quain, pl. 86, figs. 4 and 5 respectively; 37 from Barkow, pl. 10, fig. 4; 39 from Tiedmann, pl. 37, fig. 6.

represents a case in which the arcus plantaris has been replaced by an arterial plexus which probably represents a partial survival of the embryonic rete plantare. Blood enters the plexus through the ordinary channels, namely the r. plantaris profundus and the a. plantaris lateralis. There is an additional connection between the a. plantaris medialis and the plexus by means of a branch which probably has arisen also from the embryonic rete.

Figs. 38 and 39, from Quain (pl. 86, fig. 5), and Tiedmann (pl. 37, fig. 6), respectively represent cases in which the a. plantaris lateralis is unusually small. The arcus plantaris appears to be of normal size in both examples, although, in Tiedmann's, the lateral end of the arcus has been replaced by what appears to be a survival of the embryonic rete plantare.

The maintenance of the calibre of the arcus plantaris is due, in Quain's case, to reinforcement of blood-flow through a branch (probably a lateral tarsal) arising upon the dorsum of the foot. In Tiedmann's anomaly, compensation has been established by the r. plantaris profundus and by a branch of the unusually large a. plantaris medialis. In the former case the disturbance of calibre is localised to the part of the loop formed by the a. plantaris lateralis, while in the latter, the size relations have been disturbed throughout a much more extensive section of the loop.

The anomalies cited in the literature as consisting in the smallness of one or other of the vessels entering into the composition of the arterial loop of the foot are not actually confined to the vessels most obviously concerned. The compensatory enlargement which occurs in other parts of the loop, or in a neighbouring vessel, is also a part of the anomaly.

The production of anomalies of this class seems to depend rather more frequently upon irregularities affecting the development of the arteries passing from the leg to the foot than upon developmental irregularities of the retia themselves. While figs. 38 and 39 suggest the former conclusion, the conditions shown in fig. 37 would seem to show that it is not of universal application. That the size of the a. dorsalis pedis is not necessarily dependent upon the condition of the distal end of the a. tibialis anterior is shown by figs. 12 and 13.

An interesting class of minor anomaly of the a. dorsalis pedis is that afforded by modification of the usual course of this artery in cases in which the a. perforans arteriae peronaea is not of unusual magnitude. The a. dorsalis pedis, instead of pursuing its usual direct course, exhibits a lateral convexity which brings the distal end of the artery into a line between the interior end of the tibio-fibular interval and the first inter-metatarsal interspace. Such cases suggest that the a. perforans arteriae peronaeae may have maintained a temporary ascendency over the distal part of the a. tibialis anterior during a sufficiently long period of development to have impressed an unusual direction upon the course of the a. dorsalis pedis. Cases in which a less obviously indirect a. dorsalis pedis passes immediately over the dorsal end of the sinus tarsi suggest in a like manner that the r. perforans tarsi may

have been unusually tardy in yielding its area of supply to the later developed a. tibialis anterior.

19. PERSISTENCE OF THE R. PERFORANS TARSI. Fig. 35, from Hyrtl (pl. 9, fig. 3), represents a case in which an artery of considerable size, derived from the embryonic r. perforans tarsi, occupies the tarsal sinus.

A minute artery, of which the connections are similar to those shown in Hyrtl's figure, is not infrequently to be found traversing the sinus of a well-injected subject. No case, however, seems to have been published of which the importance approaches that of Hyrtl's.

In this case the artery is described as a branch of the a. dorsalis pedis which, arising from the lateral side of the parent vessel, traverses the tarsal sinus to join the a. plantaris medialis. In accordance with the description, the figure suggests that the blood-stream through the anomalous vessel takes a direction contrary to that which it follows in the embryo.

The vessel of Hyrtl's case appears to be of composite origin. Its plantar end is derived from a portion of the embryonic rete plantare which, possibly combined with an element derived from the a. interossea, has formed a permanent connection with the a. plantaris medialis. The dorsal end is a derivative of the rete dorsale which might otherwise have become an ordinary a. tarsea lateralis. The extent and connections of the vessel have been admirably shown by the removal of the anterior part of the foot after the manner of Chopart's amputation.

Cases in which the circulation of the foot is modified by the presence of the a. saphena magna and a. suralis magna have already been noted.

THE RELATION OF EACH OF THE EMBRYONIC ARTERIES TO THE FORM ASSUMED BY THE ARTERIAL SYSTEM OF THE ADULT LEG AND FOOT

A. interossea. A short section of this artery persists as the third part of the normal a. peronaea. A similar section becomes the third part of the single anomalous artery of the posterior crural region known as the a. peronaea magna (figs. 18, 21 and 24), and as the corresponding part of the main artery of that region shown in figs. 22 and 23.

The section of the a. interossea in question has contributed little to the formation of the a. peronaea magna, of fig. 23, and nothing to the a. peronaea of figs. 17 and 18. In the last case it persists but has formed abnormal connections.

The a. interossea has persisted in the upper third, and in the middle two-fourths of the leg respectively, in the cases reproduced as figs. 22 and 23.

A small piece of the proximal end of the a. interossea not infrequently persists in the adult as an insignificant branch of the second part of the a. tibialis anterior. This branch usually arises near, or in common with, the origin of the r. fibularis, and runs downwards in contact with the posterior

surface of the membrana interossea. An example of its persistence is recorded in fig. 19.

A. ischiadica. Two sections of this artery are present in the normal adult. The more proximal of these becomes the a. glutaea inferior, while the more distal is transformed into the post-femoral anastomosis.

Anastomosis between a persisting part of the a. ischiadica and the adult a. poplitea is illustrated in figs. 10 and 11. Whether the a. suralis magna (see figs. 29 and 30) should be regarded as representing an abnormally large a. glutaea inferior is an open question.

A. peronaea posterior superficialis. Two parts of this artery persist in the normal adult, also its two terminal branches. The proximal portion of the vessel participates in the formation of the distal part of the a. poplitea and the proximal part of the a. tibialis posterior. A more distal section becomes the first part of the a. peronaea. A still more distal section persists, in combination with the r. calcaneus lateralis which arises from it, as the fourth part of the same artery. The medial and lateral terminal branches become the proximal and distal parts, respectively, of the a. plantaris lateralis.

The entire a. peronaea posterior superficialis has persisted, together with its lateral terminal branch, in the case represented in fig. 25; the main stem is present also in the case shown as fig. 26. In the latter case it is likely that the terminal branches have participated normally in the production of the a. plantaris lateralis.

The proximal part of the a. peronaea posterior superficialis has formed the distal part of the a. poplitea without the participation of the embryonic a. tibialis posterior superficialis in the cases reproduced in figs. 21, 22, 23 and 24.

The entire failure of the proximal part of the a. peronaea posterior superficialis to blend with the adjacent section of the a. tibialis posterior superficialis of the cases represented as figs. 6, 25 and 26 has led to anomalies of the aa. poplitea, tibialis posterior and peronaea. The partial failure shown in figs. 7 and 8 has resulted in anomalies of the aa. tibialis posterior and peronaea, and in the latter case, of the aa. poplitea and tibialis anterior also.

A portion of the a. peronaea posterior superficialis which normally disappears in the course of development has been retained as a branch of the a. peronaea magna of fig. 24. It appears, also, as a branch of the right a. peronaea of the case represented in Haller's fasciculus 8, pl. 2, which is not reproduced here.

The distal end of this artery has persisted in the form of the fourth part of the a. peronaea magna of figs. 18, 20, 21 and 24, and as the corresponding part of the chief artery of the posterior crural region of figs. 22, 23 and 25.

A. poplitea profunda. The proximal portion of this artery invariably persists to become the part of the adult a. poplitea which extends from the hiatus tendineus to the origin of the a. genu inferior medialis. Its distal portion is represented by the root of the a. genu inferior medialis, by the

second part of the a. tibialis anterior and by the entire a. recurrens tibialis posterior of the normal adult.

Persistence of the entire distal portion of the a. poplitea profunda, in the form of the first part of an abnormal a. tibialis anterior, is shown in fig. 9. Persistence of this portion of the vessel as the distal part of the adult a. poplitea occurs normally in many mammals.

The nature of the connections of the proximal part of the a. poplitea shown in figs. 10, 29 and 30, respectively, have been noticed above (see a. ischiadica).

A. poplitea superficialis. This artery, formed by the union of the proximal parts of the aa. tibialis posterior superficialis and peronaea posterior superficialis, normally becomes the distal part of the adult a. poplitea.

The part of the a. poplitea derived from this vessel is of normal composition, though small, in the case represented in fig. 9. Its composition in the cases shown in figs. 21, 22, 23 and 24, and the cause of its absence in figs. 6, 25 and 26, are noted above (see a. peronaea posterior superficialis).

The a. poplitea superficialis was probably derived mainly from the a. peronaea posterior superficialis in the cases reproduced as figs. 18, 19 and 20. The significance of the connection between the persisting part of the a. ischiadica and the distal part of the a. poplitea of fig. 11 is suggested above (see a. ischiadica).

A. tibialis anterior, pars distalis. In normal development this artery becomes the fourth part of the adult a. tibialis anterior. Its imperfect development is illustrated by fig. 13. Its absence, probably secondary, is shown in fig. 12.

A. tibialis posterior superficialis. This artery persists in adult life in its entirety. The proximal portion normally participates, with the a. peronaea posterior superficialis, in the formation of the distal part of the adult a. poplitea and of the proximal part of the a. tibialis posterior. A more distal portion becomes the part of the latter artery which lies beyond the origin of the a. peronaea. The most distal part of all becomes the a. plantaris medialis.

The absence of this artery in the cases reproduced in figs. 21, 22, 23 and 24, has led to the absence of the adult a. tibialis posterior. The effect of its absence upon the composition of the a. poplitea has already been noted (see a. peronaea posterior superficialis). The probable effect of absence of the a. tibialis posterior upon the form of the aa. plantares has been discussed upon p. 164. Imperfect development of this artery probably lies at the root of the anomalies of the a. tibialis posterior and a. peronaea shown in figs. 18, 19 and 20.

The effect of the complete failure upon the part of the a. tibialis posterior superficialis to unite with the corresponding section of the a. peronaea posterior superficialis, shown in figs. 7 and 8, has been referred to above (see a. peronaea posterior superficialis).

The peculiar form of the a. tibialis anterior in the case reproduced as fig. 12,

and that of the a. saphena magna in the case of fig. 15, appears to depend upon the formation of unusual anastomoses by the a. tibialis posterior superficialis. The normal communication (*R*) between the a. tibialis posterior superficialis and the a. peronaea posterior superficialis is responsible for the fourth part of the a. peronaea having become a branch of the a. tibialis posterior in the case represented in fig. 16.

R. calcaneus lateralis. This branch of the a. peronaea posterior superficialis persists to form the larger portion of the fourth part of the a. peronaea, and is represented by the termination of that adult artery.

It appears as a branch of the fourth part of the a. peronaea magna in figs. 18 and 21, and of the chief artery of the posterior crural region in figs. 22 and 23. It appears also as a branch of the persisting a. peronaea posterior superficialis of fig. 26, and of the lateral element of the double a. peronaea of fig. 27. In the case represented in fig. 24, it appears as the termination of a large branch of the a. peronaea, and in that reproduced as fig. 16, as a branch of the a. tibialis posterior.

R. communicans inferius. In normal development this branch becomes the second part of the adult a. peronaea. In the case represented as fig. 17 it seems to have formed the third part also.

In the cases reproduced as fig. 22 it follows upon a persisting section of the a. interossea in the formation of the chief artery of the posterior crural region. It is reduplicated in the case forming the subject of fig. 27.

R. communicans medius. This branch becomes the first part of the normal a. tibialis anterior.

It is absent in the case represented by fig. 9, forms the second part of the abnormal a. tibialis anterior of fig. 8, and enters into the composition of the abnormal a. poplitea of fig. 22.

R. coronarius malleolaris. This branch of the a. interossea normally persists in the adult leg as the r. communicans and as the aa. malleolares posterior et anterior mediales.

In the case reproduced as fig. 19 it reinforces the distal part of the a. tibialis posterior.

R. perforans cruris. This branch of the a. poplitea profunda forms the third part of the normal a. tibialis anterior of the adult.

The r. perforans cruris seems to have failed to fulfil its usual function in Velpeau's case discussed on p. 141. There are no graphic records of anomalies which depend upon the abnormal disposition of this branch, or upon its absence.

R. perforans tarsi. This terminal branch of the a. interossea disappears during the course of normal development. Fig. 35 records an example of its persistence.

R. saphenus. This, the medial terminal branch of the embryonic a. femoralis, persists as the a. genu suprema and as the r. saphenus of that vessel.

Examples of abnormal overgrowth of this branch to form a vessel known

as the a. saphena magna are recorded as figs. 14 and 15. The origin of this artery from the a. tibialis posterior, in the latter case, is the result of a secondarily acquired anastomosis.

The arterial retia of the embryonic foot give rise, in normal development, to the arcus plantaris, to the aa. dorsalis pedis, arcuata, tarseae, metatarseae and digitales and to the rr. plantaris profundus and perforantes.

Abnormal development of the embryonic *retia pedis* is exemplified as follows:

In figs. 34, 36 and 39 the arcus plantaris is defective, in fig. 37 it is absent. Figs. 32 and 33 illustrate absence of the a. dorsalis pedis and of the a. arcuata. In the case represented in fig. 33, the aa. metatarsales et digitales dorsales are absent; so also is the r. plantaris profundus of the cases shown in fig. 32, in figs. 33 and 34, and in fig. 36. The rr. perforantes are absent in the cases represented in fig. 12 and in figs. 33 and 34.