DEVELOPMENT AND VARIATION OF THE NERVES AND THE MUSCULATURE OF THE INFERIOR EXTREMITY AND OF THE NEIGHBORING REGIONS OF THE TRUNK IN MAN.

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WITH 10 PLATES AND 7 TEXT FIGURES.

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In a previous article in this journal (Bardeen and Lewis, **01**), an outline was given of the early development of the limbs, body-wall and back in the human embryo. Lewis subsequently, **01**, gave a more detailed account of the development of the arm, and I have recently, **05**, described at some length the development of the spine and of the skeleton of the leg. The purpose of the following paper is a more detailed account of the development of the nerves and musculature of the leg and of the neighboring regions of the trunk and a consideration of the relation of developmental conditions to variations found in the adult. The embryological studies have been based chiefly on embryos belonging to the collection of Professor Mall of the Johns Hopkins University, who kindly placed them at my disposal. The statistical studies of nerve variation are based upon charts drawn from specimens in the dissecting rooms of the Johns Hopkins University and at the University of Wisconsin.

A. OUTLINE OF THE DEVELOPMENT OF THE MUSCLES AND NERVES OF THE INFERIOR EXTREMITY.

I. GENERAL FEATURES.

For a description of the development of the external form of the limbs and of the chief features which characterize the earlier stages in the internal differentiation, reference may be made to the three papers mentioned above. The posterior limb-bud is first seen as a massing of the mesenchyme at the posterior extremity of the Wolffian ridge, usually opposite the 21st to the 26th spinal segments. This mesenchyme arises in part from the axial mesenchyme, in part possibly from the somatopleure. There is no good evidence that in the mammals the myotomes contribute directly to it. On the contrary the myotomes are sharply marked off by a limiting membrane from the mesenchyme of the limb-bud until this has become extensively developed. Afterwards this limiting membrane disappears, but there is little likelihood that cells derived from the myotomes then wander any considerable distance into the limb-bud. See Bardeen, **00.** A capillary network connected with the umbilical artery and the cardinal vein is formed in the limb-bud at an early period. Somewhat later nerves extend into the limb. At the same time the mesenchyme begins to be differentiated into skeletal, muscular and dermal regions. During the development of the limb it shifts distally so that the distal margin of the limb-bud is brought opposite the 27th and 28th, and sometimes also the 29th, spinal segments. As this occurs, bundles of nerve fibres from these more distal spinal segments extend into the limb-bud to contribute to the posterior nerves of the limb. In the adult the most distal nerve to contribute to the nerves of the limb varies from the 26th to the 29th, but is most commonly the 28th. (Bardeen and Elting, **01**). The number of spinal nerves contributing to the chief nerves of the limb varies from six to nine, but is usually seven or eight (Op. cit.). These variations are in all probability associated with variation in position of the limb-bud to the spinal axis during embryonic development.

The development of the main nerve trunks of the limb may be called the primary stage of nerve development and the associated variation in origin of the nerves, primary variation. As opposed to this primary development and primary variation we may call the growth which distributes the nerves within the limb the secondary stage of development and the variation there found secondary variation. During the primary period the spinal nerves send fibre bundles by direct paths to certain cutaneous areas and muscular anlages. During the secondary period the cutaneous nerves extend over the surface of the limb from the areas to which they are first distributed and the muscle anlages become differentiated into specific muscles to each of which nerve branches are given.

II. PRIMARY PERIOD OF NERVE DEVELOPMENT.

The general structural relations at the period when the nerves begin to extend into the limb-bud are shown in Plate I, Figs. 1 and 2. In Fig. 1 are shown the right limb and the distal half of the trunk from the 17th (9th thoracic) to the 29th (4th sacral) spinal segments in Embryo II (length 7 mm., age 26 days). The limb-bud lies opposite the 21st to the 26th spinal segments. The cœlom extends to a point opposite the 26th segment, but in the region of the limb it does not extend so far dorsally as in the thoracic region. In the figure several of the myotomes of the left side, the axial mesenchyme, the aorta, the left cardinal vein, the intestines and the uro-genital organs are not shown. A portion of the right cardinal vein and a portion of the right umbilical artery are represented, reduced in size for the sake of clearness. The umbilical artery curves about the distal extremity of the cœlom. From the umbilical artery a branch passes into the limb-bud. Veins pass from the limb-bud into the cardinal vein. The blood-vessels of the limb exist at this time in the form of an irregular plexus.

The second, third and fourth lumbar nerves may be seen sending spreading bundles of nerve fibres into the dense tissue of the limb, dorsal to the cardinal vein. They extend, however, for no considerable distance into the limb-bud. The myotomes end abruptly near the base of the limb-bud.

Plate II, Fig. 1, represents the tissue differentiation in a section through the posterior limb-buds of Embryo II. At the left the bud is shown cut through an area near the distal extremity of the cœlom. At the right the cut is more dorsal and extends through the tips of the lumbar spinal nerves.

In Plate I, Fig. 2, are shown the right limb and the posterior half of the trunk from the 26th (8th thoracic) to the 30th (5th sacral) spinal segments in a slightly older embryo (CLXIII, length 9 mm.). Bundles of nerve fibres from the five lumbar and first two sacral nerves have become anastomosed into a plexus from which in turn four nerves have sprung. These represent the femoral, obturator, tibial and peroneal nerves. Within the limb the central mesenchyme, near the axis of the embryo, has become condensed. This condensed mesenchyme represents the femur and hip bone of the adult limb. In the drawing the outline of this sclerogenous tissue is made diagrammatically sharp. The femoral portion of the skeletal mass fades gradually into the undifferentiated mesenchyme of the distal portion of the limb. It is this skeletal mass which seems to divide the bundles of nerve fibres into the four main divisions which constitute the origin of the four chief nerves of the limb. The main artery and vein of the limb are represented at a reduced scale. The border vein at this period is well developed (see also Fig. C, Plate III of the article by Bardeen and Lewis, 01).

The differentiation of the tissue of the limb-bud, first noticed in a condensation of tissue in the region corresponding to where the femur projects against the hip girdle, is quickly followed by further changes. Externally there becomes visible a differentiation of the limb into foot-plate, crus and thigh, while within the limb-bud the further development of the skeleton is marked by condensation of tissue, *scleroblastema*, to form the anlage of the skeleton of the foot, leg, thigh and hip girdle. About the scleroblastema is a myogenous zone, the *myoblastema*, composed of a slightly less dense tissue. In Embryo CIX, length 11 mm., this zone is best marked in the region of the hip (Plate II, Fig. 2). It is not clearly defined in the foot region. Between the myoblastema and the ectoderm lies a zone of less condensed tissue, the *dermoblastema*.

The chief nerves of the limb extend into the myoblastema. This is not a homogeneous layer. On the contrary from the time of its formation regions which represent the anlages of muscles or groups of muscles may be more or less clearly distinguished from regions which represent intermuscular spaces. In Plate III, Figs. 1 and 2, an attempt has been made to outline the muscle masses which represent the anlages of future muscle groups in Embryo CIX, length 11 mm. It is impossible to do this with exactness because the various regions are indefinitely bounded.

In this embryo the pelvic portion of the skeleton consists of a central region continuous with the head of the femur. From this central acetabular portion spring iliac, ischial and pubic processes. The femur is short and thick. The tibia and fibula are fairly definitely outlined, the foot-plate less definitely so.

The main nerve trunks have grown for a considerable distance into the limb. From them several of the chief muscular and cutaneous branches have sprung. The figures show these branches fairly well. In addition to the intrinsic nerves of the limb the anterior and posterior border nerves are also represented.

In Fig. 1 it may be seen that the myotomes in the region of the body wall have fused to form the anlage of the abdominal musculature. The lower margin of this extends distally about to the 21st spinal (1st lumbar) nerve. In Fig. E, Plate V of the article by Bardeen and Lewis, 01, it is represented slightly too short. From the ventro-posterior extremity of the abdominal musculature a somewhat indefinitely differentiated band of tissue may be followed to the pubic process of the pelvic girdle.

A slight communicating branch connects the twelfth thoracic with the first lumbar nerve. The main portion of this latter nerve extends forward on the internal surface of the distal margin of the anlage of the abdominal musculature and gives off a lateral, "iliac," branch. Ventrally the nerve divides into branches which represent the hypogastric and inguinal nerves. The 1st lumbar nerve also gives off a branch which passes to the lumbar plexus.

The obturator nerve arises from the first four lumbar nerves, passes through the obturator notch of the hip girdle and divides into two main divisions. Each of these terminates in a differentiated mass of tissue, the more anterior of which represents the adductor longus and brevis and the gracilis muscles, the more posterior, the obturator portion of the adductor magnus and possibly also the obturator externus muscle.

The tibial nerve arises from the fourth and fifth lumbar and first three sacral nerves. From it branches pass to muscle masses representing the obturator internus, quadratus femoris, hamstring, and the superficial and the deep posterior crural musculature. Distal to the tibial nerve the posterior cutaneous nerve of the thigh and the pudendal and caudal nerves may be seen.

In Fig. E, Plate V of the article by Bardeen and Lewis, **01**, the urachus was represented much foreshortened in order to reveal the muscle masses of the leg. In Fig. 1, Plate III, the urachus is outlined in its true position as seen directly from the side.

In Plate III, Fig. 2, the genital and lumbo-inguinal nerves are seen passing ventro-laterally from the junction of the 1st and 2d lumbar nerves. The femoral nerve is seen passing outwards over the region of the acetabulum. It is surrounded laterally by the iliopsoas muscle mass and terminates in the quadriceps femoris muscle mass. From it arise lateral and anterior cutaneous branches, a branch which passes to the sartorius muscle mass, and the saphenous nerve.

The peroneal nerve arises from the 4th and 5th lumbar and first two sacral nerves, gives off branches for the anlages of the superior gluteal, inferior gluteal, short head of the biceps and peroneal muscle masses and terminates in the anterior crural muscle mass.

An idea of the relations of the main nerves as they enter the limb in Embryo CIX may likewise be gained from Plate III, Fig. 3. The pelvis, the abdominal and dorsal musculature, the lining of the body cavity, the border nerves and the main nerve trunks of the limb are here represented as viewed from in front. The femur and the main nerve trunks are shown cut in a plane somewhat distal to the head of the femur. The division of the main nerve trunks into separate branches for individual muscles is schematic.

III. MUSCLE DIFFERENTIATION.

At the period under consideration several possibilities of muscle differentiation must be considered. *1st.*—The tissue which represents the muscle masses just mentioned may extend into the limb-bud with the nerves and become differentiated as the muscle branches are given off. The fact that Harrison, 04, has shown that in the tadpole muscle differentiation may take place when no nerves are developed makes this possibility highly improbable. *2d.*—The ingrowth of the nerves and the development of muscle branches may cause a "precipitation" of premuscle tissue about these branches. This likewise is rendered improbable by Harrison's experiments. *3d.*—Muscle differentiation begins in specific regions. Under normal conditions this differentiation begins simultaneously with the ingrowth of the nerves into the limb. Muscle branches extend into the differentiating musculature, owing perhaps to some specific attraction exerted upon the growing nerves. This seems on the whole to be the most probable course of development. The considerable variation shown in the origin and distribution of the nerves to the muscles renders it not improbable that their ingrowth is due in part to some special attraction exerted by the developing musculature upon the growing nerves, and variously responded to by the latter.

The paths opened up for the growth of the nerves to the muscles are, however, at first not as a rule in regions in which muscle tissue is to be differentiated, but in intermuscular areas. Thus the chief nerve trunks usually grow along paths which lie between main muscle groups. As the muscles of these various groups become differentiated the main nerve trunks of each muscle group are distributed in the septa which separate the individual muscles and finally after a nerve has entered the muscle for which it is destined it is usually distributed at first in the coarser intramuscular septa. During the early stages of development, however, the true muscle tissue cannot be sharply distinguished from the tissue which is to make up the skeletal framework of the muscle. For this reason it often appears as though the nerve to a muscle plunged at once into the midst of muscular tissue.

At a slightly later stage of development than that of Embryo CIX the differentiation of muscular tissue from the skeletal framework of the musculature is much better marked than in that embryo. Thus in Embryo CXLIV, length 14 mm., the individual muscles of the thigh may many of them be clearly distinguished (Plate II, Fig. 3). It may be seen in this embryo that although muscle differentiation in a given muscle is most clearly marked in the region where the respective nerve has come in contact with or has entered the muscle, the differentiation is not limited to this area but extends for a considerable distance toward the skeletal areas to which the muscle is to be attached. It is probable, however, that the differentiation of a given muscle begins as a rule in a region which corresponds with the site of entrance of the chief nerve of that muscle. In Plate II, Fig. 3, several nerves and muscles are shown. The nerve to the gracilis muscle shows especially clearly. From this region the gracilis muscle may be traced in successive sections toward the pelvis and toward the tibia. The entrance of the inferior gluteal nerve into the gluteus maximus muscle also shows well in the figure. The two parts of the adductor magnus muscle, the obturator and sciatic portions, are shown near the site of entrance of the respective nerves. The semitendinosus muscle and the two heads of the biceps are shown cut at some distance from the site of entrance of nerves. About the two divisions of the sciatic nerve there is some dense tissue which probably does not, however, represent muscle tissue.

It is to be noted that during these earlier stages of muscle differentiation the muscle anlages are often connected at one extremity, less frequently at both extremities, with the skeletal anlages to which the muscle is subsequently attached. The tendons of the muscles are developed in continuity with the anlages of the muscles. As a rule the differentiation of the longer tendons begins in the vicinity of the muscle bellies and gradually extends toward the skeletal attachments.

In a considerably older embryo, CXLV, length 33 mm. (Plate II, Fig. 4), differentiation of the muscles is much further advanced. Not only the muscles but also the fasciculi are separated by a large amount of connective tissue. This shows especially well in the gluteus maximus muscle. The main branches of the nerves of the muscle may be followed in the larger intramuscular septa, the smaller branches in the smaller intramuscular septa. I have elsewhere described the intramuscular growth of nerves in the mammals (Bardeen, 00 and 03). It is of interest to note that after muscle differentiation is well under way there is relatively a much greater amount of connective tissue in the musculature of the embryo than in that of the adult.

After the stage of development exhibited by Embryo CIX the conditions within the limb become so complex that they can be better followed by tracing through the development of specific groups of nerves and muscles than by attempting to picture all the details of each successive stage of differentiation of the whole limb. In order, however, that the relations of specific groups of nerves and muscles to the general structural condition of the limb may be followed we shall first briefly describe the relations of the peripheral nervous system to the skeleton at two important stages of development.

IV. OUTGROWTH OF THE NERVES.

In Embryo CXLIV (length 14 mm.) the main nerve trunks are well developed as far as the foot. The relations of the nerves to the spinal column, abdominal musculature, skeleton of the limb and the surface of the limb are represented in Plate IV, Figs. 1 and 2. The 12th thoracic nerve sends a communicating branch to the first lumbar and from this latter arise the hypogastric and inguinal branches.

From the first lumbar nerve a branch is also given off to the lumbar plexus. From the 1st and 2d lumbar nerves arise genital and lumbo-inguinal branches. The femoral and obturator nerves arise from the 1st, 2d, 3d, and 4th lumbar nerves and give off the branches shown in the figures. The sciatic nerve, which arises from the 4th and 5th lumbar and first three sacral nerves, is composed for the greater part of its course of separate peroneal and tibial nerves. The various muscular and cutaneous branches are labeled in the drawing.

In Embryo XXII, length 20 mm. (Plate V, Figs. 1 and 2), the various nerves mentioned are much more highly developed than in Embryo 144. This difference of development is especially to be noticed in the feet. The figures indicate sufficiently well the relations of the nerves to the skeletal apparatus, the skin and the abdominal musculature.

A noteworthy fact brought out by these figures is that the cutaneous nerves are distributed at first to the anterior, distal and posterior margins of the embryonic limb, while the dorsal and ventral regions of the limb are given up to the differentiation of musculature.

Having thus considered in brief outline the more general features in the development of the muscles and nerves of the posterior limb we shall take up in turn a more specific study, first, of the development of the cutaneous nerves and then of that of the muscles.

B. DEVELOPMENT AND VARIATION OF THE CUTANEOUS NERVES.

Grosser and Frohlich, 02, have given a good account of the development of the cutaneous nerves of the trunk. I have been unable to find any specific account of the embryonic development of the cutaneous nerves of the limbs, although the work of Sherrington, Head, and others on the segmental distribution of these nerves makes it of interest to inquire whether or not embryonic conditions can help to explain the phenomena these authors have described. In the following section the embryonic development and the variations in distribution of specific groups of nerves are first described and then the more general facts disclosed by this study are briefly reviewed.

I. ANTERIOR BORDER NERVES.

a. Development.

When the nerves begin to enter the limb-bud this lies, as pointed out above, usually opposite the five lumbar and first sacral nerves (Plate I, Fig. 1). The posterior margin of the developing body-wall and the anterior margin of the limb-bud usually overlap opposite the 21st segment. The nerves arising from the 21st spinal (1st lumbar) nerve are therefore true border nerves, being in part distributed to the abdominal wall and in part to the limb. The 20th and 22d spinal nerves (12th thoracic and 2d lumbar) also usually contribute to a greater or less extent to both regions, the 20th contributing to the cutaneous supply of the leg, the 22d slightly to the extreme margin of the abdominal musculature.

In Embryo CIX, length 11 mm. (Plate III, Figs. 1, 2 and 3), the border nerves are beginning to extend toward the skin. At this stage the oblique and the rectus muscles of the abdomen are beginning to be differentiated. The transversus muscle has not yet appeared. Between the ventro-anterior margin of the pubis and the ventro-caudal angle of the differentiating abdominal musculature a slight thickening of the mesenchyme represents the beginning of the tendon of the rectus and of the inguinal ligament. A considerable interval exists between the distal margin of the abdominal musculature and the anlage of the iliac crest. The musculature lies near the peritoneal cavity, while the crest is in the mesenchyme lateral to this cavity. Between body cavity and crest lies the femoral nerve with its branches (Fig. 3). From the first and second lumbar nerves the iliohypogastric and inguinal and the genital branch[1] of the genito-femoral extend ventrally between the cœlomic wall and the distal margin of the developing abdominal musculature. From the common trunk of the iliohypogastric and inguinal nerves a lateral branch, the "iliac," extends toward the skin in an area considerably anterior to the ilium. The lumbo-inguinal nerve and the lateral and anterior cutaneous branches of the femoral extend toward the anterior margin of the limb-bud.

In a slightly older embryo, CXLIV, length 14 mm. (Plate VI, Fig. 1) differentiation of the abdominal musculature has proceeded much further. The external oblique muscle is a thin sheet, somewhat wrinkled in the specimen. In the figure merely its origin from the lower ribs is shown. It extends distally into a sheet of mesenchyme which is thick-

[1] The term "genital" nerve is here used in preference to "spermaticus externus."

ened at its distal border into an embryonic inguinal ligament (lig. ing.). This latter extends from an anterior mesenchymatous process of the ilium toward the pubis. Ventrally it becomes continuous with the blastema of the pubic crest. Beneath the external oblique lies the internal oblique muscle. Distally this is connected by a mesenchymatous membrane with the inguinal ligament. In the figure merely the costal and inguinal portions of the muscle are shown.

The transversus muscle is differentiated immediately beneath the peritoneal membrane. It is not clear whether the material of the transversus musculature is derived from the cœlomic lining or from the myotomes. If from the latter the tissue wanders along the peritoneum from the region of the ribs.

At this early stage the anlage of the processus vaginalis may be seen in the form of a thickened mass of tissue which is continued from the plica gubernatrix through the internal oblique muscle and the aponeurosis of the external oblique above the inguinal ligament to the junction of the thigh with the trunk. Here it spreads out into processes which extend on the one side toward the mid line of the body, on the other toward the femur.

Between the transversus musculature and the internal oblique run the main trunks of the thoracico-abdominal nerves. The ilio-hypogastric and inguinal nerves pierce the internal oblique muscle and the aponeurosis of the external oblique much as in the adult. The iliac branch of the ilio-hypogastric, however, pierces the oblique muscles in a region anterior to its relative adult position. This is also the case in Embryo XXII, length 20 mm., Plate V, Fig. 1. Beyond the region of the inguinal nerve the cœlomic wall, backed by a thickened membrane representing the transversalis fascia, curves medially while the oblique musculature takes a somewhat lateral direction toward the inguinal ligament. Between the two is a space in which lie the femoral nerve, its proximal branches and the anlage of the ilio-psoas muscle. The genital branch of the genito-femoral nerve follows along the cœlomic wall almost parallel with the hypogastric and inguinal nerves but converging toward the latter. The point " X " in the figure represents a region where later the peritoneal wall will be pushed laterally over the ilio-psoas muscle so as to cover this and be brought in contact with the iliac crest. The lumbo-inguinal nerve passes out beneath the inguinal ligament in the vicinity of the femoral artery. It probably represents a lateral branch of the genito-femoral considered as the ventral division of a typical spinal nerve.

Ventrally the genital nerve, usually after anastomosing with the inguinal, passes along the vaginal process through the aponeurosis of the external oblique and over the inguinal ligament to the thigh. It is interesting to note that this development considerably precedes the descent of the testicle.

In Plate VI, Fig. 2, the border nerves of Embryo XXII, length 20 mm., are pictured. It is somewhat difficult to trace with certainty the border nerves in this embryo, but the figure is believed to illustrate approximately the actual relations. While in Embryo CXLIV a considerable interval separates the anlage of the iliac crest from the distal margin of the abdominal musculature, in Embryo XXII the crest is much further developed and at the same time has been rotated toward the dorsal portion of the distal margin of the oblique abdominal musculature. This at the same time has extended distally and become attached to the iliac crest. Meanwhile the peritoneal wall has bulged laterally so that the fascial extension of the transversus muscle covers the ilio-psoas muscle in the region of the pelvis and the transversus muscle has formed its pelvic attachments. The main trunks of the border nerves have been brought by these changes into relations which closely resemble those characteristics of the adult. Adult conditions are reached by some further relative shifting of parts and by the growth of the nerves within the areas for which they are destined.

The segmental relations of the border nerves may be best understood by comparing the position of the pelvic girdle when the nerves first extend toward the skin with the condition brought about by the shifting of the girdle. See Plates III, IV, V and VI. In Embryo CIX, the stage in which the nerves first extend toward the skin, the border nerves arise from the spinal nerves in the following order: iliohypogastric, inguinal, genital and lumbo-inguinal. As these nerves grow forward there takes place a rotation of the base of the limb medially, ventrally and posteriorly. At the same time the spinal column becomes straightened and the limb-bud as a whole descends posteriorly. The pubis is carried from a point opposite the 21st (12th thoracic) segment to a point opposite the 26th, and at the same time the posterior margin of the ilium is usually brought to lie opposite the 26th and 27th vertebræ to which it becomes attached. The two pubes are carried forward ventrally until they are united by the symphysis pubis.

As the pubis rotates ventrally and posteriorly the inferior portion of the abdominal wall is extended in a corresponding direction. The ventral margins of the distal portion of the rectus muscles are brought into approximation when the symphysis pubis is formed. By the rotation of the hip bone the crest of the ilium is brought up against the dorsal portion of the distal margin of the abdominal musculature. The ventral portion of this margin becomes converted into the inguinal ligament. The courses of the abdominal nerves and the hypogastric and inguinal nerves are determined by their positions in the abdominal musculature. The genital nerve takes a more direct course towards its region of termination, although it too is usually bound up for some of the distal part of its course with the distal margin of the abdominal wall.

The peripheral region to which the lumbo-inguinal nerve extends is carried in a ventral, medial and posterior direction by the rotation of the limb. The main trunk of the lateral cutaneous nerve is caught by the rotating hip bone usually in the vicinity of the future anterior superior iliac spine and is carried up against the inguinal ligament. Thus by this rotation and shifting marked changes in the relative positions of the more anterior nerves arising from the lumbar plexus are brought about.

b. *Variation.*

A study of variation in the distribution of the fibre bundles of the spinal nerves to the various peripheral areas of the limb reveals the fact that any two nerves shown in Plate III, Figs. 1, 2 and 3, may be combined into a single trunk when they arise ordinarily in succession, but not otherwise. Thus the 12th thoracic and the hypogastric, the hypogastric and the inguinal, the inguinal and the genital, the lumbo-inguinal and the lateral cutaneous, the lateral cutaneous and the femoral, may be bound together for a greater or less part of their courses from the plexus to the limb. On the other hand, two or more nerve trunks may serve to convey fibres commonly carried in a single nerve. Separate iliac branches, extra lumbo-inguinal and genital nerves belong to this category as do also those "middle cutaneous" nerves which arise directly from spinal nerves, and the accessory obturator nerve. The frequency of variation of this sort in the border nerves I have previously described in this journal, **02.** In the same paper I have treated of the frequency of variation in segmental origin of the various border nerves. This is most marked. Thus the hypogastric nerve arose in 2% of instances from the 19th and 20th spinal nerves; in 32% from the 20th; 34% from the 20th and 21st; and 32% from the 21st. The iliac arose in 2.1% of instances from the 19th and 20th spinal nerves; 27.4% from the 20th spinal nerve;

37.7% from the 20th and 21st spinal nerves; and 32.7% from the 21st spinal nerve. The inguinal nerve arose from the 20th spinal nerve in 3.5% of instances; from the 20th and 21st in 38.3%; from the 21st in 51.5%; and was absent in 6.6%. The genito-femoral nerves arose from the 21st spinal nerve in 19% of instances; from the 21st and 22d in 79% of instances; and from the (21st) 22d and 23d in 2% of instances. In 1.2% of instances no lumbo-inguinal (crural) branch was found. It is probable that the variation in origin of the border nerves is due in part to a variation in position of the base of the limb-bud with respect to the spinal column, the more anterior spinal nerves serving to supply the limb when the limb-bud has a more anterior position at the time of the outgrowth of the spinal nerves. There is, however, no perfect correspondence between variation in origin of individual border nerves and that of the border nerves as a group.

In the same paper I showed that out of 133 instances, in 27 (20.30%) the lumbo-inguinal (crural) nerve emerged from the pelvis into the thigh in a lateral (external) region; in 81 instances (60.9%) in the middle (anterior) region; and in 25 instances (18.8%) in a medial (internal) region. After the nerve has passed into the thigh it may have a slight, a moderate or an extensive distribution to the skin. While this distribution usually corresponds to the region of exit, lateral, middle or medial, this is not always the case. For instance, a nerve emerging laterally may send a branch over to supply the fascia on the medial side of the leg. The following table indicates the frequency and extent of distribution of the lumbo-inguinal nerve to the skin of the lateral, anterior and medial portions of the thigh. By "lateral" region is meant an area lying lateral to a line drawn from the anterior inferior spine of the ilium to the lateral edge of the patella; by "medial," an area lying medial to a line drawn from the medial margin of the hip joint to the medial edge of the patella; and by "anterior," the intervening area. By "slight distribution" it is meant that by gross dissection the branches of the nerve could be followed but a short distance below the inguinal ligament; by "extensive distribution" it is meant that the branches could be followed readily over half way down the thigh. By "moderate distribution" is meant a distribution lying between these extremes. It will be understood, of course, that no hard-and-fast lines can be drawn between the various types of distribution tabulated. The table is intended merely to give an idea of the approximate frequency of distribution of the lumbo-inguinal nerve to approximate areas.

TABLE I.

Table Showing the Region and Extent of Distribution of the Lumbo-inguinal Nerve.

Type of Distribution.	Extent of Distribution. Slight. No. of inst.	Moderate. No. of inst.	Extensive. No. of inst.		
Lateral	5	8	6	19	15.4%
Anterior	11	36	8	55	44.7%
Medial	6	15	10	31	25.2%
Lateral and Medial........			18	18	14.6%
	22	59	42	123	
	(17.9%)	(48%)	(34.1%)		

From this table it will be seen that the type of distribution most commonly met with is that of a moderate anterior distribution (36 instances, 29.2%). This corresponds to the distribution commonly given as the "normal" in the text-books and shown on the left side of the widely borrowed Léveillé figure given on Plate LIV of the Hirschfeld-Léveillé Neurologie.[2] The other types of distribution are, however, met with two thirds of the time. A study of the association of the types of distribution above given with race, sex and side of body, with various types of lumbo-sacral plexus and with variations in the spinal column has brought to light no intimate relations. The following table illustrates the relations of origin to distribution of the lumbo-inguinal nerve.

TABLE II.

Spinal Nerves from which the Lumbo-inguinalis arises.	Frequency of Types of Distribution of the N. Lumbo-inguinalis. Lateral. Slight.	Lateral. Mod.	Lateral. Extens.	Anterior. Slight.	Anterior. Mod.	Anterior. Extens.	Medial. Slight.	Medial. Mod.	Medial. Extens.	Lateral and Medial.
XX, XXI	..	2	..	..	5	1	..	..	3	..
XXI	1	1	1	..	4	3	..	1	2	1
(XX), XXI, XXII	..	1	1	1	5	..	2	3	..	3
XXI, XXII	3	3	2	8	18	3	4	10	5	3
XXII	1	1	..	2	3	..	..	1	..	..
(XXI), XXII, XXIII	1	..	1	..	..	2	..	..	..	1

From this it will be seen that there is slight relationship between the origin from the plexus and the distribution of this nerve. In case of

[2] Paris, 1853.

origin from the 23d spinal nerve the distribution is extensive in most of the instances studied.

The inguinal and genital nerves show relatively much less extensive variation in distribution. My data concerning the variation in their distribution as well as that of the iliac nerves are less accurate than those of the lumbo-inguinal so that the latter nerve may serve as an example of variation in the distribution of the border nerves.

II. CUTANEOUS NERVES OF THE FEMORAL GROUP.

a. Development.

By "cutaneous nerves of the femoral group" may be designated the lateral (external) cutaneous nerve of the thigh and the cutaneous nerves which usually spring directly from the femoral nerve. These nerves are all directed at first toward the anterior margin of the limb-bud. Figs. 1-3, Plate III, show their situation in an embryo of 11 mm. length. In Plate IV, Figs. 1 and 2, and Plate VI, Figs. 1, their position is shown in an embryo of 14 mm.

In this latter embryo (CXLIV) the lateral cutaneous nerve arises from the main trunk of the femoral, passes outwards through the anlage of the psoas muscle and approaches the skin near the junction of the anterior margin of the limb with the thigh. Several anterior and medial cutaneous nerves arise from the femoral nerve. The most proximal of these approaches the surface of the limb-bud somewhat more distally than the lateral cutaneous. A branch may likewise be followed through the anlage of the sartorius muscle and two through the septal tissue which divides the sartorius from the adductor group of muscles. The saphenous nerve passes between the anlages of the tendons of the sartorius and gracilis muscles to reach the subcutaneous tissue near the knee (Plate VI, Fig. 1).

In an older embryo, XXII, length 20 mm. (Plate V, Figs. 1 and 2, and Plate VI, Fig. 2), the further growth of the nerves just mentioned may be followed. The lateral cutaneous nerve has spread out in several branches toward the lateral surface of the thigh. The anterior and medial cutaneous branches have spread out over the antero-medial surface of the thigh, while the saphenous nerve has continued its growth toward the ankle. During the ventro-posterior rotation of the hip the lateral cutaneous nerve has been caught near the anterior superior spine of the ilium.

The further growth of these nerves to reach the conditions characteristic of the adult may easily be deduced by comparing Plate VI, Fig. 2.

with Plate VII, Fig. 1. The fascia lata which covers the lateral, anterior and medial cutaneous nerves for a considerable part of their course is just beginning to be differentiated in Embryo XXII.

b. Variation.

1. N. Cutaneus Femoris Lateralis.

The lateral cutaneous nerve in the adult usually springs by one or more roots from the lumbar plexus and takes a direct course through the psoas muscle and beneath the iliac fascia to a region near the anterior superior spine of the ilium whence it passes for some distance beneath the fascia lata and is finally distributed to the skin of the lateral region of the thigh.

The nerve varies considerably in origin. Out of 287 instances I found it arising in 39% from the 20th, 21st and 22d; in 43% from the 21st, 22d and 23d; and from the main trunk of the femoral in 18%. (Bardeen, 02).

The region where the nerve passes out into the thigh varies somewhat. It may be over the crest of the ilium just above the anterior superior spine or some distance below the latter. In two instances out of 146 it was found to emerge near the femoral nerve and then curve sharply outwards toward the lateral surface of the thigh. Rarely it is absent, its place being supplied by branches which spring directly from the femoral nerve below the inguinal ligament.

It varies considerably in extent of distribution. The distribution of the chief branches was found to be lateral to a line drawn from the anterior inferior iliac spine to the outer edge of the patella in 92 out of 146 instances (63%), Plate VII, Fig. 1. The area of distribution corresponds here essentially with that given as the normal one in most textbooks. In 45 instances (30.8%) the branches of the lateral cutaneous extended medially over the anterior portion of the thigh taking the place to a greater or less extent of the anterior cutaneous branches of the femoral nerve. An instance of this sort is figured on the right side of the Léveillé figure mentioned above (p. 276). In 9 instances out of 148 (6.2%) a "lumbo-inguinal" branch, given off by the lateral cutaneous nerve, was distributed to the skin of the upper antero-medial region of the thigh. In two instances out of 148 the lateral cutaneous nerve was missing, its place being supplied by a large nerve which in origin, course through the psoas muscle and entrance into the fasciæ of the thigh resembled a lumbo-inguinal nerve. In two of the instances in which the "anterior or middle" distribution was extensive the lateral cutaneous nerve passed into the thigh near the femoral nerve and then curved laterally towards the anterior superior spine. In one instance it gave a large communicating branch to the lumbo-inguinal nerve.

No relationship between race, sex or side of body and variation in the distribution of the lateral cutaneous nerve is apparent in the charts. An extensive distribution on the front of the thigh is somewhat more often associated with anterior than with posterior forms of lumbo-sacral plexus. This may be seen from the following table.

TABLE III.

Type of Plexus from which the N. Cut. Fem. Lat. arose:				Frequency of Types of Distribution of the N. Cutaneus Femoris Lateralis:		
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Lateral.	Lateral and Anterior.	Lateral and Medial.
Ant.	A	XXIV	XXVI	1		
	B	XXIV	XXVII	6	8	
	C	XXIV chiefly to sacral plexus	XXVIII	22	15	1
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII	37	16	6
Post.	E	(XXIV) XXV	XXVIII	8	4	1
	F	XXIV	XXIX	8	2	1
	G	(XXIV) XXV	XXIX	10		

The extensive anterior type of distribution is also most frequently associated with an "abnormal" type of vertebral column, especially a short one, as may be seen in the following table.

TABLE IV.

Vertebræ of Spinal Column.	Distribution of Lateral Cutaneous Nerve.		
	Lateral.	Lateral and Anterior.	Lateral and Medial.
7c 11t 5l 5s 4c		4	
7c 11t 5l 6s 2c	2	2	
7c 12t 4l 6s 3c		2	
7c 12t 4l 5s 3c		1	
7c 12t 5l 4s 2c		1	
Rudimentary 12th rib	19	9	2
Normal	29	11	7
7c 12t 5l 6s 3c	1	1	
7c 12t 6l 5s 3c	2	3	
7c 13t 5l 4s 3c	2	2	

The extensive anterior type of distribution is also more frequently associated with an anterior origin of the lateral cutaneous nerve than with a posterior origin. This is indicated in the following table.

TABLE V.

Spinal Nerves from which Lateral Cutaneous Nerve arose.	Distribution of Lateral Cutaneous Nerve. Lateral. No. of inst.	Lateral and Anterior. No. of inst.	Lateral and Medial. No. of inst.
(XX) XXI XXII	10	8	2
XXI XXII	18	10	1
XXII	9	3	
(XXI) XXII XXIII	25	13	5
XXII XXIII	5	3	1
XXII XXIII	10	3	
Trunk of femoral nerve...............	15	3	

The relations existing between the various types of distribution of the lateral cutaneous nerve and the various types of distribution of the lumbo-inguinal nerve are shown in the following table.

TABLE VI.

Types of Distribution of Lateral Cutaneous Nerve.	Types of Distribution of the Lumbo-inguinal Nerve. Lateral.			Anterior.			Medial.			Lat. and Med.	Wnt'g.
	Sl't.	Mod.	Ext.	Sl't.	Mod.	Ext.	Sl't.	Mod.	Ext.		
Lateral	2	5	1	4	21	4	3	4	0	9	1
Lateral and anterior	1	2	2	4	3		1	7	7	4	2
Lateral and medial.	1	1		3	1		1		1		1
Wanting			2			1					

The most striking feature brought out by this table is the frequent association of an extensive anterior distribution of the lateral cutaneous nerve with a moderate or extensive medial distribution of the lumbo-inguinal nerve. This is shown in the Léveillé plate referred to above. This extensive distribution on the thigh of nerves derived directly from the 21st and 22d spinal nerves is, as has been pointed out above, most frequently associated with an anterior type of lumbo-sacral plexus and this in turn probably with a somewhat anterior position of the limb-bud at the time of the ingrowth of nerves. When the 21st and 22d spinal nerves are called upon to furnish a greater supply than usual of nerve fibres to the limb they are more apt to do so through direct paths (the lateral cutaneous and lumbo-inguinal nerve trunks), than through the more indirect route of the femoral nerve and its branches. This feature is further brought out in the not infrequent association with the anterior forms of plexus of a direct anterior cutaneous branch from the plexus to the front of the thigh.

2. Separate Anterior Cutaneous Nerves.

Nerves of this sort spring usually from the XXI and XXII spinal nerves, but also sometimes from the XXIII and very rarely from the XXIV as well. Henle considers them as varieties of the lumbo-inguinal. In their course, however, they usually, at least, lie beneath or deep in

TABLE VII.

Type of Plexus from which the N. Cut. Fem. Lat. arises:			Origin of Separate Anterior Cutaneous Nerve.	
Type.	Furcal Nerve.	Most Distal Spinal Nerve to Limb.	From (XXI) XXII Spinal Nerves. No. of instances.	From XXII XXIII Spinal Nerves. No. of instances.
B	XXIV	XXVII	1	
C	XXIV chiefly to sacral plexus	XXVIII	10	1
D	XXIV chiefly to lumbar plexus	XXVIII		2
Type of vertebral axis	7c 11t 5l 6s 2c		1	
	12th rib rudimentary		8	1
	Not recorded		2	1
	Normal			1

the psoas muscle and beneath the iliac fascia instead of lying above the latter like the lumbo-inguinal nerve. A direct anterior (high middle) cutaneous nerve of the thigh was found 14 times in 123 instances (11.4%). It arose 11 times from the XXI and XXII spinal nerves and 3 times from the XXII and XXIII (once from a region opposite the XXIV spinal nerve). In the last instance entrance of fibres from the XXIV nerve was possible but was not certain. In all instances except two it arose in association with an anterior form of plexus. In all instances recorded except one the spinal axis showed a tendency to reduction by the presence of a rudimentary 12th rib and in one instance there were but eleven thoracic vertebræ. These facts are illustrated in the above table.

The following table illustrates the relation of a separate anterior cutaneous nerve of the thigh to the lateral cutaneous and lumbo-inguinal nerves.

TABLE VIII.

Types of Distribution of Lateral Cutaneous Nerve	Origin of Separate Anterior Cutaneous Nerve. From the XXI XXII Spinal Nerves. No. of instances.	From the XXII XXIII Spinal Nerves. No. of instances.
Lateral distribution	10	3
Wanting	1	
Types of Distribution of Lumbo-inguinal Nerve.		
Slight lateral	1	
Moderate lateral	1	
Extensive lateral	1	
Slight anterior	1	
Moderate anterior	2	2
Extensive anterior	1	
Slight medial	1	
Moderate medial	2	1
Lateral and medial	1	

From this table it will be seen that a separate anterior cutaneous nerve may be associated with a moderately developed lateral cutaneous nerve and with any form of distribution of the lumbo-inguinal nerve.

There is no indication that sex or race has influence on the frequency of development of this nerve. It was found more frequently on the left side than on the right, but this might not hold true were a greater number of instances studied. In only one instance was the nerve found on both sides of the same body. The following table indicates the race, sex and side of body in which the fourteen instances here studied were found.

TABLE IX.

Special Anterior Cutaneous Nerve from	White. Male. R	White. Male. L	White. Female. R	White. Female. L	Negro. Male. R	Negro. Male. L	Negro. Female. R	Negro. Female. L
XXI XXII sp. nerve	2	3		1	1	2		2
XXII XXIII sp. nerve		1				1	1	

The separate anterior cutaneous nerve is distributed on the thigh in company with branches derived directly from the femoral nerve. As a rule it is distributed in a territory separating that of the lateral cutaneous nerve from that of the branches of the femoral nerve, but occasionally it may have a more medial distribution. We may now pass to a consideration of the cutaneous branches of the femoral nerve arising beyond the inguinal ligament.

3. Anterior and Medial Cutaneous Branches of the Femoral.

The cutaneous branches of the femoral nerve to the thigh have been commonly divided by English and other anatomists into two groups, the "middle cutaneous" (nn. cutanei anteriores of Henle) and the "internal cutaneous" (nn. cutanei medii of Henle). It is not possible always to draw a sharp distinction between these two groups of nerves.[3] In the most common form of distribution (Plate VII, Fig. 1) two "anterior cutaneous" nerves, a lateral and a medial, arise in the upper part of Scarpa's triangle. These branches descend in Scarpa's triangle, pass to the medial side of or through the substance of the sartorius muscle, pierce the fascia lata over the upper third of the sartorius muscle and are distributed to the skin of the lower two-thirds of the front of the thigh. The lateral branch pierces the sartorius muscle more frequently than does the medial branch. In place of two branches there may be three or only one. The "medial cutaneous" nerves arise as rami from one or more branches of the femoral nerve. The rami usually pass outwards in the septum between the sartorius muscle and the adductor group of muscles. Sometimes one or more of the rami pass through the substance of the sartorius muscle. The various rami supply the skin of the medial surface of the thigh and the more distal usually extend to the knee and join the saphenous and obturator nerves in supplying the medial side of the knee and upper part of the medial side of the back of the leg. There is great variation in the number and distribution of these rami of the "medial cutaneous" nerves. In two instances out of 80 a medial cutaneous nerve sent a branch as far as the ankle, parallel with the saphenous nerve.

Frequently the most proximal ramus of the medial cutaneous nerves on reaching the subcutaneous tissue, or even beneath the fascia lata turns back to take a course toward the region of distribution of the inguinal nerve (5 out of 80 instances).

The great variation in the number and territory of distribution of the anterior and medial cutaneous nerves of the thigh makes their statistical study both difficult and unsatisfactory. They vary in extent of distribution inversely with the lumbo-inguinal, lateral cutaneous, saphenous

[3] In the B. N. A. but one set of nerves is recognized, the *nn cutanei anteriores*. We shall here, however, adopt the Henle terms.

and obturator nerves, with branches of which anastomoses are usually formed.

Considering as a group the nerves which supply the front of the thigh it is found that the most common form of distribution is that of a moderately extensive lateral cutaneous nerve associated with two anterior and one or two medial cutaneous nerves the branches of which are distributed over the front and medial side of the thigh. As a rule the skin beyond the knee is supplied mainly by branches from the saphenous. This general mode of distribution was found in 64% of instances. In about 33% of instances there was an extensive distribution of the lateral cutaneous nerve with a more restricted distribution of the anterior and medial cutaneous nerves.

In the following table an attempt has been made to show the number of chief nerve branches distributed to the anterior surface of the thigh

TABLE X.

Cutaneous Nerves.	Number of Main Nerve Branches Distributed to the Anterior Surface of the Thigh.																											
N. cut. fem. lat....	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	4	4	4
N. cut. fem. ant. from plexus....	..	..	1	1	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
N. cut. fem. ant. from N. femoralis..............	2	1	1	..	1	..	1	2	2	2	2	2	3	3	1	1	2	2	2	2	3	1	1	1	2	1	1	2
N. cut. med.......	1	1	1	1	1	2	2	3	2	1	2	1	1	2	0	1	1	2	1	2	1	1	1	2	1	1	2	1
N. saphenous R. infrapatellaris..	1	1	1	1	1	1	0	2	0	1	1	0	1	1	1	1	1	1	2	0	1	0	1	1	1	1	1	1
No. of instances..	1	1	2	6	1	2	1	1	3	5	3	1	1	1	1	6	14	2	3	1	2	1	2	3	13	3	2	5

in 87 instances. The lateral cutaneous nerve has been counted as single when numerous small rami are given off from the main trunk; as double when the nerve divides into two main trunks before or soon after passing under the inguinal ligament; as triple and quadruple when it divides into three or four main nerve trunks. By separate anterior cutaneous is meant a branch arising directly from the plexus. The anterior cutaneous nerve is counted as single when one main trunk arises from the femoral nerve; as double when two separate trunks arise; and as triple when three such trunks arise. The same is true of the medial cutaneous nerve.

4. N. Saphenous.

The saphenous nerve is fairly constant in its general mode of distribution. The greatest variation comes in the distal extent of its distribution. In three instances out of 75 it was found to extend to the great toe. Although in several instances students failed to trace the nerve further than the knee, I do not feel that their work is sufficiently accurate to give figures as to the frequency of extremely limited distribution of the saphenous nerve. I have seen no instances of the passing of the saphenous nerve to the back of the thigh through the adductor magnus muscle as described by Hyrtl (Henle, Nervenlehre, s. 573). As a rule the main trunk of the saphenous nerve passes skinwards between the tendons of the sartorius and gracilis muscles. The patellar branch of the saphenous usually passes through the substance of the sartorius muscle but may pass over the anterior margin of the tendon. Below the knee the saphenous nerve may be continued in one or two main trunks toward the ankle.

III. CUTANEOUS BRANCHES OF THE OBTURATOR NERVE.

The superficial branch of the obturator nerve may terminate in a cutaneous branch of variable size. In the embryos studied I have been unable satisfactorily to trace the development of this nerve. In the adult it usually passes distally between the gracilis and adductor longus and becomes superficial between the gracilis and sartorius muscles in the middle third of the thigh. It commonly anastomoses with branches either from the medial cutaneous nerves of the thigh or from the saphenous nerve or both, and helps to form the subsartorial plexus. The fibres of the cutaneous branch of the obturator may join the medial cutaneous or the saphenous nerve beneath the sartorius and be distributed in the branches of these nerves without giving rise to any independent branches. How constant the cutaneous branch of the obturator may be I have been unable satisfactorily to determine. Students dissecting frequently fail to find it. Owing to the fact that this may often be due to its small size the negative records cannot safely be used in making up statistics.

Out of 80 instances in which the nerves of the thigh were carefully charted, in 12 a large cutaneous branch passed from the obturator to the region of the knee and in 10 other instances one passed to or beyond the middle third of the crus. A well developed obturator branch to the skin is found more frequently associated with "normal" and "anterior" than with posterior types of lumbo-sacral plexus and relatively more frequently in white than in negro subjects.

IV. ACCESSORY OBTURATOR NERVE.

This nerve was not found in the embryos studied. Out of 250 plexuses in the adult it was found in 21 (8.4%). It seems to be especially frequently associated with the anteriorly situated types of plexuses. It was found relatively more frequently in males (9.3%) than in females (5.4%) and in white (10.8%) than in negro subjects (6.4%). In most instances an anastomotic branch could be traced to the cutaneous branch arising from the obturator nerve. The following table shows the frequency with which accessory obturator nerves of various types of origin were associated with various types of lumbo-sacral plexuses.

TABLE XI.

Type of Plexus from which the N. Cut. Fem. Lat. arises.			Origin of Accessory Obturator.		
Type.	Furcal Nerve.	Most Distal Spinal Nerve to Limb.	From (XXI) (XXII) XXIII Sp. Nerves.	From (XXII) XXIII XXIV Sp. Nerves.	From XXIV Sp. Nerve.
B	XXIV.	XXVII.	1		1
C	XXIV chiefly to sacral plexus.	XXVIII.	5	2	1
D	XXIV chiefly to lumbar plexus.	XXVIII.	2	5	2
F	XXIV.	XXIX.	1		
G	(XXIV) XXV.	XXIX.	1		

V. CUTANEOUS NERVES OF THE SCIATIC GROUP

The cutaneous nerves originally extending toward the posterior and distal margins of the embryonic limb are greater in number and have a more extensive distribution than those of the anterior border. They consist of the posterior cutaneous nerve of the thigh, n. cutaneus femoris posterior (small sciatic), with its cluneal, perineal, hamstring and terminal branches, and the cutaneous rami which arise from the peroneal and tibial nerves. We may consider first the early embryonic development of these nerves and then the variations found in the adult.

a. Embryonic Development.

1. N. Cutaneus Femoris Posterior.

In Embryo CXLIV, length 14 mm., Plate IV, Figs. 1 and 2, two nerves may be seen extending out toward the posterior margin of the base of the limb. One of these nerves represents the posterior cutaneous nerve, the other either the perineal ramus (inferior pudendal) of that nerve or the perforating cutaneous nerve. The gluteus maximus muscle does not at this period completely overlap the sciatic nerve and the two cutaneous nerves have a free path for growth. In Embryo XXII, length 20 mm. (Plate V, Figs. 1 and 2) but one cutaneous nerve can here be distinguished. This is clearly the posterior cutaneous nerve. In subsequent development the nerve is shifted from the posterior margin over a region corresponding to the original medial surface of the limb-bud and gives rise to extensive branches. In Embryo XXII perineal and cluneal rami may be traced for a short distance from the main trunk.

2. N. Suralis.

The main trunk of the sural nerve (external saphenous) may be seen arising, through the N. cut. sural medialis, from the tibial nerve in Embryo CXLIV (Plate IV, Figs. 1 and 2). In Embryo XXII, Plate V, Figs. 1 and 2, it is well developed and branches may be traced over the dorsum of the foot. The main trunk of this nerve at this period occupies a much more lateral position than subsequently. With the development and shifting of the gastrocnemius muscle the trunk of the nerve near its origin becomes shifted toward the middle of the calf and buried between the two heads of the gastrocnemius muscle.

3. N. Surae Lateralis.

In Embryo CXLIV (Plate IV, Fig. 2) this may apparently be recognized as short branch. In Embryo XXII (Plate V, Fig. 2) it is not much more highly developed. Subsequently it too becomes shifted over the back of the calf, but its branches are supplied to the original posterior margin of the limb (the external surface of the leg) as well as to the back of the leg. One of these branches finally anastomoses with the main trunk of the sural nerve. Variations on the adult indicate that the latter may at times arise from the N. suræ lateralis.

4. Nn. Peronei.

The superficial and deep branches of the peroneal nerve may readily be distinguished in Embryo CXLIV (Plate IV, Fig. 2) but the terminal cutaneous rami are not clearly developed. In Embryo XXII (Plate V, Fig. 2) these cutaneous rami may be followed over the dorsum of the limb-bud. They seem to have a simple direct growth toward the areas they are subsequently to supply.

5. N. Tibialis.

The terminal cutaneous branches of this nerve likewise cannot be distinguished in Embryo CXLIV (Plate IV, Fig. 1) but are clearly to be made out in Embryo XXII (Plate V, Fig. 1). Like those of the peroneal nerve they seem to have a fairly direct path of growth. From the dorsal surface of the tibial nerve the calcaneal branch may be seen taking its rise.

b. Variation.

1. N. Cutaneus Femoris Posterior (small sciatic).

This nerve shows considerable variation in origin and distribution.

a. ORIGIN FROM SACRAL PLEXUS.—As stated in most text-books, it commonly arises from the 26th, 27th, and 28th spinal nerves (1st, 2d, and 3d sacral). It may, however, arise from the (25th) and 26th; (25th), 26th, and 27th; 26th and 27th; (25th), 26th, 27th, and 28th; 27th and 28th, or from the (27th), 28th, and 29th spinal nerves. In table XII the frequency of these various modes of origin is shown. It is possible that in some of the instances tabulated the origin of the posterior cutaneous nerve was more extensive than the tabulation charts show, because in tracing back a nerve to the spinal roots from which it springs, small bundles of nerve fibres are sometimes torn. It is believed, however, that the chief roots of the nerve are indicated in the charts from which the table was made. It is to be noted that while an anterior position of the roots of the posterior cutaneous nerve of the thigh usually corresponds with an anterior position of the lumbo-sacral plexus, this correspondence is not perfect.

In these variations no special relations to race, sex, or side of body are apparent in the charts tabulated.

According to A. Soulie (Poirier and Charpy, 01), the branch from the 2d sacral nerve to the posterior cutaneous nerve is constant while branches from the 1st and 3d are less constant and occasionally one may find a branch from the 4th sacral.

There is great variation in the extent to which the roots and the trunk of the posterior cutaneous nerve are bound up with neighboring nerve trunks, such as the inferior gluteal, sciatic and pudic nerves. As a rule, however, the union between these trunks is so slight that they may be readily separated. It has not seemed, therefore, worth while to attempt a tabulation of relations of this sort. Not infrequently (in about 25% of instances) the perineal rami arise from a trunk which springs by special roots from the plexus. See table XIII.

b. DISTRIBUTION.—*Gluteal branches (nn. clunium inferiores).* These most commonly arise from a single branch given off from the posterior cutaneous nerve while this lies beneath the gluteus maximus muscle. This branch may pass up over the lower margin of the muscle before dividing into terminal rami (31 out of 77 instances) or it may divide into two or more rami which pass out under and turn back over the muscle in several

TABLE XII.

Type of Plexus from which the N. Cut. Fem. Post. arises.				Frequency of Origin of N. Cut. Femoris Post. from:							
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Nn. Sp. (XXV) XXVI	Nn. Sp. XXV XXVI XXVII	Nn. Sp. (XXV) XXVI XXVII	Nn. Sp. (XXV) XXVI XXVII XXVIII	Nn. Sp. XXVI XXVII XXVIII	Nn. Sp. (XXVI) XXVII XXVIII	Nn. Sp. (XXVII) XXVIII XXIX	Total Number.
Ant.	A	XXIV	XXVI	1							1
	B	XXIV	XXVII		3	11		5	4		23
	C	XXIV chiefly to sacral plexus	XXVIII			14	2	25	20		61
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII		3	22		31	37	5	98
Post.	E	(XXIV) XXV	XXVIII			4	1	5	6	2	18
	F	XXIV	XXIX					4	4	6	14
	G	(XXIV) XXV	XXIX					6	5	5	16
Total Number				1	6	51	3	76	76	18	231

areas. In 33 out of 77 instances two such rami were found (Plate VII, Fig. 2); in 9, three; in 2, four; and in 2, five.

Perineal branches.—As a rule the perineal rami arise from a single trunk which branches from the posterior cutaneous nerve (70 out of 94 instances) or arises separately from the plexus and runs a parallel independent course (24 out of 94 instances). In the latter case a small anastomosing twig usually passes from the perineal branch to the main trunk of the posterior cutaneous. A separate perineal branch occurs much more frequently in the unusual forms of plexus than in the usual, as shown by the above table.

TABLE XIII.

No. of subject.	Race, sex, and side of body.	Type of plexus. See Table XII.	Origin of N. Cut. Fem. Post.	Origin of N. Perinealis.	Vertebral Column.
218	B, M, R	B	XXV, XXVI, XXVII	XXVI, XXVII	11t, 5l, 5s, 4c
269	W, M, L	B	XXVI, XXVII	XXVII	12th rib, short
395	B, F, R	B	XXVI, XXVII	XXVII	12t, 5l, 4s, 4co
607	W, M, L	B	?	?	12th rib, short
649	B, F, R	B	XXVI, XXII	XXVI, XXVII	12t, 4l, 5s, 3co
243	W, M, L	C	XXVI, XXVII, XXVIII	XXVII, XXVIII	12th rib, short
301	B, F, L	C	XXVI, XXVII, XXVIII	XXVII, XXVIII	12th rib, short
282	W, M, L	C	XXVI, XXVII, XXVIII	XXVII, XXVIII	12t, 5l, 6s, 2co
218	B, M, L	C	XXVII, XXVIII	XXVII, XXVIII	11t, 5l, 5s, 4co
476	B. M, R	C	XXVII, XXVIII	XXVII, XXVIII	12th rib, short
423	B, M, R	C	XXVI, XXVII	XXVII, XXVIII	11t, 5l, 6t, 2co
583	W, M, L	D	XXVI, XXVII, XXVIII	XXVII, XXVIII	Normal
405	W, M, R	D	XXVI, XXVII, XXVIII	XXVII, XXVIII	"
303	W, F, R	D	XXVI, XXVII, XXVIII	XXVII, XXVIII	"
211	B, M, L	D	XXVI, XXVII, XXVIII	XXVII, XXVIII	"
152	B, F, L	D	XXVII, XXVIII	XXVII, XXVIII	"
547	B, M, L	E	XXVI, XXVII, XXVIII	XXVII, XXVIII	"
108	B, F, L	E	XXVI, XXVII, XXVIII	XXVII, XXVIII	"
108	B, F, R	E	XXVII, XXVIII	XXVII, XXVIII	"
612	B, F, R	E	XXVII, XXVIII	XXVII, XXVIII	12t, 6l, 5s, 3co
282	W, M, R	F	XXVIII, XXIX	XXVIII, XXIX	12t, 5l, 6s, 2co
42	B, M, R	G	XXVI, XXVII, XXVIII	XXVII, XXVIII	13t, 5l, 4s, 3co
247	W, M, L	G	XXVII, XXVIII, XXIX	XXVII, XXVIII, XXIX	12t, 5l, 6s, 2co
418	B, M, L	G	XXVI, XXVII	XXVII, XXVIII, XXIX	Normal

Frequently the perineal branch arises from the posterior cutaneous nerve in common with a large branch which passes to supply the medial surface of the leg (31 out of 110 instances). A branch of considerable size may arise in common with the perineal nerve and then pass upwards to be distributed over the medial margin of the gluteal muscle (15 out of 110 instances). Two separate perineal branches are given off from the posterior cutaneous nerve infrequently (5 out of 110 instances). Rarely the perineal branch gives off rami both for the buttock and for the medial surface of the leg (2 out of 110 instances).

Occasionally a root containing fibres destined mainly for the perineal nerve arises separately from the plexus, passes through the sacrotuberosal ligament and then joins the posterior cutaneous nerve immediately before this gives off the perineal branch (2 out of 94 instances).

Femoro-popliteal branches.—As a rule several branches arise from the posterior cutaneous nerve as it passes down the back of the thigh. Those on the medial side of the nerve are the better developed. In the most common form of distribution (67 out of 94 instances) three or four branches arise from the medial side of the nerve between where it emerges from under the gluteus maximus muscle and the popliteal space. On the lateral side two to three branches are commonly given off. Another common type of distribution is one in which the upper half or two-thirds of the medial posterior surface of the thigh is supplied by a branch which arises in common with the perineal branch of the posterior cutaneous nerve (24 out of 94 instances). This condition was found most frequently associated with an anterior type of plexus (type A, 1; type B, 4; type C, 9; type D, 5; type F, 1; type G, 1).

In one instance soon after the posterior cutaneous nerve emerged from under the gluteus maximus muscle a long medial branch arose to supply the inner side of the leg as far as the knee, and a long lateral branch to supply a corresponding lateral area. This was found on the right side of a subject with a normal, type D, plexus and a normal vertebral column. In another instance the posterior cutaneous after it emerged divided into two branches which extended to the knee and in addition a long medial branch arose from the perineal division of the nerve. This was found on the right side of a subject with a posterior, type G, form of plexus and 13 thoracic, 5 lumbar, 4 sacral and 3 coccygeal vertebræ. In one instance the upper medial portion of the thigh was supplied by a nerve arising from the perineal branch of the pudic nerve. This was found on the right side of a subject with a normal, type D, plexus and a normal skeleton.

Terminal branches.—The absence of a posterior cutaneous nerve has been reported, but this condition I have not seen. In one instance (308-R) the terminal branches could not be followed as far as the knee by gross dissection. In the great majority of instances (81 out of 110) the terminal branches could be readily followed into the upper third of the back of the leg. But rarely was there found the branch described in Poirier and Charpy's anatomy as extending to anastomose with the sural nerve. In 21 out of 110 instances the chief terminal branch extended on the medial side of the leg well into the middle third of the back of the leg. In 8 instances out of 110 the chief terminal branch could be followed nearly to the medial malleolus. This extensive distribution of the posterior cutaneous nerve of the thigh was found twice associated with the B type of plexus, once with the C type, four times with the D type, and once with an F type. No obvious relation therefore exists between the extent of distribution of the posterior cutaneous nerve and the form of the plexus from which it springs. This also is true of relations to the origin of the nerve from the sacral plexus and to race, sex, and side of body.

2. Perforating Cutaneous Nerve.

A distinct perforating cutaneous nerve arising from the 2d and 3d sacral nerves and passing through the sacro-tuberosal ligament to supply the skin over the medial margin of the buttock was found in but 8 instances out of 94. To what extent this small percentage is to be attributed to lack of sufficient care in dissection cannot at present be stated. Only the better charts have been used in this tabulation. Eisler found the nerve in 22 out of 34 instances.

In one instance the perineal branch of the posterior cutaneous passed beneath the sacro-tuberosal ligament on the way to its destination.

3. Cutaneous Branches of the Peroneal Nerve.

a. N. Cutaneus surae lateralis.—This nerve arises in the popliteal space and runs down over the lateral head of the gastrocnemius to supply the lateral cutaneous area of the leg and usually sends a branch to anastomose with the n. cutaneus suræ medialis to form the sural (external saphenous) nerve. This form of distribution was found in 38 out of 76 instances. In 30 out of 76 instances the communicating branch to the n. surae medialis was not found. In 7 out of 76 instances two branches arose from the peroneal nerve in the popliteal space. One of these supplied the side of the leg below the knee; the other supplied the back of the leg and sent a branch of communication to the n. surae medialis. This mode of distribution is described as the normal by many authors. In one instance the peroneal nerve gave rise to the sural (external saphenous) while the tibial furnished a cutaneous branch for the skin over the calf. In five other instances the n. cutaneus surae medialis gave rise to a cutaneous branch for the supply of the upper part of the calf. The extent of distribution of the various branches mentioned is inversely proportional to the extent of distribution of the posterior cutaneous nerve of the thigh and the saphenous and obturator nerves. Great individual variations are found.

b. N. Cutaneus peronei femoralis.—In one instance in which the tibial and peroneal nerves arose separately from the plexus the peroneal nerve passed between two divisions of the pyriformis muscle, then lateral to a fasciculus of the short head of the biceps which arose from the proximal end of the gluteal tuberosity. It crossed the antero-lateral surface of this fasciculus, and then between it and the main portion of the muscle to its usual position in the thigh. Near the middle of the shaft of the femur it gave off a branch which passed through the short head of the biceps to the side of the thigh where it divided into ascending and descending branches and supplied a large area between the territories of the n. cutaneus femoris lateralis and the n. cutaneus femoris posterior. This abnormal cutaneous nerve I have not found previously described. It resembles somewhat a nerve in the orang described by Klaatsch, **02**.

c. Nn. Cutanei dorsales pedis.—In the great majority of instances the n. cutaneus peroneus superficialis divides into two main terminal branches just above the ankle. One of these, the n. cutaneus dorsalis medialis, passes directly to the outer side of the big toe, giving off on its way a branch to supply the contiguous sides of the 2d and 3d toes and small branches to anastomose with those branches of the n. peroneus profundus which supply the contiguous sides of the first and second toes. The other, the n. cutaneus dorsalis intermedialis, passes down to supply the contiguous sides of the third and fourth, and fourth and fifth toes. This general mode of distribution was found in 44 instances out of 111 (about 40%). In two of the 44 cases above mentioned the sural nerve failed to extend to the little toe and a special branch arose from the n. cutaneus dorsalis intermedialis to supply the outer side of the little toe. Variations in the cutaneous nerve supply of the dorsum of the foot occurred with the following frequency.

In 17 instances the n. cutaneus dorsalis lateralis (external saphenous) supplied the place of the n. cutaneus dorsalis intermedius and sent branches to the contiguous sides of the 4th and 5th, and 3d and 4th toes. In two instances a branch from the n. cutaneus dorsalis lateralis anastomosed with the n. cutaneus dorsalis intermedialis and the combined nerve then divided into branches for the contiguous sides of the 4th and 5th, 3d and 4th, and 2d and 3d toes. With the branch to the last a ramus from the n. cutaneus dorsalis medialis anastomosed. In 15 instances a branch from the n. cutaneus dorsalis lateralis anastomosed with one from the n. cutaneus dorsalis intermedius and the branches arising from the combined nerve supplied the contiguous sides of the 3d and 4th, and 4th and 5th toes. In two instances the n. cutaneus dorsalis lateralis sent a branch to anastomose with one from the n. cutaneus dorsalis intermedialis going to the 2d and 3d toes. In five instances the n. cutaneus dorsalis lateralis supplied the outer side of the little toe and the contiguous sides of the 4th and 5th toes. In 10 instances a branch from the n. cutaneus dorsalis lateralis anastomosed with the branch from the n. cutaneus dorsalis intermedialis sent to supply the contiguous sides of the 4th and 5th toes. In four instances the n. cutaneus dorsalis intermedialis supplied the contiguous sides of the 2d and 3d, 3d and 4th, and 4th and 5th toes while the n. cutaneus dorsalis medialis supplied the outer side of the first toe and aided in the supply of the contiguous sides of the 1st and 2d toes. In one of these instances the n. cutaneus dorsalis medialis arose in the leg from the n. peroneus profundus. In five other instances the nerve distribution was similar in nature but an anastomotic branch passed from the n. cutaneus dorsalis medialis to the nerve going to supply the contiguous sides of the 2d and 3d toes. In one of these instances the n. cutaneus dorsalis medialis arose from the n. peroneus profundus nerve and emerged from between the peroneus tertius and the extensor digitorum longus muscles. In two instances the n. cutaneus dorsalis medialis supplied, in addition to its usual territory, the contiguous sides of the 3d and 4th toes; the n. cutaneus dorsalis intermedialis was confined in distribution to the 4th and 5th toes. In one instance the n. peroneus profundus supplied in addition to its usual branches, the chief branches to the medial side of the great toe and the lateral side of the 2d toe.

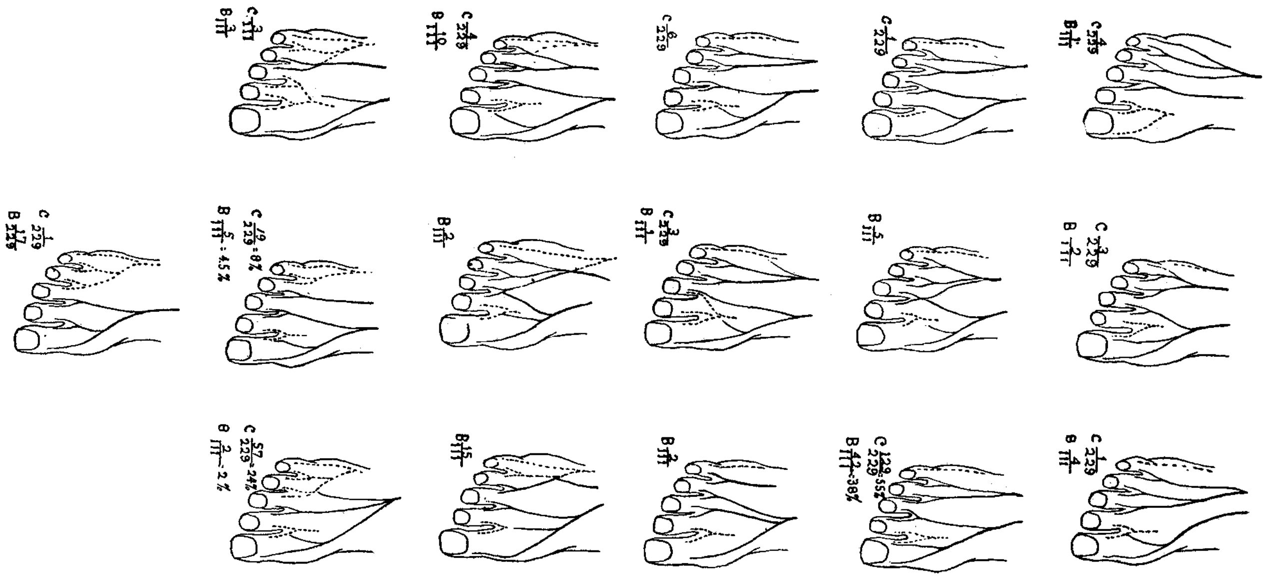

FIG. 1. The diagrams represent various types of distribution of the cutaneous nerves of the back of the foot. The frequency with which the various types of distribution were found by the Committee of Collective Investigation is indicated by *C* followed by a fraction of which the denominator represents the total number of feet tabulated; the frequency with which the various types occurred in the feet studied by the writer is indicated by *B* followed by a fraction of which the denominator is 111, the total number of feet tabulated.

In another instance it sent a branch to aid in the supply of the contiguous sides of the 2d and 3d toes and in three instances it formed the chief source of supply for the contiguous sides of the 1st and 2d, and 2d and 3d toes.

In two instances, as we have seen above, the n. cutaneus dorsalis medialis arose in the leg from the n. peroneus profundus. In five instances the n. cutaneus dorsalis medialis arose from the peroneal nerve soon after this passed beneath the head of the peroneus longus muscle. The nerve then took a course somewhat independent of that of the n. cutaneus dorsalis intermedialis.

The very great variation found in the distribution of the nerves of the dorsum of the foot seems not to be associated with such factors as age, sex, race, side of body or relative position of the lumbo-sacral plexus. Rough estimation of these factors have given so little promise of positive results that I omit here a detailed tabulation.

For the sake of comparison the following data obtained by the Committee of Collective Investigation of Great Britain and Ireland[4] are appended. Our results agree with regard to the condition most frequently observed, although I found this condition in but 40% of the feet examined while the committee found it in 55%. In those instances in which the n. cutaneus dorsalis lateralis served wholly or in part to supply the contiguous sides of the 3d and 4th, and 4th and 5th toes, although the total frequency is approximately the same there is considerable difference in frequency in variation in the nature of the relations between the n. cutaneus dorsalis intermedialis and lateralis.

4. Cutaneous Branches of the Tibial Nerve.

The nearly constant origin of the chief root of the n. suralis from the tibial nerve and the account of it which I have given above in treating of the cutaneous branches of the peroneal nerve render further description here unnecessary. The rami calcanei mediales vary somewhat in extent of distribution but offer no features of special interest. The cutaneous supply of the toes is singularly constant, the main variation being found in the extent of development of a branch from the n. plantaris medialis to the nerve supplying the 4th and 5th toes, or from the n. plantaris lateralis to the nerve supplying the 3d and 4th toes.

In 69 out of 87 instances no well developed branch of this nature

[4] Journal of Anatomy and Physiology, Vo. 26, 1892, p. 89.

was found. In eight instances a branch passed from the n. plantaris medialis to the nerve to the 4th and 5th toes. In seven instances a branch passed from the n. plantaris lateralis to the nerve supplying the contiguous sides of the 3d and 4th toes. In two instances the n. plantaris lateralis furnished the chief supply of the contiguous sides of the 3d and 4th as well as of the 4th and 5th toes. In one instance the n. plantaris medialis supplied the contiguous sides of all the toes.

VI. CUTANEOUS BRANCHES TO THE INFERIOR EXTREMITY FROM THE DORSAL DIVISIONS OF THE SPINAL NERVES.

In Embryo CXLIV, length 14 mm. (Plate IV, Fig. 2), the lateral branches of the dorsal divisions of the last five or six thoracic and the first three lumbar nerves may be followed to the subcutaneous tissue. They take at this period a somewhat simple course and have a distinctly segmental arrangement. The dorsal divisions of the fourth and fifth lumbar and of the sacral and coccygeal nerves are connected by anastomosing branches. From these nerves rami may be followed toward, but cannot be followed distinctly into the skin.

In Embryo XXII, length 20 mm. (Plate V, Fig. 1), the lateral branches of the first three lumbar nerves may be followed distally to the base of the limb where they terminate over the proximal margin of the iliac crest. The branches of the second and third lumbar nerves are connected at this period by anastomoses, although the plexiform arrangement characteristic of the adult is not yet apparent. In subsequent development these nerves extend over the postero-lateral surface of the thigh, nn. clunium superiores. For the variations in origin of these nerves in the adult, see Bardeen and Elting, 01.

The lateral branches which arise from the dorsal divisions of the first three sacral nerves anastomose and from them in Embryo XXII two delicate branches may be traced toward the skin, nn. clunium mediales. There is considerable variation in these nerves in the adult, but I have not sufficient data on which to base a statistical study of the subject.

VII. SUMMARY AND GENERAL CONCLUSIONS.

The cutaneous nerves of the posterior limb in the embryo first approach the anterior, posterior and distal margin of the limb-bud and from these areas send branches of distribution over the medial (ventral) and lateral (dorsal) surfaces of the developing limb. This method of development may be recognized in the adult. The chief nerve trunks approach the fascia in a line which corresponds fairly closely with the primary margins of the limb. The posterior cutaneous nerve of the thigh and the sural nerve are both shifted over the dorsal (primary medial) surface of the thigh during development, but none the less distribute their cutaneous branches from a line which corresponds to some extent to the posterior margin of the limb-bud. The line along which the anterior cutaneous nerves of the thigh reach the fascia likewise corresponds with the original anterior margin of the limb-bud. In Plate VII, Figs. 1 and 2, a schematic diagram is given to illustrate the mode of distribution of the cutaneous nerves of the adult limb. So far as possible each main nerve is represented approximately as it occurs with the greatest frequency.

This mode of distribution of the cutaneous nerves from the region of the margin of the limb-bud is probably due to a differentiation of function, the musculature of the limb-bud being differentiated on the medial and lateral surfaces and the margins serving for the primary development of the cutaneous areas. In sharks the cutaneous branches supplied to the dorsal and ventral surface of the fin extend upwards in numerous branches between the muscle bundles. In most higher forms a distribution of cutaneous nerves from the margins of the limb is well marked, although numerous exceptions occur.

It is of interest to inquire whether or not anything may be found during embryonic development to account for the segmental distribution of the nerves of the limb described on the basis of physiological and clinical evidence by Head, Sherrington, Bolk and a large number of other investigators. It is quite certain that no evident dermatomes associated with specific spinal nerves are to be found in the embryo. It seems probable that the cutaneous nerve fibres contained in a given spinal nerve find a path of least resistance toward the marginal area lying most directly opposite and that to any given area one or two nerves may thus serve to furnish the bulk of the fibres. In Figs. 2 and 3 I have shown diagrammatically the approximate marginal areas to which each spinal nerve most directly contributes in the embryo. Subsequently these areas become extended by the growth of branches from the margins of the limb over the medial and lateral surfaces.

The great variation in the distribution of the nerves supplied to different areas can be best accounted for, I think, by assuming that the nerves grow as plants grow: in part they are guided in their course by definite paths, as climbing plants may be guided by strings, but where definite paths are not offered great variation in the distribution of the cutaneous rami may be seen. Extensive development of one nerve tends to retard its neighbors, lack of development tends to excite them to more active growth.

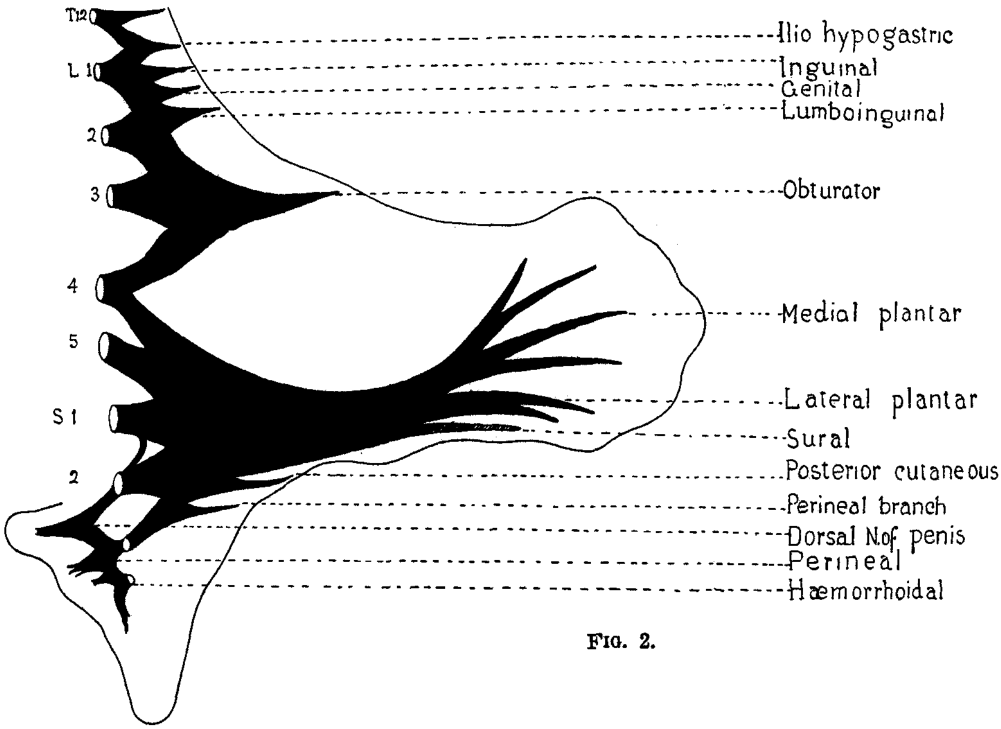

FIG. 2.

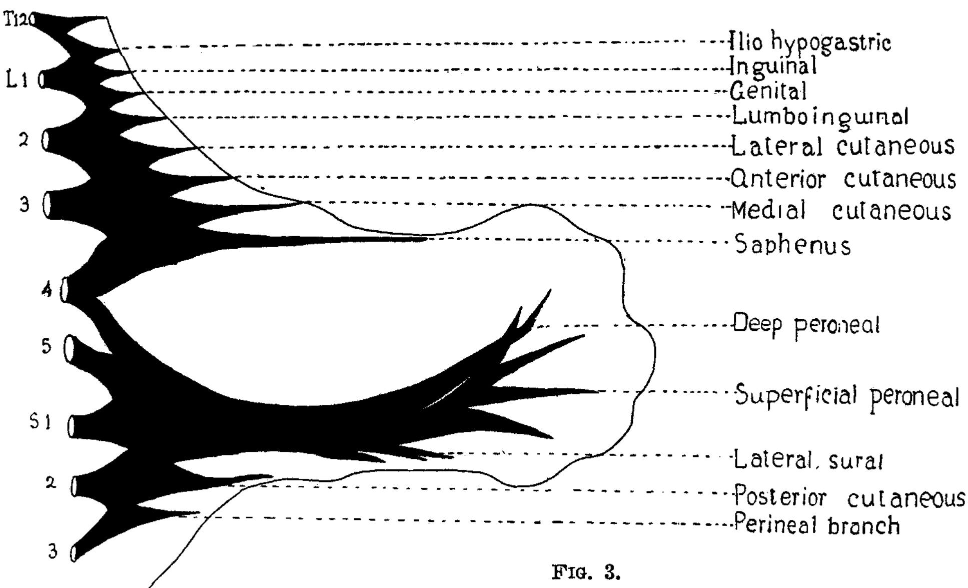

FIG. 3.

FIG. 2. Diagram of the early course of growth of the cutaneous nerves arising from the ventral side of the lumbo-sacral plexus.

FIG. 3. Diagram of the early course of growth of the cutaneous nerves arising from the dorsal side of the lumbo-sacral plexus.

C. DEVELOPMENT OF THE MUSCULATURE AND DEVELOPMENT AND VARIATION IN DISTRIBUTION OF THE NERVES TO THE MUSCLES OF THE INFERIOR EXTREMITY.

I. FEMORAL GROUP.

a. Embryonic Development.

1. General Features.

Soon after the femoral nerve begins to extend into the base of the limb differentiation of the femoral musculature commences. At about the center of the shaft of the femur a mass of tissue may be distinguished as the anlage of the quadriceps muscle (Plate III, Fig. 2). Into a cleft in this tissue the main trunk of the femoral nerve extends and gives off branches for each of the main divisions of the quadriceps. Anterior to this an ill defined mass of tissue may be distinguished as the anlage of the sartorius muscle. A special nerve is given to this. About the main trunk of the nerve as it passes over the region of the acetabulum a mass of tissue represents the anlage of the iliopsoas and possibly also the pectineus muscles. In this region the lateral and anterior cutaneous nerves of the thigh pass toward the ectoderm. Distalward the anlage of the saphenous nerve may be seen.

In a slightly older embryo (Plate VI, Fig. 1) the muscle differentiation is much further advanced. The sartorius muscle extends well toward the blastema of the ilium and toward the medial surface of the proximal end of the tibia. Definite tendons are not, however, developed. The nerve to the sartorius extends a short distance distally within the substance of the muscle. The iliopsoas muscle is likewise further differentiated and has extended more toward the vertebral column. The pectineus muscle has become distinct and to it runs a branch from the femoral nerve.

The quadriceps muscle begins to show definite differentiation. Tendons of attachment are not, however, clearly differentiated. The various branches of the nerve to this muscle, Fig. a, have extended further into the body of the muscle. They follow in this course developing lines of cleavage of the muscle into its constituted portions.

The various cutaneous nerves mentioned above have extended considerably in length and in addition there are two medial cutaneous branches. These run toward the skin in the dense fascia which now separates the obturator from the femoral group of musculature.

In an embryo of 20 mm. (Plate VI, Figs. 2 and b) the individual muscles of this group are clearly demarkated. The figures illustrate sufficiently clearly the position of the various nerves and muscles. The muscles are all attached to the skeletal apparatus by distinct tendons. The main nerve trunks run in the connective tissue which serves to separate the various muscles from one another and to divide each muscle into its constituent parts.

2. Individual Muscles.

Iliopsoas muscle (Plate VI, Figs. 1 and 2). The iliopsoas muscle arises from a mass of tissue which embraces the femoral nerve as it passes into the limb-bud. In subsequent development the iliacus muscle spreads out over the ilium, the psoas major muscle extends up along the course of the roots of the femoral nerve to form its attachments to the vertebral column, and in close union the two muscles extend distally to be attached to the lesser trochanter. The psoas minor seems to be differentiated from the psoas major muscle anlage, but this is uncertain.

To the psoas major as it is developed toward the vertebral column branches are given from the femoral nerve or its roots of origin as far anterior as the 22d spinal (2d lumbar) and occasionally as far as the 21st spinal nerve. These branches extend in between the developing bundles of the muscle and have a complex, extensive distribution.

The nerve to the psoas minor muscle frequently arises from the trunk of the genito-femoral or from the lumbo-inguinal branch of this nerve.

To the iliacus muscle as it spreads out over the surface of the ilium several branches, often united in a plexiform manner, are given. These branches pass across or near the superficial surface of the muscle about midway between the crest of the ilium and the combined iliopsoas tendon. Special nerve branches are likewise usually distributed from the main trunk of the femoral nerve to the fleshy portion of the muscle as it passes over the acetabulum and the head of the femur.

There is considerable variation in the exact mode of distribution of the nerves mentioned. Frequently a special layer of the iliacus covers the nerves distributed to this muscle. The trunk of the femoral nerve may be divided by one or more bundles of the iliopsoas muscle. The variations in the distribution of the nerves to the iliopsoas muscle do not readily lend themselves to statistical treatment and hence this is here omitted.

The iliopsoas is probably represented in the urodela and reptiles by the posterior portion of the pubi-ischio-femoralis internus and the anterior margin of the ilio-femoralis. The psoas muscle, which is phylogenetically younger than the iliacus, is by many (see Pardi, 02) considered to be a prevertebral muscle belonging primitively to the trunk musculature. Its ontogenetic development from an anlage common to it and the iliacus muscle indicates that it should be placed with the intrinsic musculature of the limb.

The phylogenetic development of the psoas minor, on the other hand, is somewhat uncertain. It may be derived from the trunk musculature. This is perhaps indicated by its frequent innervation through a branch from the genitofemoral nerve, while the psoas major is innervated by branches which arise from the femoral nerve or its roots. Its embryonic origin should be studied in some of those forms in which the adult muscle is highly developed.

In mammals with an ilium triangular in cross-section the iliacus lies externally, a position which corresponds with the situation in which its anlage appears in the human embryo (Lubsen). In those forms in which the iliac blade is developed the muscle comes to have an internal position.

The variations of the iliopsoas in man are chiefly those of a greater or less independence of the two muscles composing it and a greater or less specialization of fasciculi in either. There are also slight variations in the origin and attachment of the muscles. The very inconstant psoas minor varies chiefly in the extent of its development. The inferior insertion may take place into the iliac fascia, the inguinal ligament, the femur between the small trochanter and the head, or together with the iliopsoas into the small trochanter (Le Double). Fasciculi may unite the psoas major and the psoas minor. These variations may indicate a common origin of the two muscles.

Pectineus (Plate VI, Figs. 1 and 2). In an embryo 11 mm. long the anlage of the pectineus is not distinct. It may be represented in those portions of the iliopsoas and the obturator muscle anlages which lie nearest the region in which the pectineus will be developed. Gräfenberg, 04, describes in the region immediately distal to the superior pubic ramus a union of a branch of the obturator nerve with a branch of the femoral before the muscle anlage of the pectineus appears. This I have not found in the embryos of a corresponding stage which I have examined. Gräfenberg describes the pectineus anlage when it first appears as fused proximally with the iliopsoas anlage. It is probable that the superficial portion of the pectineus is thus at one stage usually fused with the iliopsoas anlage. In the youngest embryo in which I have found it distinct it is, however, separated by a small interval from the iliopsoas muscle mass (Plate II, Fig. 3) and seems more closely associated with the anlage of the adductor longus.

In this 14 mm. embryo (Plate VI, Fig. 1) the anlage of the muscle is closely applied to the pubic blastema and can be followed from the body of the pubis to the blastema of the femur. Into it a nerve branch may be traced from the femoral nerve. Dorsal to the obturator nerve in the obturator foramen is a mass of tissue closely associated with the anlage of the obturator externus on the one side and with that of the pectineus on the other. No definite nerve branch can be traced into it from the obturator nerve, but it seems not improbable that this represents the anlage of that portion of the pectineus which is supplied by the obturator nerve in many individuals.

In an embryo of 20 mm. (Plate VI, Fig. 2), the pectineus occupies a position which corresponds with that of the adult muscle. The femoral nerve gives to it a large branch which passes at first across its outer surface about midway between its tendons of origin and insertion. I have been unable to trace a branch to it from the obturator nerve.

In the adult, as is well known, the nerve supply of the pectineus is usually through a branch from the femoral but not infrequently also from the obturator or the accessory obturator nerve. Paterson (91, 95) has shown that in man the muscle is often divisible into a superficial portion supplied by the femoral nerve and a deep portion supplied by the obturator nerve. Similar conditions are normal in some of the lower mammals, while in others the muscle may be supplied by the femoral nerve only or the obturator nerve only. The dorsal or femoral portion is probably derived from an anlage intimately associated with the iliopsoas anlage, the ventral portion from the anlage of the obturator externus. W. Leche has shown that in many mammals there is separated from the obturator externus a muscle which he calls the obturator intermedius and that in those forms in which the pectineus is supplied by the obturator nerve it is probable that this obturator intermedius has entered into the formation of the anlage of the pectineus.

The pectineus of the mammals is, together with the iliopsoas, probably represented in the urodeles and reptiles by the pubo-ischio-femoralis internus. This, like the pectineus, may be supplied wholly by the femoral, or in part also by branches from the obturator. The accessory obturator nerve, which in about 10% of bodies innervates, or helps to innervate, the pectineus muscle in man, indicates, perhaps, that the division of the limb musculature in man into dorsal and ventral portions is not strictly to be traced in the respective territories of the femoral and obturator nerves. Nerve elements belonging to the ventral territory may be normally bound up in the femoral nerve in those branches which supply the pectineus muscle. When those branches become isolated we have the accessory obturator nerve (see Eisler, 92).

There is considerable variation in the extent of separation of the pectineus into two portions in the human body. The muscle is very frequently fused with the adductor longus. Occasionally a fasciculus passes from the iliacus to the pectineus or between the pectineus and the obturator externus.

Sartorius.—The sartorius develops from an anlage not directly fused with that of the quadriceps. Gräfenberg has described a fusion near the ilium of the proximal ends of the anlages of the rectus muscle and the sartorius with that of the iliacus. In those embryos I have studied in which these anlages are beginning to appear the quadriceps anlage is quite distinct from that of both the sartorius and iliacus. The upper limit of the sartorius anlage approaches closely, however, the iliacus anlage. The first well marked differentiation of the sartorius anlage takes place in a region corresponding with that in which the nerves enter the muscle in the adult, Plate VI, Fig. 1. From here the differentiation of the muscle extends towards its iliac and tibial attachments. The embryonic muscle is proportionately larger than the adult muscle and forms more extensive tibial attachment. (Plate VI, Fig. 2, Plate VIII, Fig. 2).

Simultaneously with the differentiation of the muscle, branches extend into it from the femoral nerve. These branches are more or less intimately bound up with the anterior (middle) cutaneous nerve. As a rule there are two main branches, one of which serves to supply chiefly the lateral and proximal, the other the distal and medial, portion of the muscle. For the distribution of branches in the adult, see Frohse, 98.

In the urodeles the sartorius does not seem to be represented. In reptiles it is probably represented by the ambiens or the pubi-tibialis or both. The ambiens arises either from the ilium, as in the crocodile, or from the pubis, as in most forms. Its tendon passes to the front of the leg. It is an extensor of the knee. The tendon of the pubi-tibialis passes to the back of the leg. It is a flexor of the knee (Gadow, 82). It is probably not homologous with the pubi-tibialis of urodeles, which is innervated by the sciatic nerve and is a differentiated portion of the pubi-ischio-tibialis.

In the monotremes and insectivora the proximal attachment of the sartorius is in the neighborhood of the ilio-pectineal eminence. In the marsupials, prosimians, and primates it takes place into the ventral margin of the ilium. In other mammals it may take place in either place or from an intermediate region, from the ilio-pectineal fascia, the tendon of the psoas minor, the inguinal ligament, etc. (W. Leche). The insertion takes place into the medial side of the tibia or into the crural fascia. It may be fused with the gracilis at its insertion. It may be double (dog—Ellenberger and Baum). The partial longitudinal splitting of the muscle found in the dog and other carnivora and as a variation in man may possibly indicate a primitive relationship to two muscles, the ambiens and the pubi-tibialis of reptiles. There seems to be nothing either in the phylogenetic or the ontogenetic history of the muscle to account for the transverse tendinous inscription or tendon which occasionally is found dividing the muscle into two parts.

Quadriceps Femoris Muscle, Plate VI. *Rectus Femoris.*—This muscle is developed from the quadriceps muscle mass by gradual differentiation. Its tendon of attachment to the anterior inferior iliac spine is developed later than that to the supra-acetabular groove, Roger Williams, 78, and is a consequence of the development of the iliac blade, Le Double, 97. As a rule the nerve to the muscle divides into two main branches, one of which goes chiefly to the medial half, the other chiefly to the lateral half of the muscle. The main trunk of the former, which enters about a third of the distance from the anterior extremity of the muscle, may be followed for a considerable distance toward the distal extremity of the muscle; the main trunk of the latter, which enters more anteriorly, extends a less distance distally and has a recurrent branch which extends toward the proximal extremity of the muscle. This branch has been followed to the iliac insertion of the muscle and has been reported as extending to the M tensor fasciæ latæ. This last condition I have never seen.

Vastus Lateralis.—This muscle is differentiated from the quadriceps muscle mass by the development of septa between it and the vastus intermedius. The muscle is usually composed of two distinct layers. an outer and an inner, separated by fascia containing nerves and blood vessels. Often the inner layer is further partially subdivided into two sheets by fascia in which nerves and blood vessels run. Commonly the nerve to the vastus lateralis divides into three branches of which one runs on the inner surface of the outer layer of the muscle, the second betwen the two sheets of the inner layer, and the third passes through the inner sheet of the inner layer to be distributed to the most lateral part of the vastus intermedius muscle. The larger intrinsic nerve trunks cross the fasciculi of the muscle sheets and about midway between the extremities of the fasciculi.

Vastus Intermedius.—This is differentiated from the quadriceps muscle mass at the time of the ingrowth of the main nerves and blood vessels of the muscle. The muscle is composed of muscle lamellæ concentrically arranged about the diaphysis of the femur. The lowest, most distal, and most completely separated of these lamellæ is the subcrureus muscle. Several nerves are distributed to the muscle. To the lateral region a branch from the nerve to the vastus lateralis usually extends. A special ramus from the femoral nerve generally passes to the middle portion, and from the nerve to the vastus medialis several branches are often given to the medial side of the muscle.

Vastus Medialis.—This muscle is differentiated from the quadriceps muscle mass by the formation of a connective tissue sheet between it and the vastus intermedius. Its nerve of supply runs along on the medial surface of the muscle sending branches from time to time into its substance and finally near Hunter's canal the terminal twigs of the nerve enter the muscle. The nerve is often more or less bound up with the saphenous nerve. The rami which enter the muscle extend at first across the fibre-bundles of the muscle sheet about midway between the extremities of the fibre-bundles.

The rectus is phylogenetically the oldest part of the quadriceps. In the urodela, where it is represented by that part of the ilio-tibialis supplied by the femoral nerve, there seem to be no muscles which correspond with the vasti but these are differentiated in the reptiles and the higher forms. In some of the mammals the three vasti of the muscle are more or less fused. In man the chief variations found in the quadriceps result from a greater or less division of the primitive extensor mass into individualized parts.

b. Nerve Variation.

1. Variation in Origin of the Femoral Nerve.

The femoral nerve in the great majority of instances arises in the main from the 22d, 23d, and 24th spinal (2d, 3d, and 4th lumbar) nerves. There is, however, considerable variation in the size of the nerve bundles derived from the 22d and 24th spinal nerves. The 21st spinal nerve usually contributes some fibres, and the 20th and 25th spinal nerves occasionally do so. In Table XIV there is shown the frequency with which certain root origins of the femoral nerve were found and the relation of these various modes of origin to various types of plexuses. A study of these variations in relation to race, sex, and side of body has revealed no marked associations, and therefore the tables embracing these data are omitted.

2. Relations of the Branches Springing from the Femoral Nerve to the Nerve Roots.

In considering the cutaneous nerves we have seen reason to believe that the peripheral segmental distribution of the spinal nerves disclosed by physiological experiments, is due to a directness of growth which a given spinal nerve has toward a given peripheral area so that the nerve can send more fibres into this area than its neighbors can and hence serves in the main to innervate the area. This is also probably true of muscle innervation. In Plate III, Fig. 3, is shown the position of the femoral nerve as it enters the femoral muscle mass in a young embryo. The following diagram shows a cross section of the adult femoral nerve as it passes under the inguinal ligament. The regions occupied by the fibres of the chief motor and sensory branches are outlined, while the approximate areas occupied by the main bulk of the fibres of each spinal nerve are shown by stippling the position occupied by the fibres of the 23d spinal (3d lumbar) nerve. While the diagram is schematic it may serve to illustrate the relation of peripheral to spinal nerves of the femoral

TABLE XIV.

Type of Plexus from which N. Femoralis arises:				Frequency of Origin of N. Femoralis from:						
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Nn. Sp. [XX][5] XXI XXII XXIII XXIV	Nn. Sp. [XX] (XXI) XXII XXIII XXIV	Nn. Sp. [XXI] (XXII) XXIII XXIV	Nn. Sp. (XXII) XXIII XXIV	Nn. Sp. [XXI] (XXII) XXIII XXIV XXV	Nn. Sp. (XXII) XXIII XXIV XXV	Total Number.
Ant.	A	XXIV	XXVI	1						1
	B	XXIV	XXVII		15	5	5			25
	C	XXIV chiefly to sacral plexus	XXVIII	2	42	10	9			63
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII	28		50	26			104
Post.	E	XXIV-XXV or XXV	XXVIII					6	12	18
	F	XXIV	XXIX	3		3	9			15
	G	XXIV-XXV or XXV	XXIX					4	16	20
Total Number				34	57	68	49	10	28	246

[5] The nerves enclosed in brackets contribute fibres to the N. cut. fem. lat. but probably not to other branches of the N. femoralis; those enclosed in parentheses contribute few fibres to the N. femoralis.

group. A truly accurate determination could be made only by sectioning each of the various roots and each of the various nerves of distribution in various plexuses and then following the paths of degeneration.

3. Variation in the Association of the Terminal Branches Arising from the Femoral Nerve.

Soon after the femoral nerve passes under the inguinal ligament it gives rise to the various branches which serve to innervate the skin and muscles of the front of the thigh and the arteries and joints. There

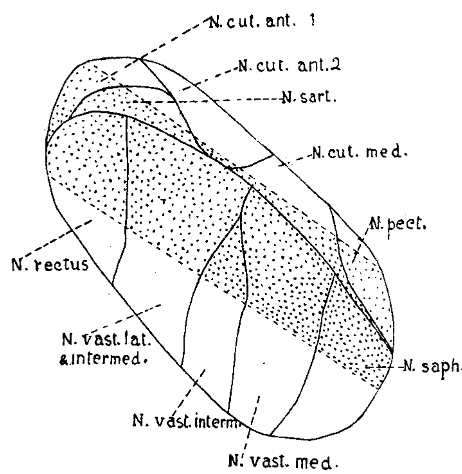

Fig. 4. Diagram to illustrate the approximate regions of the femoral nerve trunk occupied by the fibers which pass out into its muscular and cutaneous branches. The stippled area indicates the position of the main bulk of the fibers of the third lumbar nerve.

is great variation in the association of the nerves going to these various structures. Now one set of nerves may be bound in a common trunk for a part of their course, now another. The association of the various nerves into common trunks is limited, however, to the association of contiguous regions shown in the diagram, Fig. 4. Two or more of these regions may continue for a time to be associated after the femoral trunk has split into branches. Thus the nerves of the rectus femoris muscle are often bound for a part of their course with those of the vastus lateralis or with those of the vastus lateralis and intermedius before the final division takes place. But the nerve to the rectus femoris muscle is never found bound up in a common trunk with the nerve to the vastus medialis or the saphenous nerve unless the nerves to the vastus lateralis and vastus intermedius are also included in the trunk. In the following table the association of nerve branches found in 77 instances is indicated, and at the left is shown the number of times each condition was found. Minor differences are not recognized and no attempt has been made to include the nerves for the arteries and joints. In one instance the femoral nerve was found to furnish a branch to the adductor longus muscle. This is said by Poirier to be a normal condition.

TABLE XV.

ASSOCIATION OF THE BRANCHES OF DISTRIBUTION OF THE FEMORAL NERVE IN COMMON NERVE TRUNKS.

A. No distinct division into two parts.

1 [P] [(S1, S2, S1) (S3, A2) (I)] [(R1, R2) (L1, L2, L3) (C1, C2) (M) (Sph)]
7 [P] [I] [(A1) (A2)] [(S1, S2)] [(R1) (R2) (L1, L2, L3) (C1, C2)] [(M) (Sph)]
1 [a] [(P) (I)] [(S1, S2) (A2)] [(R1, R2) (L1, L2, L3) (C1, C2)] [(M) (Sph)]
1 [P] [(A1) (A2) (S2)] [I] [(R1, R2) (L1, L2, L3) (C1, C2)] [M] [Sph]
1 [X[6]] [(A2, S1) (S2) (I1) (I2)] [(R1, R2) (L1, L2, L3) (C1, C2)] [M] [Sph]
2 [P] [A1, A2, S1, S2, S3] [(R1, R2) (L1, L2) (C1) (C2)] [M] [(Sph) (I)]
3 [P] [(A1, S2) (S2, S3)] [(I1) (I2) (I3)] [R1, R2] [L1, L2, L3] [C1, C2] [M1, M2, M3] [Sph]
1 [P] [I] [S1] [A, S2] [(R1, L1) (R2, L2)] [L3, C1, C2] [M] [Sph]
1 [P] [S1, S2, A] [R1, R2, L1] [C1, C2, M] [I] [Sph]
1 [?] [S1, S2, A1, A2] [(R1, R2) (L1, L2)] [L3] [C1, C2] [M] [Sph, I]
1 [?] [(A1) (S1, S2) (A2, S3)] [(R1, R2) (L1, L2)] [C1, C2] [M1, M2] [Sph, I]
1 [(P) (branch to adductor longus)] [I] [S1, S2, A1, A2] [(R1, R2) (C1, C2) (L1, L2, L3)] [(M) (Sph) (I)]
1 [P1, P2] [(S1) (A, S2, S3) (I)] [(R1, R2) (L1, L2, L3)] [C] [(M) (Sph)]
7 [P] [(A1, S1, A2, S2) (I)] [R1, R2] [(L1, L2, L3) (C1)] [(C2) (M)] [Sph]
4 [(P1, P2) (I)] [S1, S2, A1, A2] [R1, R2] [(L1, L2, L3) (C)] [(M) (Sph)]
1 [X] [S1, S2, A1] [I] [R1, R2, R3] [(L1, L2, L3) (C1, C2)] [(M) (Sph)]
2 [X] [P] [S1, S2, A1, A2] [R1, R2] [(L1, L2) (C)] [M] [(Sph) (I)]
4 [P] [(S1, S2) (A1)] [R1, R2] [L1, L2, L3] [C1, C2] [(M) (Sph) (I)]

[6] From the 23d spinal nerve.

1 [a] [P] [S1, S2] [A] [R1, R2] [(L1, L2, L3) (C1, C2)] [(M) (Sph) (I)]
3 [P] [I] [A1] [S1, S2, A2] [R1, R2, R3] [L1, L2, L3, C1] [(M) (C2) (Sph)]
4 [P1, P2] [I] [S1, S2, A1, A2] [R1, R2] [L1, L2, L3] [C1, C2] [(M) (Sph)]
2 [a] [P] [I] [(S1, S2) (A2)] [R1, R2] [L1, L2, L3] [C1, C2] [(M) (Sph)]
1 [X] [a] [(S1, S2) (A2)] [(L) (I2)] [R1, R2] [L1, L2, L3] [C1, C2] [M] [Sph]
1 [P] [I] [S1, S2, A1] [R1, R2, R3] [L1, L2, L3] [(M1, M2) (C1, C2)] [Sph]
3 [P] [(S1, S2) (A)] [R1, R2] [L1, L2] [C1, C2] [M] [(Sph) (I)]
1 [P] [I] [(S1, S2) (A1, A2) (R1, R2)] [L1, L2] [(C) (M)] [Sph]
11 [P] [I] [S1, S2, A1, A2] [R1, R2] [L1, L2, L3] [C1, C2] [M] [Sph]
3 [a] [P] [S1, S2, A2] [I] [R1, R2] [L1, L2, L3] [C1, C2] [M] [Sph]
2 [a] [X] [P] [S1, S2, A2] [I] [R1, R2] [L1, L2, L3] [C1, C2] [M] [Sph]
1 [X] [(S1, S2) (S1, A1)] [R1, R2] [L1, L2, L3] [C1, C2] [M] [Sph]

B. Distinct division of femoral nerve into two parts.

1 I. [(P) (I)] [(S1, S2) (A1, A2)] [R1, R2, R3] [L1, L2] [C1] [C2]
II. [C3] [M] [(Sph) (I)]
1 I. [P] [S1, S2, A1, A2] [S3] [C1, C2] [M] [(Sph) (I)]
II. [R1] [R2] [L1, L2]
1 I. [P] [I] [A1, A2] [L2, L3] [M] [Sph]
II. [S1, S2] [R1, R2] [L1, L2]
1 I. [a] [P] [I] [(S1) (S2) (A2)]
II. [S2] [R1, R2] [L1, L2] [C1, C2] [(M1, M2, M3) (Sph)]
1 I. [P] [S1, S2] [(A1) (A2)] [S3] [(I1) (I2)]
II. [(R1) (R2)] [(L1) (L2)] [M1, M2] [Sph]

P—Nerve to pectineus muscle.
S—Nerve to sartorius muscle.
R—Nerve to rectus femoris muscle.
L—Nerve to vastus lateralis muscle.
C—Nerve to vastus intermedius muscle.
M—Nerve to vastus medialis muscle.
A—Anterior cutaneous nerve.
a—Anterior cutaneous nerve arising directly from plexus.
I—Medial cutaneous nerve.
S—Saphenous nerve.
X—Accessory obturator nerve.

In this table the various muscular and cutaneous nerves are represented by letters. The numerals placed after a letter indicate a first, second, or third nerve. The nerve trunks arising directly from the femoral are enclosed in brackets. The component nerves which are bound up in a common trunk for but a short distance are enclosed in parentheses. Those which are united for a longer distance are separated by commas. In several instances the femoral nerve divided into two main divisions before separating into branches. These are shown in part B of the table.

II. OBTURATOR GROUP.

a. Embryonic Development.

1. General Features.

In an embryo 11 mm. long (Plate III, Fig. 1), the obturator nerve passes about the pelvic blastema between the pubic and ischial process and terminates some distance beyond in several branches. Differentiation of musculature is beginning in the region about the terminus of the nerve. One branch of the nerve terminates in a mass of tissue which represents the anlage of the obturator portion of the M. adductor magnus, and possibly also the M. obturator externus. The main nerve trunk then breaks up into several short branches about which lies a mass of tissue representing the anlage of the adductor longus and brevis and the gracilis muscles

In an embryo of 14 mm. (Plate VIII, Fig. 1) the individual muscles may be clearly recognized. None of them have well developed tendons. The figure represents sufficiently well the relations of the adductor muscles at the period under consideration. The gracilis muscle is merely outlined in order to show the short and long abductors. Each muscle is separated from its neighbors by a loose connective tissue. In this tissue the nerves take their course to the muscles. The nerve to each muscle strikes it about the center of greatest development, and may extend into the muscle substance for some distance. The paths for this intramuscular nerve growth are not in all cases clearly marked. In older embryos they are much plainer. The obturator and sciatic portions of the adductor magnus muscle are distinctly separate. See also Plate II, Fig. 3.

In an embryo of 20 mm. (Plate VIII, Fig. 2) the muscles have all become attached by tendons to the skeleton. Merely the origins and attachments of the adductor brevis and gracilis muscles are shown in Fig. 2. Figs. a and b represent the gracilis and adductor brevis muscles seen from the deep surface. The obturator and sciatic portions of the adductor magnus muscle have become fused.

In slightly older embryos the muscles become much more separated by relatively great development of intermuscular connective tissue than is found in late fœtal life and after birth. Compare Figs. 2, 3, and 4, Plate II, with figures of frozen sections of the adult limb.

The cutaneous branch of the obturator nerve is not clearly distinguishable in the embryos studied. In embryo XXII the articular branch of the nerve to the adductor magnus muscle is well marked.

2. Individual Muscles.

Gracilis.—The anlage of this muscle becomes distinctly differentiated at an early stage (Plate II, Fig. 3; Plate VIII, Figs. 1, 2, and a). It first appears in a region which corresponds with that in which the nerve enters the deep surface of the muscle in the adult, near the junction of the proximal with the middle thirds. From this region the muscle extends toward its pubic and tibial attachments.

In urodeles and reptiles (Saurians) the place of the gracilis is taken by the pubi-ischio-tibialis, which is innervated by the tibial portion of the sciatic nerve in the former and by the sciatic and obturator nerves in the latter (Gadow, 82). In all the mammals it is innervated by the obturator nerve. In several mammals the origin takes place from the abdominal wall anterior to the pubis. The insertion is usually in considerable part into the crural fascia and in some forms (edentates) extends to the foot (W. Leche). In many mammals the gracilis near its insertion is fused with the sartorius. Origin by two heads and fusion near the insertion with the sartorius have been found as variations in man. On the whole, however, the muscle is singularly independent.

Adductor brevis. Plate II, Fig. 3; Plate VIII, Figs. 1, 2, and b. This muscle is differentiated at first in somewhat close association with the obturator externus muscle and with the obturator portion of the adductor magnus. From its anlage processes of attachment are sent toward the pubis and femur (Plate VIII, Fig. 2). In the adult the muscle is usually innervated by a nerve which enters its middle third near the proximal border.

Adductor longus. Plate II, Fig. 3; Plate VIII, Figs. 1 and 2. This is differentiated from a muscle mass at first not perfectly distinct from that of the adductor brevis and in a region corresponding with that where the nerves enter the muscle. From here the muscle extends to its attachments. In the adult the nerve usually enters the deep surface of the muscle in several branches about midway between its tendons of origin and insertion.

Obturator externus. Plate II, Fig. 3; Plate VIII, Figs. 1 and 2. This muscle is differentiated from dense tissue lying beneath the obturator nerve in the obturator foramen and close to the embryonic hip joint. From here it extends to its attachment to the femur. The relations of the obturator externus to the pectineus muscle have been described above, p. 302. The nerve for the obturator externus usually arises before the obturator nerve enters the obturator foramen. The nerve generally divides into two branches, one of which enters the superior border of the muscle, and the other passes to its external surface.

Some of the superior fasciculi of the obturator externus muscle may be separated from the main belly by the obturator nerve or its deep branch.

Adductor magnus. Plate II, Fig. 3; Plate VIII, Figs. 1 and 2. This muscle is developed from two distinct anlages, to one of which a branch from the obturator nerve is given, and to the other a branch from the sciatic nerve. These anlages are distinct in an embryo of 14 mm., but in one of 20 mm. (Plate VIII, Fig. 3) they have fused and a rearrangement of tissue has begun so that the three divisions of the muscle described by Poirier[7] are beginning to be distinct. The exact steps in this rearrangement of tissues I have been unable clearly to follow in the material at my disposal. In the adult muscle the obturator nerve usually gives off one or more branches which enter the main body of the superior division of the muscle, the adductor minimus, on its obturator surface about midway between the tendons of origin and insertion, and several branches which pass in between the larger fasciculi of the middle and inferior divisions of the muscle about midway between their tendons of origin and insertion. The branch from the sciatic nerve likewise enters between the main muscle bundles on the posterior surface of the middle and inferior divisions of the muscle about midway between their tendons of origin and insertion and usually sends a recurrent branch into the lower border of the superior division of the muscle. Not infrequently the nerve to the quadratus femoris muscle sends a branch into the upper margin of the superior division of the adductor magnus. In one instance a special branch of the sciatic was given to this portion of the muscle.

There is nothing to indicate that either the obturator or the sciatic branch is confined in its distribution to the tissue of the muscle mass to which it is originally sent. On the contrary it is exceedingly probable that the sciatic branch helps to innervate a portion of the obturator muscle mass and the obturator branch a portion of the sciatic muscle mass.

Comparative Anatomy and Variation in the Adductor Group.

In this group are included the obturator externus and the three adductor muscles. The pectineus also belongs anatomically and physiologically and probably in part also morphologically with this group (see p. 303). The

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[7] Traité d'Anatomie, Tome 2, p. 229.

adductor magnus in most mammals is innervated merely by the obturator nerve and there is a special præsemimembranosus muscle (W. Leche) which extends usually from the tuber ischii to the medial side of the distal end of the femur parallel with the semimembranosus. In the gorilla, orang, and gibbon the præsemimembranosus is combined with the adductor magnus, as it is in man (W. Leche). In many forms the præsemimembranosus is more or less fused with the semimembranosus. It may be looked upon as derived phylogenetically from the semimembranosus or medial flexor of the thigh (A. Bühler, 03). In echidna the adductor magnus is innervated both by the obturator and sciatic nerves (W. Leche).

In urodeles the elements of the adductor group are probably contained in the pubi-ischio-femoralis externus and possibly also in part in the pubi-ischio-femoralis internus. The pubi-tibialis may represent the mammalian præsemimembranosus and the sciatic portion of the adductor magnus in man. In reptiles the adductor elements are contained in the pubi-ischio-femoralis externus (and the ischio-femoralis, Gadow). In the different groups of mammals there is considerable variation in the number of individual muscles into which the adductor musculature is divisible; from one to six according to Le Double (97). In man the chief variations noted have to do with the greater or less fusion of the different muscles into which the group is divided. The adductor magnus may be united by fasciculi or fused not only with the neighboring long adductor but also, owing to the origin of its posterior portion from the hamstring group, with the semimembranosus muscle. The adductor minimus portion of the adductor magnus is frequently fused with the quadratus femoris and may be supplied by the same nerve although this portion of the muscle belongs normally chiefly to the territory of the obturator nerve. The short adductor is frequently fused with the obturator externus.

b. Nerve Variation in the Adult.

1. Variation in the Origin of the Obturator Nerve.

In the great majority of instances the obturator, like the femoral, nerve arises chiefly from the 22d, 23d, and 24th spinal (2d, 3d, and 4th lumbar) nerves. Table XVI indicates the spinal roots from which the nerve arose in 246 instances and the various types of lumbo-sacral plexus with which the various modes of origin were associated.

2. Relations of the Nerves Springing from the Obturator Nerve to the Spinal Nerves.

In the case of the obturator nerve it is even more difficult than in case of the femoral nerve to trace with accuracy the relations of the nerves of distribution to the nerve roots. Examination of several nerves leads me to the belief that the bulk of the nerve fibres distributed to each of the nerves of distribution occupy in the obturator nerve as it approaches

TABLE XVI.

Type of Plexus from which the N. Obturatorius arises.				Frequency of Origin of the N. Obturatorius from:						
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Nn. Sp. [XX][8] XXI XXII XXIII XXIV	Nn. Sp. [XX] (XXI) XXII XXIII XXIV	Nn. Sp. [XXI] (XXII) XXIII XXIV	Nn. Sp. (XXII) XXIII XXIV	Nn. Sp. [XXI] (XXII) XXIII XXIV XXV	Nn. Sp. (XXII) XXIII XXIV XXV	Total Number.
Ant.	A	XXIV	XXVI		1					1
	B	XXIV	XXVII		15	5	5			25
	C	XXIV chiefly to sacral plexus	XXVIII	2	42	10	9			63
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII	25		53	26			104
Post.	E	XXIV-XXV, or XXV	XXVIII					6	12	18
	F	XXIV	XXIX					6	9	15
	G	XXIV-XXV, or XXV	XXIX					4	16	20
Total Number				27	58	68	40	16	37	246

[8] The nerves enclosed in brackets contribute fibres to the N. cut. fem. lat., but probably not to other branches of the N. femoralis; those enclosed in parentheses contribute few fibres to the N. femoralis.

the obturator foramen a position approximately shown in the following diagram. The position occupied by the chief bulk of the fibres of each of the main nerves of distribution is shown in outline while the approximate area of the 23d spinal (3d lumbar) nerve is indicated by stippling, in this diagram.

3. Variation in the Branches of Distribution Arising from the Obturator Nerve.

In the great majority of instances the obturator nerve divides at the proximal border of the adductor brevis muscle in such a way that the nerves of supply to the gracilis muscle and to the adductor longus and brevis muscles pass in the anterior division of the nerve external to the

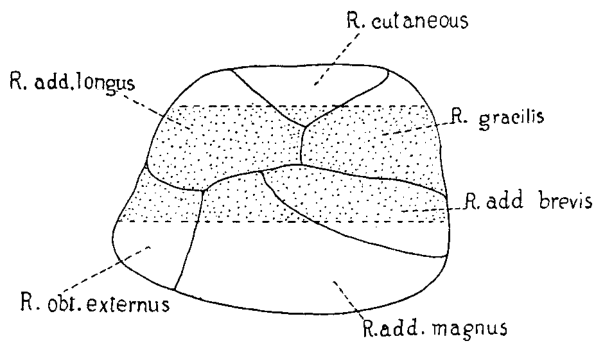

FIG. 5. Diagram to illustrate the position occupied in the obturator nerve by the nerve fibers going to the muscular and cutaneous branches.

adductor brevis muscles, while the nerves to the adductor magnus muscle and to the obturator externus muscles arise from the posterior division of the nerve. Very often the nerve to the obturator externus muscle is given off before the obturator nerve passes through the obturator foramen or above the place of division of the obturator nerve into anterior and posterior divisions. The nerves of distribution, the fibres of which occupy contiguous areas in the cross section of the main trunk shown above, may be associated for some distance in a common trunk before ultimately becoming independent.

In the following table are indicated the relations of the chief muscular and cutaneous branches of the obturator nerve in 88 instances. In all instances the branch to the obturator externus is included with the internal division of the obturator nerve, although in the majority of instances this branch was given off from the main trunk of the nerve before it split into anterior and posterior divisions. The articular and arterial branches are not included in the table because the data concerning them are too incomplete. It is possible that in several instances the small cutaneous twig which anastomoses with the medial cutaneous nerve was lost in dissection. This table therefore indicates a minimum number of instances in which the obturator furnished a cutaneous branch. The same is true of the nerve to the pectineus muscle.

The parentheses in the table indicate the simultaneous division of a nerve trunk into the branches included within them. The commas indicate that the division of the nerves thus separated took place later than that of the combined nerve from the parent trunk.

TABLE XVII.

B—Nerve to adductor brevis muscle.
C—Cutaneous branch.
E—Nerve to obturator externus muscle.
G—Nerve to gracilis muscle.
L—Nerve to adductor longus muscle.
M—Nerve to adductor magnus muscle.

a. Branch to adductor brevis from anterior division.

No. of inst.	Anterior division.	Posterior division.
26	(E) (M)	(B) (L) (G)[9]
9	(E) (M)	(B) (L) (G, C)
	In all instances extensive distribution of cutaneous branch; in one half way down back of leg (481), in another nearly to ankle (693).	
12	(E) (M)	(B) (L, C) (G)[10]
	In five instances extensive distribution of cutaneous branch.	
18	(E) (M)	(B) (G, L)[11]
6	(E) (M)	(B) (G, L, C)
	In three instances the distribution of cutaneous branch was fairly extensive.	
5	(E) (M)	(B, L) (G)[10]
2	(E) (M)	(B, L, C) (G)
1	(E) (M)	(B, L) (C) (G)
1	(E) (M)	(B, G) (L)
1	(E) (M)	(B, G) (L, C)

[9] In one instance a branch to adductor minimus from nerve to quadratus femoris.

[10] In one instance a branch to the pectineus muscle was found.

[11] In two instances a branch to the pectineus muscle.

b. Branches to adductor brevis from anterior and posterior divisions.

2	(E) (B) (M)	(B) (L) (G)

c. Branch to adductor brevis from posterior division.

4	(E) (B) (M)	(G) (L)
1	(E) (B) (M)	(G) (L, C)

III. THE SCIATIC NERVE.

In early embryonic life the separation between the tibial and peroneal nerves is well marked nearly to their origin from the sacral plexus. Near the plexus there intervenes between them a considerable amount of dense tissue (Plate II, Fig. 3) and more distally they are separated by the anlage of the fibula (Plates III, IV, and V).

a. Embryonic Development.

The *peroneal nerve* in an embryo 11 mm. long (Plate III, Fig. 2) may be traced as far as the middle of the dorsal side of the limb-bud. Four fairly distinct muscle anlages are visible along its course. The first of these, the gluteus medius mass, represents the anlage of the gluteus medius and minimus, the piriformis and the tensor fasciæ latæ, and toward it special branches are proceeding from the plexus. The second muscle mass represents the anlage of the gluteus maximus and the third that of the short head of the biceps. These two anlages adjoin one another. The fourth represents the anlage of the extensors of the ankle and peroneal muscles. Some differentiation is apparent between the anlages of the last two groups of muscles. In an embryo of 14 mm. (Plate IV, Fig. 2; Plate VIII, Fig. 4; Plate IX, Fig. 1) muscle differentiation has taken place in each of the anlages mentioned above and the anlage of the short extensor of the toes has appeared. To each muscle rudiment a nerve branch is given. In an embryo of 20 mm. (Plate V, Fig. 2; Plate VIII, Fig. 5; Plate IX, Fig. 2) muscle differentiation is more marked and the branches to each muscle resemble somewhat those of the adult.

The *tibial nerve* in an embryo of 11 mm. (Plate III, Fig. 1) extends to the middle of the plantar side of the leg. Along its course several muscle anlages may be seen. Of these the first is that of the obturator internus, the second that of the quadratus femoris, the third that of the hamstring muscles, the fourth that of the gastrocnemius—soleus group, and the fifth that of the deep muscles of the back of the leg. In an embryo of 14 mm. (Plate IV, Fig. 1; Plate VIII, Fig. 1; Plate IX, Figs. 3 and 4) individual muscles have appeared in each of the anlages mentioned and a muscle mass has appeared in the foot. In the leg the lateral and medial plantar nerves are separated from one another. Nerves are given to the various muscle anlages. In an embryo 20 mm. long (Plate V, Fig. 1; Plate VIII, Figs. 2 and 3; Plate IX, Figs. 5 and 6) the muscles of the foot are beginning to be differentiated, the medial and lateral plantar nerves on the back of the leg have become fused and the branches to the various muscles somewhat resemble those of the adult.

b. Adult Conditions..

1. Separate Origin of the Peroneal and Tibial Nerves.

During early embryonic development, as mentioned above, the peroneal and tibial nerves arise separately from the plexus. In about 10% of instances studied at the Johns Hopkins University this condition was found present in the adult, the two nerves being separated by a portion of the piriformis muscle or more rarely by the whole muscle (see Bardeen and Elting, **01**). Eisler, **92**, found the condition in 18.1% of 123 plexuses and Paterson, **94**, in 13% of 23 plexuses. The nerves arise separately from "normal," proximal or distal types of plexuses with about equal frequency.

2. Frequency of Variation in Origin of the Peroneal and Tibial Nerves.

In Tables XVIII and XIX are shown the frequency of various modes in origin of the tibial and peroneal nerves from the sacral plexus, and the types of plexus with which these various modes of origin were associated. No detailed explanation of these tables seems requisite. Tabulation of the relation of the various types of origin in relation to race, sex, and side of the body has revealed no facts of special interest, and hence tables covering these points are here omitted.

3. Relations of the Branches Springing from the Peroneal and Tibial Nerves to the Nerve Roots.

It is not often possible to trace back with certainty to their origin from the plexus the various branches springing from the peroneal and tibial nerves. It can be done only under special conditions and cannot be well carried out by students in the dissecting room. For this reason no attempt has been made to collect statistical data on this subject. The following diagram based on special dissections, indicates roughly the regions occupied by the chief nerve branches in the peroneal and tibial trunks, and their relations to the spinal roots of these nerves. Although the peroneal and tibial nerves are usually bound up on the back of the

TABLE XVIII.

Type of Plexus from which N. Peroneus arises.				Frequency of Origin of N. Peroneus from:						
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Nn. Sp. [XXIII][12] XXIV XXV XXVI	Nn. Sp. XXIV XXV XXVI	Nn. Sp. XXIV XXV XXVI (XXVII)	Nn. Sp. XXV XXVI XXVII	Nn. Sp. (XXIV) XXV XXVI XXVII XXVIII	Nn. Sp. XXV XXVI XXVII (XXVIII)	Total Number.
Ant.	A	XXIV	XXVI		1					1
Ant.	B	XXIV	XXVII	1	6	7				14
Ant.	C	XXIV chiefly to sacral plexus	XXVIII	1	12	18				31
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII		5	26				31
Post.	E	XXIV-XXV, or XXV	XXVIII			3	5		1	9
Post.	F	XXIV	XXIX			8		2		10
Post.	G	XXIV-XXV, or XXV	XXIX			3	3	1	3	10
Total Number				2	24	65	8	3	4	106

[12] Fibres from 23d spinal nerve possible but not certain.

TABLE XIX.

Type of Plexus from which the N. Tibialis arises.				Frequency of Origin of the N. Tibialis from:								
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Nn. Sp. XXIV XXV XXVI	Nn. Sp. [XXIII][13] XXIV XXV XXVI (XXVII)	Nn. Sp. XXIV XXV XXVI (XXVII)	Nn. Sp. (XXIII)[13] XXIV XXV XXVI XXVII (XXVIII)	Nn. Sp. XXIV XXV XXVI XXVII (XXVIII)	Nn. Sp. XXV XXVI XXVII (XXVIII)	Nn. Sp. XXIV XXV XXVI XXVII XXVIII XXIX	Nn. Sp. XXV XXVI XXVII XXVIII (XXIX)	Total Number.
Ant.	A	XXIV	XXVI	1								1
Ant.	B	XXIV	XXVII		1	24						25
Ant.	C	XXIV chiefly to sacral plexus	XXVIII				5	58				63
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII					104				104
Post.	E	XXIV-XXV, or XXV	XXVIII					7	11			18
Post.	F	XXIV	XXIX							15		15
Post.	G	XXIV-XXV, or XXV	XXIX							8	12	20
Total Number				1	1	24	5	169	11	23	12	246

[13] Fibres from 23d spinal nerve possible but not certain.

thigh into a common trunk there seems normally to be no crossing of nerve fibres from one nerve to the other. Branches arising from each nerve may be bound for a certain distance into a common trunk provided that they occupy contiguous positions in the parent nerve, as indicated in the diagram Fig. 6.

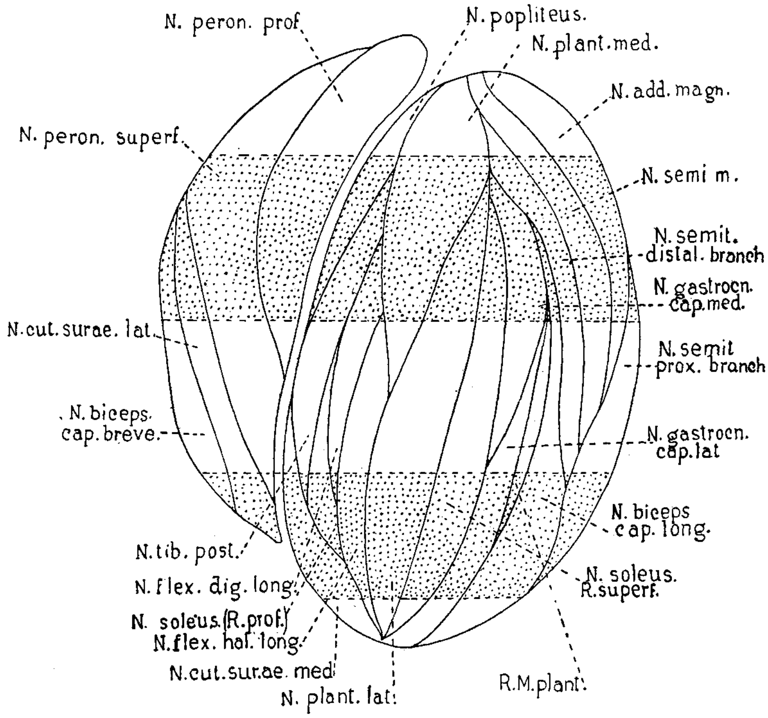

Fig. 6.
See text above.

IV. SUPERIOR GLUTEAL GROUP.

a. Embryonic Development.

1. General Features.

This group consists of the gluteus medius and minimus muscles, the piriformis, and the tensor fasciæ latæ. The last becomes distinct from the general muscle mass at a very early stage, the others are closely bound together during the earlier stages of differentiation in the anlage. Gräfenberg, **04**, has described the development of these muscles in man. In an embryo of the fifth week he describes a cone-shaped mass of dense tissue the point of which extends toward the upper end of the femur. This he considers the anlage of the gluteus maximus, the piriformis, the gluteus medius and minimus, the tensor fasciæ latæ, quadratus femoris, and obturator internus. In the embryos of this period which I have studied I have not found an intimate union between the anlages of the gluteus medius group, the gluteus maximus, the obturator internus and the quadratus femoris groups. When differentiation of the muscles in this region begins the four anlages, though none of them sharply outlined, seem to me fairly distinct from one another as I have attempted to show in Plate III, Figs. 1 and 2.

In an embryo of 14 mm. (Plate VIII, Fig. 4) the m. tensor fasciæ latæ is quite distinct from the rest of the group. Gräfenberg states that at first it is closely connected with the anlage of the gluteus minimus. There is no connection between the anlages of the tensor fasciæ latæ and that of the gluteus maximus. The separation of the gluteus medius from the gluteus minimus is marked best in the region through which the superior branch of the superior gluteal nerve passes out to end in the tensor fasciæ latæ (Plate II, Fig. 3). The piriformis is still closely bound to the anlage of the two gluteals. I can find no connection between it and the gluteus maximus such as that described by Gräfenberg. The anlages of the two gluteal muscles and the piriformis pass distally into the proximal part of the back of the femur in the region where later the great trochanter will be developed. The gluteal anlages, closely applied to the anlage of the acetabulum, extend to the femoral margin of the embryonic ilium. The piriformis extends over the peroneal nerve toward but does not reach the pelvis. It is to be presumed that in those instances in which the peroneal nerve passes through the piriformis the course of development of the muscle toward the sacrum takes place on each side of the nerve. The dense tissue between the peroneal and tibial nerves in this region may represent an interneural process of this kind. It is continuous with the piriformis anlage.

Two distinct branches of the superior gluteal nerve may be seen. One of these extends to the tensor fasciæ latæ, the other ends in the anlage of the gluteus medius. The nerve to the piriformis is likewise beginning to grow toward this muscle.

In an embryo of 20 mm. (Plate VIII, Fig. 5) the great trochanter is becoming well marked, Bardeen, **05**, and the attachments of the two deeper gluteal muscles and the piriformis begin to resemble those of the adult. The gluteal muscles have extended a considerable distance over the ilium the ala of which is much better developed than in the 14 mm.

embryo. The two muscles are clearly differentiated from one another, but the gluteus medius is partly fused to the piriformis and in this embryo the piriformis has not extended to the sacrum. In other embryos of about this stage the piriformis has, however, become attached to the sacrum. The distribution of nerves to these muscles is very similar to that found in the adult. The tensor fasciæ latæ extends distally over the thigh into the anlage of the tractus ilio-tibialis which at this period is but slightly marked.

In subsequent development the iliac ala increases in size and the muscles extend over it to their adult attachments. With the development of the anterior superior spine of the ilium the iliac attachment of the tensor fasciæ latæ is carried far from its original position near the back of the head of the femur.

2. Individual Muscles.

Tensor fasciæ latæ.—This is differentiated near the lateral edge of the anlage of the gluteus medius and minimus. According to Gräfenberg, **04**, it is at first closely fused with this anlage and extends from the "Beckenschaufel" to the anlage of the great trochanter. In the specimens which I have studied the anlage of the muscle when it first becomes distinct has no skeletal attachment but lies near the gluteal anlage (Plate VIII, Fig. 4). From here it shifts laterally and its proximal extremity soon becomes attached to the ilium somewhat distal to the crest and behind the anlage of the anterior superior iliac spine. Distally it extends toward the lateral side of the knee (Plate VIII, Fig. 5) and is continued into the tractus iliotibialis which toward the end of the second month begins to be distinct.

In the adult the nerve usually enters the muscle about midway between its origin and insertion. This area corresponds to that first differentiated in the embryo.

It seems probable that that portion of the m. ilio-tibialis of urodeles and reptiles innervated by the sciatic nerve (the m. gluteo-rectus) represents the tensor fasciæ latæ of mammals. In different mammals the tensor fasciæ latæ varies greatly in development. It is said not to be present in monotremes and marsupials (W. Leche). It is large in all anthropoids except the orang (Le Double).

Gluteus medius and minimus.—These two muscles are differentiated in close association with one another and remain closely associated in the adult. The myoblastema from which they are derived lies close to the back of the embryonic skeleton near the junction of the femur with the pelvis (Plate VIII, Fig. 4). The anlage of the two muscles seems from the first to extend distally into the anlage of the great trochanter, but proximally it extends only to the acetabular portion of the ilium. From here the muscles extend over the lateral surface of the iliac ala and finally reach the iliac attachments characteristic of the adult. The ascending branch of the superior gluteal nerve takes a course at first distal to the transverse branch, but as the gluteus medius grows toward the iliac crest the ascending branch is carried proximally across the transverse.

The gluteus medius and minimus muscles correspond with the ilio-femoralis of urodeles and reptiles, a muscle supplied by branches from both the femoral and sciatic nerves. In the monotremes the "gluteus medius" is a thin muscle which arises from the sacro-caudal vertebræ and is supplied by a branch of the peroneal nerve while the gluteus minimus and scansorius are represented by a mass of muscle which arises from the fascia lumbo-dorsalis, the lumbar and sacral vertebræ and the ilium and is innervated by branches of both the femoral and peroneal nerves. In all higher forms the gluteus medius-minimus musculature is innervated by branches which arise directly or indirectly from the peroneal portion of the sacral plexus (Westling, cited by Leche). It seems not unlikely that in the urodeles, reptiles and monotremes elements of the ilio-psoas musculature of higher forms are included in the ilio-femoral musculature. The more superficial and posterior part of the sciatic portion of the ilio-femoral anlage has given rise in the higher mammals to the gluteus medius and piriformis, the deeper and more anterior portion to the gluteus minimus and scansorius. The degree of separation of these various elements varies greatly in different mammals.

The variations of the two muscles which have been found in man are chiefly those of a greater differentiation than usual of individual muscles from the common anlage (*i. e.*, M. scansorius) or a partial or complete fusion of the muscles with one another or with the piriformis.

The piriformis.—This is differentiated from tissue at first closely associated with the gluteus medius and minimus (Plate VIII, Fig. 4). According to Gräfenberg the muscle anlage can from its first appearance be traced to the sacrum. While it is true that a dense mass of cells surrounding the sciatic nerve and its roots of origin can be followed back to the sacrum this condensed tissue is not, I believe, to be looked upon as the anlage of the piriformis, although the two are not at first sharply to be distinguished. Differentiation of the muscle is first clearly marked in the region between the sacral plexus and the anlage of the great trochanter. From here the developing muscle may be followed in older embryos toward its sacral attachment. In embryo XXII (Plate VIII, Fig. 5) the sacral attachment has not yet been reached. The region in which the nerve enters the adult muscle corresponds with the area in which muscle differentiation is first seen. As pointed out above, the differentiation of the muscle at a period preceding the fusion of the

TABLE XX.

Type of Plexus from which the N. Gluteus Superior arises:				Frequency of Origin of N. Gluteus Superior from:						
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Nn. Sp. XXIV XXV	Nn. Sp. XXV	Nn. Sp. XXIV XXV XXVI	Nn. Sp. XXV XXVI	Nn. Sp. XXIV XXV XXVI (XXVII)	Nn. Sp. XXV XXVI (XXVII)	Total Number.
Ant.	A	XXIV	XXVI	1						1
	B	XXIV	XXVII	9		14				23
	C	XXIV chiefly to sacral plexus	XXVIII	16		44				60
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII	23		63		4		90
Post.	E	XXIV–XXV, or XXV	XXVIII	2	1	4	7	2	2	18
	F	XXIV	XXIX	2		8		1		11
	G	XXIV–XXV, or XXV	XXIX			6	5	1	3	15
Total Number				53	1	139	12	8	5	218

TABLE XXI.

Type of Plexus from which the Nerve to the Piriformis arises:				Frequency of Origin of Nerve to Piriformis from:					
Type.		Furcal Nerve.	Most Distal Spinal Nerve to I imb.	Nn. Sp. XXIV XXV	Nn. Sp. XXV XXVI	Nn. Sp. (XXV) XXVI	Nn. Sp. XXVI XXVII	Nn. Sp. (XXVI) XXVII	Total Number.
Ant.	A	XXIV	XXVI			1			1
	B	XXIV	XXVII		4	3	2		19
	C	XXIV chiefly to sacral plexus	XXVIII	1	6	26	4	2	39
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII		8	23	5	8	44
Post.	E	XXIV—XXV, or XXV	XXVIII		3	2	1	3	9
	F	XXIV	XXIX		1	1	1	2	5
	G	XXIX—XXV, or XXV	XXIX			1		6	9
Total Number					22	67	15	21	126

peroneal and tibial nerves into a common trunk may account for the variation in the relations of those nerves to the muscle in the adult.

Although Gegenbaur and others have considered the piriformis to be derived from the caudo-femoral muscle of urodeles and reptiles, both comparative anatomical and embryological studies speak against this view. The caudo-femoral muscle of these lower forms is represented in many of the mammals by a caudo-femoralis (W. Leche), which typically extends from the caudal vertebræ to the lateral side of the distal half of the femur and runs parallel with the præsemimembranosus. As in the reptiles and urodeles so here the muscle toward its femoral insertion lies in front of the sciatic nerve while the piriformis normally runs dorsal to this nerve.

The piriformis is to be looked upon as an especially differentiated portion of the ilio-femoral muscle of urodeles and reptiles. In a considerable number of mammals it is not differentiated (some ungulates, etc.).[14]

In man the piriformis is frequently fused with the gluteus medius. Its origin may take place from the great sciatic notch instead of from the sacrum.

b. Nerve Variation in the Adult.

1. Variation in the Relations of the Superior Gluteal Nerve and of the Nerve of the Piriformis to the Nerve Roots.

The preceding tables, XX, XXI, indicate the frequency of certain modes of origin from the sacral plexus of the superior gluteal nerve and the nerve to the piriformis muscle and the relation of these modes of origin to certain types of lumbo-sacral plexuses. While there is some correspondence between an anterior or a posterior form of plexus and a "high" or "low" mode of origin of the nerves this correspondence is by no means perfect.

2. Variation in the Branches of Distribution.

Superior gluteal nerve.—Most frequently this nerve arises by two roots, one from the lumbo-sacral cord (4th-5th lumbar) and the other from the first sacral nerve. The trunk usually soon divides into two branches. The ascending branch is distributed mainly to the more dorsal part of the gluteus medius muscle in the middle third between its tendons. According to some authors it also sends fibres to the gluteus minimus muscle. I have found it much more frequently confined in distribution to the gluteus medius muscle. The transverse branch passes across the external surface of the gluteus minimus muscle about midway between its tendons and near the lateral border of the muscle passes beneath a

[14] According to Kohlbrugge, 97, the piriformis has a double origin, on the one side from the gluteal musculature, on the other from the metameric caudal muscles.

special slip of the muscle and terminates in the proximal portion of the middle third of the m. tensor fasciæ latæ. It gives branches of innervation to the gluteus minimus muscle, to the lateral portion of the gluteus medius muscle and to the tensor fasciæ latæ. The fibres of the ascending branch always arise from the plexus lower down than those of the transverse branch. Sometimes it arises as a separate branch from the first sacral nerve. It may then pass through the substance of the piriformis muscle and be associated with the nerve to the piriformis muscle.

Nerve to the piriformis muscle.—Very commonly the nerve to this muscle may arise from a loop connecting the first and second sacral nerves, but more often the branches arise directly from the first or second sacral nerve and pass into the substance of the muscle in the middle third between the tendons. The ascending branch of the superior gluteal nerve may send a ramus to the piriformis muscle. I have never seen a branch from the third sacral nerve to the piriformis such as those described by Weber, Hildebrandt, Valentine and Henle.

V. THE GLUTEUS MAXIMUS AND THE SHORT HEAD OF THE BICEPS.

The studies in comparative anatomy of Ranke, 97, Klaatsch, 02, and others have gone to prove the close morphological association of the gluteus maximus and the short head of the biceps.

It seems probable that both the short head of the biceps and the gluteus maximus are represented in the urodeles by the ilio-(femoro)-fibularis and in reptiles by the ilio-fibularis muscle which is supplied by the peroneal portion of the sciatic. In the mammals the proximal attachment of this musculature has extended well into the caudal region from the ilium. In the monotremes it is represented by a muscle which extends from the caudal region to the foot and in Echidna lies posterior to and does not cover the other glutei (Westling). In most of the higher forms it is divisible into three muscles, the superficial gluteus, or gluteus maximus, the femorococcygeus (Leche), and the gluteo-crural (Klaatsch). The superficial gluteus is inserted into the femur or into the fascia of the thigh. The femorococcygeus is inserted into the shaft of the femur, and the gluteo-crural into the fascia of the leg or into the fibula. The superficial gluteus and the femoro-coccygeus are not infrequently fused to form the gluteus maximus. The gluteo-crural is absent in some forms. In most mammals it extends as the tenuissimus from the caudal vertebræ or the gluteal fascia to the leg. In man and a few of the higher primates it arises from the femur and becomes applied to the tendon of the long head of the biceps to form the short head of this muscle. Klaatsch, 02, has given an especially valuable account of the gluteo-crural muscle. See also Windle and Parsons, 00.

In man the gluteus is not infrequently found divided into two portions, a condition normal in the embryo. The short head of the biceps not infrequently has a tendon of insertion more or less distinct from that of the long head. Its tendon of origin may be attached to the tuber ischii, the fascia covering the gluteus maximus, or the sacrotuberosal ligament.

a. Embryonic Development of Gluteus Maximus.

The gluteus maximus arises from an anlage which lies dorso-lateral to the anlage of the great trochanter (Plate III, Fig. 2). Its proximal edge overlaps and lies near but does not seem to be fused with the gluteus medius anlage. Distally it is slightly fused with the anlage of the short head of the biceps. Into the gluteus maximus anlage two nerves extend from the back of the sacral plexus.

In an embryo of 14 mm. (Plate II, Fig. 3; Plate VIII, Fig. 4) the gluteus maximus is quite distinct from the neighboring muscles.[15] It is beginning to show a division into two portions each of which is supplied by a separate nerve. The more distal of the two portions is continuous with the blastema of the femur. Proximally the muscle is extending over the gluteus medius and obturator internus anlages toward the ilium and sacrum. I find no primitive intrapelvic extension of the gluteus maximus such as that described by Gräfenberg, but the fascial extension which he describes from the dorsal muscles over the gluteal muscles is quite evident (see Plate II, Fig. 3).

In an embryo 20 mm. long (Plate VIII, Fig. 5) the gluteus maximus has extended from the trochanteric region where it first appears to the ilium, sacrum and coccyx. It is at this period very distinctly separated into two portions the more distal of which is inserted into the femur distal to the great trochanter while the more proximal is inserted into the fascia over the attachment of the distal portion. In the adult the two portions are only rarely thus distinct. The distal portion represents the femoro-coccygeus muscle so common in the lower mammals. In the younger embryos two nerves pass from the plexus to the muscle. In this embryo a special nerve is given to each portion of the muscle, but the two nerves arise by a common trunk from the plexus. The nerve to the superficial portion of the muscle curves toward the ilium and passes upwards on the deep surface of the muscle along a line about midway between the origin and insertion of the muscle. The nerve to the distal portion passes distally and enters its proximal margin (Plate VIII, Fig. 5).

[15] The early union with the piriformis described by Gräfenberg I have not found in any of the embryos I have examined, although I find, as he describes, an early transitory union between the anlages of the short head of the biceps and the gluteus maximus.

b. Variations in the Inferior Gluteal Nerve.

This nerve arises in the main from the first sacral nerve, but in part usually also from the lumbo-sacral cord; often from the 2d sacral, and rarely from the 3d sacral. Its roots may be superficially bound up with the trunks of origin of the posterior cutaneous nerve and not infrequently with the main sciatic trunk. In the great majority of instances the main trunk of the nerve divides into an ascending and a descending branch.

TABLE XXII.

Type of Plexus from which the N. Gluteus Inf. arises.				Frequency of Origin of N. Gluteus Inf. from :			
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Nn. Sp. (XXIV) XXV XXVI	Nn. Sp. [XXIV] XXV XXVI (XXVII)	Nn. Sp. [XXV] XXVI XXVII (XXVIII)	Total Number.
Ant.	A	XXIV	XXVI	1			1
	B	XXIV	XXVII	12	6		18
	C	XXIV chiefly to sacral plexus	XXVIII	24	27	3	54
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII	29	40	5	74
Post.	E	XXIV-XXV, or XXV	XXVIII		9	1	10
	F	XXIV	XXIX	1	6	3	10
	G	XXIV-XXV, or XXV	XXIX		10	1	11
Total Number				67	98	13	178

The ascending branch curves upwards on the under surface of the gluteus maximus muscle midway between the tendons of origin and insertion. The descending branch is distributed in the middle third of the deep distal portion of the muscle. The fibres of the descending branch have a more distal origin than those of the ascending branch. In the adult the two branches often arise separately from the plexus. The table above shows the frequency of origin of the nerve from various groups of spinal nerves and the frequency with which each is associated with a given type of plexus.

c. Embryonic Development of the Short Head of the Biceps.

In an embryo of 11 mm. (Plate 3, Fig. 2) the anlage of the short head of the biceps extends along the distal half of the fibular margin of the femur dorso-lateral to the peroneal nerve. Proximally it is continued to the anlage of the gluteus maximus.

In an embryo of 14 mm. (Plate II, Fig. 3; Plate VIII, Fig. 4) it does not extend proximally quite to the femoral insertion of the gluteus maximus. Distally it is beginning to be attached to the tendon of the long head of the biceps. The nerve to the muscle which at the former stage was not evident may at this stage be seen entering the fibular margin of the muscle.

G. D. Thane mentions an instance in which the nerve to the short head of the biceps arose in connection with the inferior gluteal nerve from the sacral plexus.[16]

In an embryo 20 mm. long (Plate VIII, Fig. 5) both the femoral and distal attachments of the muscle are well marked.

VI. THE MM. OBTURATOR INTERNUS, GEMELLI AND QUADRATUS FEMORIS.

These constitute a distinct group of muscles which are differentiated on the ischial side of the anlage of the hip joint. Although closely associated, the anlage of the obturator internus and gemelli seems to be from its earlier stages of differentiation distinct from that of the quadratus femoris. I do not find the anlages of these muscles fused at an early stage with the gluteal anlages as described by Gräfenberg, **04**. When they first appear (Plate III, Fig. 1) the anlage of the quadratus femoris has a somewhat more anterior position than that of the obturator internus. This may account for its nerve supply in the adult from a more proximal set of spinal nerves.

a. Embryonic Development.

Obturator internus and gemelli.—An indistinct region of tissue differentiation near the ischium in Embryo CIX, length 11 mm. (Plate III, Fig. 1) I take to be the anlage of the obturator internus and the gemelli. To it a nerve is given from the sacral plexus. The anlage of these muscles is much more distinct in an embryo 14 mm. long (Plate VIII, Figs. 1 and 4). Here it may be seen extending from the anlage of the great

[16] Quain's Anatomy, 10th ed.

trochanter across and then upwards for a short distance on the pelvic surface of the ischium toward the obturator foramen. No distinction can at this time be made between the obturator internus and the two gemelli. From the sacral plexus a nerve branch may be seen extending across the outer surface of the muscle. Beneath the muscle another nerve may be traced to the anlage of the quadratus femoris.

In an embryo 20 mm. long (Plate VIII, Fig. 5) the obturator internus has extended well over the obturator foramen and in its growth into the pelvis has carried its nerve in the same direction. The gemelli cannot yet be clearly distinguished from the obturator internus. A good description of the architecture of these muscles in the adult and of the distribution of nerves to them is given in the *Traité d'anatomie humain* of Poirier and Charpy. In the adult the chief variations in structure are those of a greater or less independence of the gemelli and a greater or less extent of the pelvic attachments of the obturator internus.

Quadratus femoris.—This is differentiated comparatively early in a region lying between the anlage of the great trochanter and that of the tuber ischii (Plate III, Fig. 1; Plate VIII, Fig. 4). It soon forms attachments which correspond well with those of the adult muscle (Plate VIII, Fig. 5). In the embryo, as in the adult, the nerve enters the deep surface of the muscle near the junction of the middle and ischial thirds. In the adult the muscle is frequently fused either with the inferior gemellus or with the adductor minimus. Its nerve of supply may extend into the adductor minimus.

The quadratus femoris, gemelli, and obturator internus muscles of mammals are apparently related to the ischio-femoral musculature of urodeles and the pubi-ischio-femoralis posterior (Gadow) of reptiles. Among the mammals the obturator internus is said not to be found in the monotremes (W. Leche) but it occurs in most, although not all, of the higher forms. The degree of isolation of the gemelli and the mode of attachment of the obturator internus vary considerably in different mammals. The quadratus femoris seems to be a fairly constant muscle in the mammalian series. In a considerable number of mammals, however, it is innervated by the obturator nerve instead of by a special branch from the sacral plexus (see W. Leche). I do not know of an instance of this kind being reported as a variation in man. The innervation of the adductor minimus portion of the adductor magnus by the nerve to the quadratus femoris is, however, frequent and rarely this nerve may send a branch to the M. obturator externus. The adductor minimus is normally supplied chiefly by the obturator nerve. In Talpa the quadratus femoris and obturator externus are fused and the combined muscle is supplied both from the obturator nerve and from the sacral plexus (W. Leche).

TABLE XXIII.

Type of Plexus from which the Nerves arise.				Frequency of Origin of the Nerve to the M. Obturator Internus from:				Frequency of Origin of the Nerve to the M. Quadratus Femoris from:				
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Nn. Sp. XXIV XXV XXVI	Nn. Sp. XXV XXVI XXVII	Nn. Sp. [XXV] XXVI XXVII XXVIII	Total Number.	Nn. Sp. XXIV XXV	Nn. Sp. XXV	Nn. Sp. XXIV XXV XXVI	Nn. Sp. XXV XXVI	Total Number.
Ant.	A	XXIV	XXVI									
	B	XXIV	XXVII	1	6		7	5		2		7
	C	XXIV chiefly to sacral plexus	XXVIII		18		18	9		9		18
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII		11	1	12	4		8		12
Post.	E	XXIV-XXV, or XXV	XXVIII		1	1	2		1		1	2
	F	XXIV	XXIX		2	1	3			3		3
	G	XXIV-XXV, or XXV	XXIX		2	4	6				6	6
Total Number				1	40	7	48	18	1	22	7	48

b. Nerve Variation.

1. Variation in the Origin of the Nerves to the Obturator Internus and Quadratus Femoris Muscles.

In Table XXIII the frequency of variation in the origin of the nerves to these muscles is shown. The nerve to the quadratus femoris muscle arises usually from the lumbo-sacral cord and the 1st sacral nerve (24th, 25th, and 26th spinal nerves.) Not infrequently the 25th spinal nerve is the most distal nerve to furnish fibres to this nerve. This condition occurs usually in the more proximal forms of plexus. In the more distal forms of plexus the 25th and 26th spinal nerves furnish the fibres for this muscle.

TABLE XXIV.

Association of the Branches Distributed to the Obturator Internus, Gemelli, and Quadratus Femoris Muscles.	Number of Instances Associated with Plexus Type:[17]						Total Number.
	B	C	D	E	F	G	
Branch 1, to Mm. obturator int. and gemellus sup. Branch 2, to Mm. quadratus femoris and gemellus inf.[18]	1	5	4	2	1		13
Branch 1, to M. obturator int. Branch 2, to M. gemellus sup. Branch 3, to Mm. quadratus femoris and gemellus inf.		1					1
Branch 1, to M. obturator int. Branch 2, to Mm. quadratus femoris and both gemelli.						3	3
Branch 1, to Mm. obturator int. and gemellus sup. Branch 2, to M. quadratus fem., gemellus inf., and adductor magnus.		2					2
Total Number.	1	8	4	2	1	3	19

[17] For types of plexus see preceding table.
[18] In one instance a branch was traced to the M. obturator externus.

The nerve to the obturator internus muscle arises usually from the (24th) 25th, 26th, and 27th spinal nerves. Rarely the 26th spinal nerve is the most distal nerve to furnish fibres to it and occasionally in distal forms of plexus the 28th spinal nerve may do so.

It is difficult to trace these nerves back to their roots of origin. The charts on which these tables are based are those recording the most accurate dissections of these nerves. They are, however, of positive rather than negative value and it is possible that a more extensive origin than here indicated was present in some of the plexuses here recorded.

2. Variation in the Nerves of Distribution.

The frequency of this variation is indicated in Table XXIV. Only those charts are used for tabulation which were based on the more accurate dissections of the distribution of the nerves to the muscles. Most frequently the nerve to the obturator internus muscle furnishes a branch to the superior gemellus muscle while that to the quadratus femoris muscle furnishes a branch to the inferior gemellus muscle. Occasionally a separate branch passes from the sacral plexus to the superior gemellus muscle. In distal forms of plexuses the nerve to the quadratus femoris muscle may furnish branches to both gemelli muscles. Not infrequently the branch to the quadratus femoris muscle is continued into the proximal portion of the adductor magnus muscle. This condition has been described by Wilson, 89. In one instance I have followed a branch to the M. obturator externus.

VII. THE HAMSTRING MUSCLES.

a. Embryonic Development.

1. General Features.

In an embryo 11 mm. long (Plate III, Fig. 1) two branches from the tibial portion of the sciatic nerve represent nerves to the hamstring muscles. They terminate in a mass of tissue on the plantar side of the femur. The more proximal of the two nerves represents the proximal branches to the long head of the biceps and the semitendinosus; the more distal nerve, that to the distal part of the semitendinosus and the long head of the biceps and to the semimembranosus and adductor magnus muscles.

In an embryo 14 mm. long (Plate VIII, Fig. 1) the various muscles mentioned are distinctly differentiated. But a single nerve branch is given to the sciatic portion of the adductor magnus (at this period a distinct muscle not closely fused with the obturator portion) and to the semimembranosus. To the semitendinosus and to the long head of the biceps proximal and distal branches are given. About the terminus of each motor nerve the muscle differentiation is best marked. The tendinous attachments at each extremity of the muscles are indefinite. Proximally they fuse with the ischial blastema.

In an embryo 20 mm. long (Plate VIII, Fig. 3) the muscles of this group are attached by tendons to the skeleton. The obturator and sciatic portions of the adductor magnus have become fused.

2. Individual Muscles.

Adductor magnus.—See p. 313. That portion of this muscle which is attached to the distal end of the femur represents the praesemimembranosus of the lower mammals and belongs primitively to the hamstring group.

Semimembranosus.—This muscle arises from a special anlage in close association with that of the sciatic portion of the adductor magnus (Plate II, Fig. 3; Plate VIII, Fig. 1). The belly of the muscle becomes distinct before the tendons. In an embryo of 20 mm. (Plate VIII, Fig. 3) there is a flat tendon of origin which is closely applied to the adductor magnus and which arises from the ischium. The tendon of insertion fuses with the tibial blastema near the back of the knee joint. The nerve enters near the center of the muscle belly. In the adult the nerve enters by several branches into the substance of the muscle about midway between the tendinous attachments of the muscle bundles composing it. The superior branches curve upwards either on the surface or within the substance of the muscle. There is much individual variation in the exact mode of distribution of the branches of the nerve to this muscle.

The semimembranosus is probably represented in urodeles by a part of the (caudali)-pubi-ischio-tibialis and in reptiles by a portion of the flexor tibialis internus. In most mammals it arises from the ischium or pubis, runs parallel with, and may be incompletely differentiated from the præsemimembranosus, mentioned above in connection with the adductor magnus, and is inserted into the tibia. It may be fused with the semitendinosus. A. Forster, 03, has shown that although in the lower mammals the semimembranosus is a flexor and may send a tendinous expansion to the plantar aponeurosis, in apes and monkeys it is chiefly an internal rotator of the leg. In many mammals it is associated with a caudo-femoral (W. Leche) muscle which extends from the caudal vertebræ to the distal end of the femur.

In man it may be longitudinally doubled, may be partially fused with the adductor magnus or the semitendinosus and may arise from the ischial spine or the sacro-tuberosal ligament as well as from the tuber ischii.

Semitendinosus.—This muscle is formed from two anlages, one of which is differentiated in close conjunction with the anlage of the ischial tuberosity, the other more distally. These anlages correspond with the two parts of the muscle found in the adult and to each a separate nerve is given (Plate VIII, Fig. 1). The anlages are visible in an embryo of 14 mm. and the muscle is well differentiated in one of 20 mm. (Plate VIII, Fig. 3). In the latter the tendinous inscription which subdivides the muscle is as distinctly marked as in later life. The tendon of insertion is inserted relatively more distally in the 20 mm. embryo than in the adult.

In the embryo as in the adult a special nerve is given to each portion of the muscle. The nerve to the more proximal part arises from a more distal set of spinal nerves than that to the more distal part. It gives rise to branches which enter between the bundles of the proximal portion of the muscle about midway between the tendon of origin and transverse tendinous inscription. The more distal nerve enters the distal portion of the muscle by branches which have a similar distribution with respect to that portion.

The semitendinosus is probably represented in urodeles in the (caudali)-pubi-ischio-tibialis and in reptiles by a portion of the flexor tibialis internus. In monotremes it arises with the semimembranosus from the tuber ischii, is inserted into the tibia, and is supplied both by the obturator and sciatic nerves. In the higher forms it is either single as in man, double as in several insectivores, or has two heads of origin, one of which usually springs from the tuber ischii, the other from the caudal vertebræ. This last, according to W. Leche, is probably the most primitive condition. The tendinous inscription of the semitendinosus marks the region where the two heads join the common belly in this type of muscle. Humphrey believed the tendinous inscription to mark the place where in the lower vertebrates the caudo-crural joins somewhat perpendicularly the flexor musculature of the thigh. In most of the lower mammals and in all the apes the tendon of insertion sends fibrous expansions far down in the crural fascia and together with similar expansions from the biceps and gracilis helps to form a sheath for the tendon of Achilles (Parsons, 04).

In man the semitendinosus and long head of the biceps sometimes arise independently from the ischium, a variation which is supposed by Le Double, 97, to be a reversion to a primitive condition in which the two muscles were quite independent. Klaatsch, 02, on the other hand, states that in the lowest mammals the muscles are more closely united than in the higher. In the human embryo the two muscles are closely united from their earliest differentiation and the union extends relatively more distal than in the adult. The semitendinosus may be more or less fused in the adult with the semimembranosus or connected by fasciculi with the long head of the biceps.

The semitendinosus in the embryo extends more distally in the crus than is normal in the adult. The fascial extension of the tendon in the adult is, however, frequently well marked and may be muscular (Gruber, 86). Proximally the semitendinosus in man may be reinforced by fasciculi from the pelvis or coccyx. These fasciculi may join the muscle at its tendinous inscription (Le Double). In the normal development I have found nothing that seems to represent a "latent" caudal head of the muscle. It is noteworthy that the proximal segment of the semitendinosus is innervated by a more distal set of spinal nerves than the distal segment (see above). The proximal end of the biceps is likewise innervated by a more distal set of spinal nerves than the distal end of that muscle. The proximal ends of these two muscles may therefore represent a caudo-femoral anlage shifted distally into the thigh.

Biceps, caput longum.—The long head of the biceps is differentiated from a special anlage which, near the ischial tuberosity, is closely fused with that of the semitendinosus. This anlage is well marked in an embryo of 14 mm. (Plate VIII, Fig. 1) and the muscle is differentiated in one of 20 mm. (Plate VIII, Fig. 3). To the anlage in the 14 mm. embryo two nerves are given each of which is associated at its origin with corresponding nerves to the semitendinosus. In the 20 mm. embryo two nerves are likewise given to the muscle, but in this instance the nerves arise nearly in conjunction with one another from the tibial portion of the sciatic nerve.

In the adult two nerves are commonly distributed to the muscle. One of these enters the proximal portion of the muscle, the other in the distal third. The terminal branches of these nerves are distributed across the muscle bundles of the biceps about midway between their tendons of origin and insertion, but nearer the proximal than the distal tendon. The more distal nerve sends back recurrent branches across the muscle bundles when the more proximal nerve is absent or ill developed.

Biceps, caput breve. See p. 332.

The long head of the biceps or lateral crural flexor is probably represented in the urodeles by the ischio-flexorius and in reptiles by the flexor tibialis externus. In the mammals it usually arises from the tuber ischii and is inserted into the tibia or into the fascia of the leg, often as far as the foot. In marsupials it arises from the tuber ischii and the caudal vertebræ. In the carnivora and some of the other mammals it has occasionally a double origin. As in the case of the semitendinosus the caudal origin of this muscle is looked upon, however, by many investigators as a caudo-femoral muscle inserted into the lateral flexor rather than as a true head of the muscle. According to Testut the long head of the biceps represents a muscle which primitively arose from the ilium and the coccyx. The sacrotuberosal ligament represents a transformation of that portion of the muscle which originally extended between the ilio-sacro-caudal region and the present origin of the muscle from the tuber so that the ligament may be looked upon as the tendon of insertion of the muscle. In the human embryo the ligament develops after the anlages of the ischial tuberosity and the long head of the biceps have appeared. It apparently is differentiated from the tuber ischii toward the ilium, sacrum, and coccyx. In the human adult fasciculi from the coccyx, sacrum, or sacrotuberosal ligament to the head of the biceps are frequent.

The distal insertion of the muscle in most of the lower mammals takes place further down the leg than in man. In most of the lower mammals, according to Parsons, 04, as mentioned above, extensions from the tendons of the semitendinosus, gracilis, and biceps into the crural fascia serve to form a sheath for the tendon of Achilles. According to A. Forster, 03, in fœtuses the insertion of the biceps takes place into the sural fascia and even

TABLE XXV.

Order in which the Branches to the Hamstring Muscles arise from the Tibial Division of the Sciatic Nerve.

1st Branch.	No. Inst.	2d Branch.	No. Inst.	3d Branch.	No. Inst.	4th Branch.	No. Inst.	5th Branch.	No. Inst.	6th Branch.	No. Inst.
Ta (1)	12	Ta (2) + Ba, b	1	A m+m+Tb	1				1		
		Ta (2)	1	Tb	1	Ba, b	1	M	2	A m	1
		Ba	4	Bb	2	A m + M	2	Tb	1		
				Tb	1	A m + M	1	Bb			
				Bb+Tb	1	A m + M	1				
		Ba, b	6	A m+M+Tb	4						
				A m + M	1	Tb	1				
				Tb	1	A m + M	1				
Ta + Ba	1	Bb	1	Tb	1	A m + M	1				

TABLE XXV.—*Continued.*

1st Branch.	No. Inst.	2d Branch.	No. Inst.	3d Branch.	No. Inst.	4th Branch.	No. Inst.	5th Branch.	No. Inst	6th Branch.	No. Inst.
Ta + Ba, b	8	A m + M + Tb	4								
		A m + M	4	Tb	4						
Ba, b	8	Ta	8	A m + M + Tb	3						
				Tb	3	A m + M	3				
				A m + M	2	Tb	2				
Ba	3	Ta	3	Bb	2	A m + M	1	Tb	1		
						Tb	1	A m + M	1		
				A m + M	1	Bb	1				
Ta + Ba, b + Tb	1	A m + M	1								
Ta, b	1	Ba, b	1	A m + M	1						

Ta = branch to proximal segment of M. semitendinosus.
Tb = branch to distal segment of M. semitendinosus.
Ba = proximal branch to long head of M. biceps.
Bb = distal branch to long head of M. biceps.
Am = branch to M. adductor magnus.
M = branch to M. semimembranosus.

in young children the attachment to the head of the fibula is weak. In embryos of the third month the tendon of insertion of the biceps can be followed for some distance down the fibular side of the leg but there seems to be some attachment to the fibula.

b. Nerve Supply.

1. Relations of the Nerves of the Muscles of the Hamstring Group to the Spinal Nerves.

In the adult it is difficult to trace back with certainty to the spinal nerves the nerves distributed to these muscles. In general the special dissections which I have made have revealed conditions which correspond well with the data given by G. D. Thane in Quain's Anatomy, Vol. III, Part II, p. 331, which in turn are based on data derived from Paterson and Eisler. According to the description there given the nerve to the adductor magnus arises from the 4th and 5th lumbar nerves, that of the semimembranosus from the 4th and 5th lumbar and 1st sacral nerves. The two nerves of the semitendinosus arise from the 5th lumbar and 1st and 2d sacral nerves. I have found the inferior nerve arising from the 4th and 5th lumbar and 1st sacral, the superior from the 1st and 2d sacral nerves. The nerves for the long head of the biceps arise from the 1st, 2d, and 3d sacral nerves; that of the short head of the biceps from the 5th lumbar and 1st, or 1st and 2d, sacral nerves. In Text Fig. 6 the relation of these nerves to the sciatic nerve is diagrammatically shown. A study of Plate III, Fig. 3, and Plate VIII, Figs. 1 and 3, will show that a distribution of spinal root fibres corresponding with this scheme would follow from the more direct paths to the muscle anlages open to fibres growing out from the sacral spinal nerves when the muscle anlages first appear.

2. Relation of the Nerves of the Hamstring Muscles to the Sciatic Nerve.

To the semitendinosus and to the long head of the biceps, as a rule, two separate nerves are given, one going to the proximal the other to the middle or distal third of each muscle. Occasionally each of these nerves may be doubled and not infrequently the nerves to each muscle are combined for a part of their course in a common trunk. For the semimembranosus and adductor magnus as a rule a single branch springs from the sciatic nerve. This branch soon divides into separate branches for each muscle. The various nerves mentioned spring at varying heights from the sciatic nerve and are variously combined in the branches which spring from this nerve. In Table XXV the relative origins of the branches of the sciatic nerve are tabulated and there is shown the frequency with which the different combinations occurred in 34 plexuses. From this table it may be seen that the nerve to the proximal segment of the semitendinosus muscle is most frequently the first of these branches to arise. Very frequently this branch is associated with one or both of the branches distributed to the long head of the biceps. Often the latter branches are the first to arise from the sciatic nerve. Rarely the branch to the distal segment of the semitendinosus arises in common with that to the proximal segment. When the most proximal branch given off is that to the proximal segment of the semitendinosus the next branch is usually that to the long head of the biceps. The more distal of the branches to the long head of the biceps may arise low down from the sciatic nerve. The nerve to the distal segment of the semitendinosus arises about on the level and often in common with the nerve to the adductor magnus and semimembranosus.

VIII. PERONEAL MUSCLES.

a. Embryonic Development.

During the sixth week the anlage of the peroneal muscles becomes separated from that of the long extensors of the toes and the tibialis anterior (Plate IX, Fig. 1). Between the two anlages runs the n. peroneus superficialis. The anlage of each peroneal muscle begins at the same time to become distinct. Schomburg, oo, has described a connection in early embryonic development between the peroneus brevis and the extensor digitorum brevis. In the embryos of corresponding stages which I have examined the two muscles are distinctly separated as shown in Plate IX, Fig. 1.

The *m. peroneus longus* occupies the more proximal and superficial position. It lies dorso-lateral to the upper end of the fibula. Its proximal extremity is some distance from the tibia. The distal extremity is continued into a tendon which can be followed to the neighborhood of the base of the fifth metatarsal where it is lost in tissue not yet distinctly differentiated.

In somewhat older embryos the tendon of the muscle may be followed as it develops across the sole of the foot toward the base of the first metatarsal. In an embryo 20 mm. long the tendon is intimately fused with the scleroblastema of the foot and can be distinctly followed only partially across the sole. In an embryo 30 mm. long the tendon can be followed to the first metatarsal, but it is considerably later than this when the tendon becomes free in its sheath. In an embryo 14 mm. long,

Plate IX, Fig. 1, the tendon passes lateral to the anlage of the lateral malleolus. In one of 20 mm. it passes behind this anlage (Plate IX, Fig. 2).

Proximally in an embryo 20 mm. long (Plate IX, Fig. 2) the origin of the muscle extends to the lateral condyle of the tibia next to the attachment of the m. flexor digitorum longus. At this period the two heads characteristic of the adult muscle may be distinguished.

A nerve may be seen entering the anlage of the peroneus longus in embryo CXLIV (Plate IX, Fig. 1) and in embryo XXII (Plate IX, Fig. 2) two nerves to the muscle may be seen. One of these enters the deep surface of the anterior head, the other passes distally into the posterior head.

From the peroneal nerve as it passes beneath the muscle two branches usually arise in the adult. One of these passes to the central third of the anterior portion of the muscle, the other extends down across the middle third of the deeper muscle bundles which run obliquely from the fibula to the tendon of the muscle. The latter branch may arise from the n. peroneus superficialis and it may extend to supply the m. peroneus brevis.

The *M. peroneus brevis,* (Plate IX, Figs. 1 and 2) arises proximally under cover of the peroneus longus and relatively higher up on the fibula than in the adult. It lies a little more on the flexor side of the leg than the peroneus longus. When first developed the tendon of insertion of the muscle is closely associated distally with that of the m. peroneus longus. It lies somewhat near the m. extensor digitorum brevis, but, as mentioned above, I can find no such intimate union with this muscle as that which Schomburg describes as lasting till the third month of development. It is attached to the base of the fifth matacarpal in an embryo 20 mm. long (Plate IX, Fig. 2).

In an embryo 14 mm. long (Plate IX, Fig. 1) a branch of the peroneal may be seen entering the muscle. In one 20 mm. long (Plate IX, Fig. 2) this branch may be readily followed beneath the peroneus longus to the peroneus brevis which here occupies a more distal position than in the 14 mm. embryo. In the adult the nerve may arise either from the distal nerve to the peroneus longus or from the n. peroneus superficialis. The nerve enters the proximal margin of the muscle and extends distally about midway between the origin and insertion of the constituent fibre bundles.

In amphibians the femoro-fibularis, which extends from the lateral epicondyle of the femur to the fibula probably represents the peroneal musculature of the higher vertebrates. In the reptiles two peroneal muscles are recognized, the peroneus anterior and peroneus posterior (Gadow, 82). The m. peroneus anterior extends in most forms from the proximal extremity of the fibula to the base of the fifth metatarsal. The peroneus posterior in crocodiles is more or less fused with the gastrocnemius and extends from the extensor musculature of the thigh to the calcaneus. In Hatteria and many saurians it is more or less fused with the peroneus anterior and extends from the lateral condyle of the femur to the outer side of the fifth metatarsal (Gadow, 82). In the mammals the peroneal group consists in most forms of three muscles, a peroneus longus, peroneus brevis, and peroneus extensorius.

The peroneus longus may be inserted into the base of the fifth metatarsal or into various structures in the sole of the foot, as far as the base of the first metatarsal. In Ornithorhynchus the tendon of this muscle may be followed to this last insertion.

The peroneus brevis and peroneus extensorius in Ornithorhynchus constitute a muscle, one part of which sends tendons to the extensor surface of the terminal phalanges of the first four toes, the other to that of the fifth toe. In marsupials the peroneus brevis is distinct from the peroneus extensorius. The latter arises from the lateral condyle of the femur and from the fibula and sends tendons to the second and fifth toes. In rodents the peroneus extensorius sends tendons to the fourth and fifth toes. In carnivora it sends a tendon to the fifth toe. In some apes the peroneus extensorius is differentiated and sends a tendon to the fifth toe. In others it is not isolated from the peroneus brevis. In man a peroneus extensorius (peroneus quartus of Le Double) is not infrequently found as a variation under most diverse forms. Most frequently the tendon only is isolated and is inserted into the fifth metatarsal, cuboid, calcaneus, etc. The tendon of the peroneus brevis frequently sends expansions to the tendon of the fifth toe, that of the fourth toe, the metatarsal of the fourth toe, etc. In normal embryonic development, however, the peroneal musculature does not seem to become connected with the extensor tendon plate.

b. Nerve Distribution.

The nerves to the peroneal muscles probably arise from the more distal spinal nerves which go to form the peroneal nerve, but this cannot be satisfactorily determined by dissection.

The nerves to the peroneal muscles (brevis and longus) may arise from the main trunk of the n. peroneus, from the n. peroneus superficialis, or from both. In 15 out of 20 instances a single branch passed from the n. peroneus superficialis to the peroneus brevis, in one instance two such nerves were given, in four instances the nerve arose from the more distal branch to the peroneus longus.

In three instances out of 20 a single nerve branch ran from the n. peroneus to the peroneus longus muscle; in 8 instances two such branches. In four of these cases the second branch sent a nerve of supply to the peroneus brevis. In four instances the nerves of supply of the peroneus longus arose from the n. peroneus superficialis (by one branch in one instance). In five instances a proximal branch (in one instance, two) arose from the n. peroneus and a more distal branch from the n. peroneus superficialis.

In some of the instances above cited the nerves of supply subdivided before entering the muscle.

IX. MUSCULATURE OF THE EXTENSOR SIDE OF THE CRUS AND FOOT.

a. Embryonic Development.

1. General Features.

In an embryo of 11 mm. (Plate III, Fig. 2) the peroneal nerve extends over the dorsal surface of the limb-bud and ends in a mass of slightly differentiated myogenous tissue, the anlage of the extensor muscles of the leg and foot. This anlage is more or less fused with the anlage of the peroneal muscles.

In an embryo 14 mm. long (Plate IX, Fig. 1) the peroneal nerve has given rise to the nn. peroneus superficialis and profundus. The n. peroneus profundus may be traced to the region between the bases of the first two metatarsals. Above and on each side of it may be distinguished muscle anlages representing the extensor muscles of the leg and foot. To these muscle anlages nerves are given as shown in the figure. The tendons of the extensor digitorum and extensor hallucis proprius are represented by a sheet of tissue in which the segmentation is just beginning. The conditions here described correspond well with those pictured by Schomburg, oo, except in a few minor details to which attention is called in considering the development of the individual muscles.

In an embryo of 20 mm. (Plate IX, Fig. 2) the individual muscles and their tendons, as well as the nerves distributed to them, indicate clearly relations corresponding in many features with those characteristic of the adult.

2. Individual Muscles.

Tibialis anterior.—The anlage of this muscle becomes distinct from the general dorsal myogenous sheet of the limb-bud during the sixth week. In an embryo of 14 mm. (Plate IX, Fig. 1) the muscle anlage is most distinctly differentiated in the region where the two nerves are extending into it. From here it may be followed distally into a broad tendon which fades out over the region of the first cuneiform and the base of the first metatarsal. In an embryo of 20 mm. (Plate IX, Fig. 2) the muscle has made tendinous attachments which correspond with those of the adult and the chief nerve branches have extended for a considerable distance into the muscle.

In the adult muscle as a rule several small branches extend into the upper extremity of the muscle and one or two large branches enter the middle third of the muscle. Within the muscle these branches run in intramuscular septa and are distributed chiefly across the middle third of the component muscle bundles. These run obliquely from their origin from the tibia and surrounding aponeurotic sheets to the tendon of insertion which arises high in the muscle.

The anterior tibial muscle is probably represented in the urodeles by the femoro-tibial muscle which extends from the lateral epicondyle of the femur to the tibia and os tarsale tibiale and is more or less fused with the femoro-digital or long extensor muscle. In reptiles and mammals the anterior tibial is fairly constant in general relations. It arises in most mammals from the proximal end of the tibia and is inserted into the lateral side of the tarsus or into the first metatarsal. In many mammals, including monkeys and apes, the muscle is partially divided into two portions from one of which a tendon goes to the metatarsal of the big toe (abductor hallucis longus), the other to the first cuneiform. This division may affect merely the tendon of insertion or extend into the belly of the muscle. In man there is not infrequently (25% of bodies, Le Double) a similar division of the terminal tendon but this rarely extends to the belly of the muscle. Schomburg, oo, describes a distinct division of the anlage of the tibialis anterior in the embryo into two parts, that toward the tibial side representing an abductor hallucis longus. This division does not appear in the embryos I have examined.

Extensor digitorum longus.—From the central portion of the dorsal myogenous sheet the extensor digitorum longus and the extensor hallucis longus are differentiated simultaneously (Plate IX, Fig. 1). The extensor digitorum occupies a position relatively more fibularwards than in the adult. It is broad and ends below in a broad flattened process, or tendon plate, at the center of the dorsum of the foot. There is no very distinct division into special tendons. Two nerve branches extend to the deep surface of the muscle where this overlies the n. peroneus profundus. Schomburg, oo, has described conditions in a six weeks embryo which do not differ very essentially from those here given.

In an embryo of 20 mm. (Plate IX, Fig. 2) we find that tendinous attachments have extended to the digits from the tendon plate and that proximally the muscle has extended more toward the tibia. The nerve supply corresponds with that of the adult.

In the adult as a rule two chief nerve branches arise from the n.

peroneus profundus. One of these runs to the muscle near its upper extremity and passes distally across the central third of the obliquely placed fibre bundles of the proximal portion of the muscle. The other branch leaves the n. peroneus profundus more distally, extends to the middle or lower third of the muscle and then distally across the middle third of the obliquely placed fibre bundles of the lower portion of the muscle and across the corresponding fibre bundles of the m. peroneus tertius. The two nerves may be bound up in one trunk or their place may be taken by a considerable number of branches, but in 9 cases out of 10 essentially the arrangement described may be found.

The extensor digitorum longus and extensor hallucis longus are represented in urodeles by the femoro-fibulæ-digiti I-V which extends from the lateral epicondyle of the femur and from the fibula to the foot and thence by means of tendinous processes to the phalanges (Hoffmann). In reptiles the two muscles are probably[20] also represented by the extensor digitorum longus which in most reptiles arises from the lateral epi-condyle of the femur and is inserted by tendinous slips into the bases of some of the metatarsals. In chelonians it is inserted by tendons into the phalanges (Gadow, 82). In the mammals the extensor digitorum and extensor hallucis are distinct in most forms. The extensor digitorum arises chiefly from the proximal part of the tibia and is united to the back of the toes by tendinous process which vary considerably in different forms (Ruge, 78). In man doubling of the digital tendons and aberrant tendon slips are very frequent (Le Double). Early in embryonic development, as we have seen above. the tendons are represented by a tendon plate. In the adult the tendons may be connected by an uninterrupted aponeurotic lamella or by tendinous slips, conditions normal in many of the lower mammals. Occasionally in man slips from the tendons of the long digital extensor pass to the first, fourth, or fifth metatarsals (Testut). This corresponds to the attachment of the extensor tendons to the metacarpals found in reptiles. In the human embryo the extensor tendon plate is at first connected with the metatarsal scleroblastema but is gradually separated from this as development proceeds.

M. peroneus tertius.—Schomburg, 00, finds this muscle distinct from the extensor digitorum pedis longus even in the sixth week. In the two embryos in which I have made the most careful study of these muscles (144, length 14 mm., Plate IX, Fig. 1; and 22, length 20 mm., Plate IX, Fig. 2) I have been unable to find a sharp distinction between the two muscles, although the tendon of the peroneus tertius in embryo 22 is quite distinct from that of the extensor digitorum longus. Schomburg finds the tendon of the m. peroneus tertius runs at first toward the third

[20] It is possible that the m. extensor hallucis proprius of reptiles is homologous with the extensor hallucis longus of mammals. It seems more likely that it should be classed with the dorsal pedal muscles.

metatarsal, but I have found no such condition in the embryos studied. The tendon when differentiated runs toward the fifth digit. The nerve supply of this muscle, described above in connection with the extensor digitorum longus, serves to support the contention of Gegenbaur that the m. peroneus tertius is but a differentiated portion of the extensor digitorum pedis longus. It varies greatly in size and is frequently fused with the m. extensor digitorum longus. Its tendon may terminate on the fourth metatarsal. Rarely a tendon slip is given to the extensor tendon of the little toe (Le Double).

M. extensor hallucis longus. Even at an early stage this muscle may be distinguished from that of the m. extensor digitorum longus as Schomburg, 00, has pointed out. Its tendon at first is fused with the tendon plate of the extensor digitorum longus (Plate IX, Fig. 1), but soon begins to acquire some independence (Plate IX, Fig. 2).

The nerve of supply in embryos CXLIV and XXII enters the muscle near the center of its oblique tibial border. As a rule in the adult the nerve approaches the tibial border and passes distally across the oblique muscle bundles midway between their origin and insertion. This single trunk may, however, be replaced by two or more branches arising independently from the n. peroneus profundus.

Variations in the muscle are most frequently found with respect to its tendon of insertion. The tendon may divide into two or more parts. In one instance it has been found sending a slip to the second toe. The body of the muscle may be more or less fused with that of the m. extensor digitorum longus.

The extensor hallucis longus is to be looked upon as an especially differentiated deep portion of the extensor digitorum longus. Occasionally in man there is found arising from the fibula a special long extensor of the second toe (Gruber, 75). This is homologous with the extensor indicis proprius of the forearm. Chudzinski, 74, has described a deep extensor sending tendons to the first metatarsal, to the second and third, and to the fourth and fifth toes, an arrangement corresponding somewhat to one normal in several mammals (marmot, porcupine, beaver, Le Double). Both the extensor hallucis longus and the extensor digitorum longus are connected with the dorsal tendon plate in the embryo at an early stage. Normally a tendon for the first toe develops from the deep surface of this plate in connection with the extensor hallucis longus muscle, but the variations found in the adult show that the primitive tendon plate may be variously subdivided during embryonic development. The tendon of the extensor hallucis may send a tendon to the first metatarsal or to the second toe, etc. (W. Gruber, 75).

Mm. extensor digitorum brevis.—This muscle becomes differentiated beneath the extensor tendon plate and is best developed on the fibular side of the dorsum of the foot. At the end of the sixth week, as pointed out by Schomburg, the muscle mass is not differentiated into special parts (Plate IX, Fig. 1), but toward the end of the second month the bellies of which it is composed and their tendons begin to stand out distinctly (Plate IX, Fig. 2). The differentiation of the terminal tendons begins on the fibular side and extends toward the tibial. The nerve to this muscle mass arises at an early stage from the n. peroneus profundus and extends across its deep surface. In the adult this nerve extends across the component muscle bundles about midway between their tendons of origin and insertion.

Extreme variability is shown in the form of this muscle in the adult. It may be absent or be reduced to two or three bundles or there may be an unusual development of the muscle and the differentiation into bellies corresponding to the digital tendons. The *m. ext. hallucis brevis* is the most frequently isolated of these bellies.

The extensor digitorum brevis doubtless represents the remains of an intrinsic dorsal pedal musculature relatively better developed in urodeles and reptiles than in most mammals. In most urodeles (Ribbing, 06) and reptiles (Gadow, 82) the extensor tendons of the toes arise from these pedal muscles and the "extensor digitorum longus" tendons are inserted into the bases of certain of the metatarsals. The great variation in the development of the extensor digitorum brevis in man is well known. It seems to be relatively better developed in the embryo than in the adult.

b. Nerve Distribution.

The relations of the nerves supplying the muscles under consideration to the spinal nerves cannot be clearly made out by dissection. It is probable, however, that the nerves supplied to the more tibially situated muscles contain the greater number of the fibres springing from the 4th lumbar nerve, and the nerves passing to muscles situated most to the fibular side contain the greater number of fibres from the 1st sacral nerve.

Variation in the Branches of Distribution Arising from the N. Peroneus Profundus.

The nerve to the extensor digitorum brevis seems to be constant in its general relations, although the height at which it springs from the main trunk varies greatly.

The nerves to the remaining muscles show considerable variation owing to the fact that the nerves to a given muscle may arise as successive branches from the main nerve trunk or they may be combined into a single nerve of distribution which has a proximal origin and as it passes distally gives off successive branches which pass to the middle third of the obliquely placed fibre bundles comprising the muscle. Usually the nerve to the peroneus tertius arises in common with the nerve that is distributed to the more distal portion of the m. extensor digitorum longus. The following table, XXVI, shows the number of branches which passed in 20 instances from the main trunk to each of the muscles under consideration. Often a branch subdivides before entering the muscle. In the part treating of the individual muscles the most frequent form of nerve distribution for each muscle is described.

TABLE XXVI.

Tibialis anterior.

	No. of instances.
1 br. to proximal portion. 1 br. to center of muscle	7
2 brs. to proximal portion. 1 br. to center of muscle	6
1 br. to proximal portion. 2 brs. to center of muscle	3
2 brs. to proximal portion. 2 brs. to center of muscle	4
	20

The branches to the proximal portion are closely associated with an articular branch to the knee and in almost all instances arise from the peroneal nerve trunk before the n. peroneus profundus separates from the n. peroneus superficialis.

Extensor digitorum longus (e. d. l.) and peroneus tertius (p. t.).

1 br. to proximal portion e. d. l. 1 br. to central area e. d. l. and p. t.	8
1 br. to e. d. l.[21]	5
1 br. to proximal portion of the e. d. l. 1 br. to central area e. d. l. 1 br. to p. t.	5
1 br. to proximal portion e. d. l.	1
1 br. to proximal portion e. d. l. 1 br. to central area e. d. l., to extensor hallucis, and to p. t.	1
	20

Extensor hallucis.

1 branch	11
2 branches	4
3 branches	4
Branch arose with distal branch to ext. dig. longus	1
	20

[21] In one instance two separate branches to p. t.; in one, one branch to p. t.; in three instances p. t. not present.

X. MUSCULATURE OF THE PLANTAR SIDE OF THE CRUS AND FOOT.

a General Features.

In an embryo 11 mm. long (Plate III, Fig. 1) the tibial nerve divides below the knee into two branches. Of these that on the tibial side represents the medial plantar, that on the fibular side the lateral plantar nerve.[22] The lateral plantar branch descends to the tarsus, the medial plantar nerve not so far distally. Near the knee a mass of slightly differentiated tissue lying superficial to the nerve represents the gastrocnemius-soleus group of muscles. Beneath the nerves beyond this region a mass of slightly differentiated tissue represents probably the anlage of the deep muscles of the calf and possibly of some of the musculature of the sole of the foot.

In an embryo 14 mm. long (Plate IX, Figs. 3 and 4) the muscles of the plantar side of the leg are so far differentiated that the individual muscles can be fairly clearly made out. In the drawing for the sake of definiteness the outlines of these muscles are made diagrammatically sharp but the main relations shown are true to the conditions found in the embryo. Two groups of muscles may be distinguished, a superficial lateral group composed of the gastrocnemius, soleus, and plantaris; and a deep more medially placed group consisting of the flexor hallucis longus, flexor digitorum longus, the popliteus, and the tibialis posterior. The gastrocnemius group is connected by a mass of tissue with the blastema of the calcaneus. The two long flexor muscles are connected by condensed tissue with a flat aponeurotic "foot-plate" from which tendinous processes extend to the blastema of the metatarsals and toes. The medial and lateral plantar nerves extend independently from the region of the knee to the foot. Near where they arise there is a plexiform arrangement of the fibres of the tibial nerve and from the back of this plexus arise the nerves to the deep muscles of the back of the leg and to the deep surface of the soleus muscle. The nerves to the gastrocnemius-soleus group, with the exception just mentioned, arise from the plantar surface of the tibial nerve proximal to where this changes its course from the thigh into the leg. In the foot the medial plantar nerve spreads out superficial to the pedal aponeurosis while the lateral plantar nerve crosses medially beneath it. Along the course of the medial plantar

[22] In the article by Bardeen and Lewis, 01, the two divisions of the tibial nerve are represented combined into a single trunk too far distally.

nerve in the foot a mass of slightly differentiated tissue represents probably the anlage of the musculature subsequently innervated by this nerve.

The general relations of the plantar nerves at this period are strikingly similar in many ways to the plantar nerves in the crus of the lower mammals as recently pictured by McMurrich in this journal (04) and offer analogies with types there pictured by him for the lower vertebrates. The chief difference between the nerves of the plantar side of the crus of mammals and that of the reptiles and amphibia is, as McMurrich has pointed out, the path for the fibers going to the medial side of the foot. In the mammals the nerve fibers take a course superficial to the deep muscles of the crus; in the inferior vertebrates they take a course in part beneath the deep muscles. In the amphibia and reptiles the nerve fibers for the medial side of the foot are more or less bound up with the nerves to the deepest muscles of the crus; in the mammals they are more or less bound up with nerves to the more superficial muscles. The nerve for the lateral side of the foot runs in most forms between the superficial and the deep musculature of the crus.

In an embryo 20 mm. long (Plate IX, Figs. 5 and 6) the various muscles of the plantar side of the leg are much more highly differentiated than in the 14 mm. embryo. The soleus and gastrocnemius muscles have begun to extend tibialwards over the tibial nerve. The tendon of Achilles is well differentiated. The long flexor muscles are attached to an aponeurosis from which tendons extend to the digits. The popliteus muscle is clearly marked. The tibialis posterior is inserted into the side of the skeleton of the foot near the base of the first digit. In the foot the anlages of most of the intrinsic muscles can be distinguished but here the muscles are but incompletely differentiated. A group of muscles innervated by the lateral plantar nerve is to be distinguished from one innervated by the medial plantar nerve.

The lateral and medial plantar nerves in this embryo are fused into a common trunk as far as the ankle. The nerves to the gastrocnemius-soleus group arise from the plantar surface of the tibial nerve in the thigh. To the deep surface of the soleus, however, a branch is given which arises from the deep surface of the tibial nerve in the leg. From this surface arise the nerves for the deep muscles of this region. In the foot the distribution of nerve branches to the muscles corresponds with that found in the adult.

b. Embryonic Development and Variation in the Nerve Supply in the Adult of Each of the Chief Groups of Muscles.

The development of the individual muscles of the back of the leg and foot can best be followed by taking them up according to the groups which develop from common anlages. We shall therefore first take up the gastrocnemius-soleus group, then the deep musculature of the back of the leg, then the musculature innervated by the lateral plantar, and finally that innervated by the medial plantar nerve. The nerve supply of the muscles of the back of the crus is taken up after treating the embryonic development of the two sets of muscles in this region; the nerve supply of the plantar musculature is taken up after considering the differentiation of the plantar muscles.

1. Development of the Gastrocnemius-soleus Group.

M. gastrocnemius.—As pointed out by Schomburg, **oo**, the lateral portion of the flexor plate of the leg gives rise to the gastrocnemius and soleus muscles. The anlage of the gastrocnemius is the more lateral and superficial of the two muscles and shows two incompletely separated heads (Plate IX, Fig. 3). These heads are connected by a fairly dense tissue with the anlage of the calcaneus but do not extend across the tibial nerve to the femur. During the latter half of the second month the heads of the gastrocnemius develop rapidly. In an embryo of 20 mm. (Plate IX, Fig. 5) the lateral head of the gastrocnemius has formed a tendinous attachment above the lateral condyle of the femur while the medial head has not yet quite reached its final destination. The nerves to the gastrocnemius enter each head of the muscle soon after the anlages appear. The nerves may be readily distinguished in an embryo of 20 mm. (Plate IX, Fig. 5).

In the adult the fibre bundles of each head of the gastrocnemius take an oblique and nearly parallel, though somewhat diverging, course from the tendons of origin to the tendon of insertion. The nerve to each head enters about the middle third of the superior margin of the muscle and its main branches take a course distally across the obliquely running fibre bundles, a course corresponding to the course of the nerve in the embryo.

M. soleus.—The anlage of this muscle is closely associated with that of the gastrocnemius. It lies beneath and projects beyond the tibial margin of the gastrocnemius (Plate IX, Fig. 4). It arises on the upper end of the fibula and distally extends into an anlage of the tendon of Achilles. At first it is as large as the gastrocnemius. During subsequent development it extends over the posterior tibial nerve to be attached to the tibia. This attachment is not completed in an embryo of 20 mm. (Plate IX, Fig. 6). The nerves for the muscle arise at an early stage as shown in Plate IX, Fig. 4. Their distribution in an embryo of 20 mm. is shown in Plate IX, Fig. 6.

In the adult the superior nerve to the soleus enters the superficial surface near the superior border and divides into two main branches, one for the tibial and one for the fibular side. The inferior nerve to the soleus divides, usually before it enters the muscle, into two branches, one for the distal portion of the fibular, the other for the distal portion of the tibial side of the muscle. From both nerves branches may usually be followed both to the main body of the muscle and to the specialized bi-pennate portion visible on its deep surface.

M. plantaris.—According to Schomburg, oo, the anlage of this muscle arises proximal to the soleus and on the tibial side of the gastrocnemius. In embryo CXLIV, length 14 mm., the muscle mass is not clearly differentiated from the anlages of the soleus and gastrocnemius but what I

TABLE XXVII.

Amphibia.	Lacertilia.	Opossum.	Higher Mammals.
Plantaris sup. med. [Ischio-flexorius, Hoffmann.]	Plantaris sup. med. [Gastrocnemius, cap. int., Gadow.]	Gastrocnemius med.	Gastrocnemius med.
	Plantaris sup. lat. [Gastrocnemius, cap. ext., Gadow.]	Gastrocnemius lat.	Gastrocnemius lat.
Plantaris sup. lat. [Femoral head sup. flexor.]	Plantaris sup. access. [Flex. long. dig., cap. fem., Gadow.]	Plantaris.	Plantaris.
	Plantaris sup. tenuis. [Flex. long. dig., cap. access., Gadow.]		Popliteus. (Sup. portion)
Plantaris prof. III. [Flex. subl. dig., Hoffmann.]	Plantaris profundus III-II. [Flex. long. dig., cap. int., Gadow.]	Gastrocnemius lat. (Soleus portion.)	Soleus.
Plantaris prof. II. [Fem. fib. metatars. I-III. Hoffmann.]		Flexor fibularis.	Flexor fibularis.

take to be the anlage of the plantaris is a small mass of tissue situated anterior to the main soleus mass and partly covered by the gastrocnemius (Plate IX, Fig. 4). Even in embryo XXII, length 20 mm., the muscle cannot be made out distinctly. I have represented in Plate IX, Fig. 6, what I take here to be the anlage of the plantaris muscle. It is closely associated with the lateral head of the gastrocnemius. No traces of the tendon were found in the early embryos I have studied, nor did Schomburg find any in the leg reconstructed by him.

Comparative anatomy of the gastrocnemius-soleus group.—McMurrich in this journal has recently (04) given an important account of the comparative anatomy of the crural flexors from the standpoint of muscle layers as seen in cross-section. He tabulates the relationships of the gastrocnemius-soleus group as shown in Table XXVII.

In the development of the human embryo it has been shown that two fairly distinct chief myogenous regions are to be distinguished on the plantar side of the crus and that one of these gives rise to the gastrocnemius-soleus group, the other to the deeper muscles of the back of the leg. Both Eisler (1895) and McMurrich have performed a distinct service in again emphasizing that in the vertebrate series a superficial plantar musculature of the crus is to be distinguished from a deep plantar musculature. In many mammals, at least, including man, the two layers of musculature are separated by a fascial septum which passes from the fibular to the tibial side of the leg and in which run the main nerves and blood-vessels of the back of the crus. In the reptiles also there appears to be a similar fairly distinct division between the superficial and the deep plantar muscles of the crus. In them, however, the muscles called plantaris superficialis tenuis and plantaris superficialis accessorius by McMurrich seem to be related proximally to the superficial musculature while distally they are inserted into the deep musculature. The plantaris superficialis tenuis lies chiefly superficial to, the plantaris superficialis accessorius, chiefly deeper than the nerve trunks which correspond with the nn. plantaris medialis and lateralis of the mammals (rr. superficiales medialis and lateralis of McMurrich). In the amphibia there seems to be a distinct division between the deeper musculature and a superficial group of muscles composed of the muscles called by McMurrich the plantaris superficialis medialis, the plantaris superficialis lateralis and the plantaris profundus III. Comparing the conditions found during embryonic development of the human crus with those present in the legs of the lower mammals and inferior vertebrates I should prefer to rearrange McMurrich's table as shown in Table XXVIII.

TABLE XXVIII.

Urodela.	Reptilia.	Marsupalia.	Man.
Ischio Flexorius.	Crural Tendon of flex. tib. ext.	Fascial Insertions of Flexors of Knee.	Fascial Insertion of Biceps, Semitendinosus and Gracilis.
Plantaris sup. minor, (Eisler.) [Plant. prof. III, minor, Mc.M.]	Plantaris sup. med.	Gastrocnemius med.	Gastrocnemius med.
Plantaris sup. major, (Eisler). [Plant. prof. III, Mc. M.]	Plantaris sup. tenuis.	Plantaris.	Plantaris.
Plant. sup. lat. (Mc. M.)	Plantaris sup. lat.	Gastrocnemius lat.	Gastrocnemius lat.
	Plantaris sup. access.		Soleus (all but deep portion.)

It seems probable that the muscles into which the superficial musculature of the plantar surface of the crus becomes divided are not perfectly homologous in the amphibia, reptiles, and mammals, although there are some obvious similarities.

In the mammals the homologies seem more certain. McMurrich considers the medial head of the gastrocnemius to be a muscle primitively distinct from the lateral head. He bases this conclusion on the fact that in many of the lower mammals each head forms a distinct muscle. The ontogeny of the muscle in man indicates that the two heads are derived from an anlage situated on the fibular side of the leg. The twisting of the tendon of Achilles may be explained by the shifting which the muscle undergoes during ontogeny. Embryological development in man supports the idea advocated by McMurrich that the plantaris is a derivative of the deeper portion of the lateral head of the gastrocnemius. When absent it is likely that this separation has failed to take place during ontogeny. In many mammals it is not differentiated (several edentates, carnivora, etc.); in others, especially in some rodents (Leche), it is highly developed. The soleus is considered by McMurrich to be derived from the profundus musculature of the crus. It seems to me likely that the deep portion of the soleus, innervated by the distal nerve to that muscle may be thus derived from the profundus musculature although I have been able to distinguish no such special anlage in the development of the muscle in man. In the monotremes the soleus is bound up with the lateral head of the gastrocnemius. This arises from the epiphysial process of the fibula. It forms a part of the lateral head of the gastrocnemius in marsupials, in most edentates, in the chiroptera and galeopithecidæ, several carnivora, ungulates, and prosimians (Leche). The great number of mammals in which it is thus undifferentiated as a distinct muscle indicates strongly that its phylogenetic as well as its ontogenetic origin is, in the main at least, from an anlage common to it and the gastrocnemius. Eisler, 95, regards it as derived from the gastrocnemius lateralis.

The variations in the muscles of the soleus-gastrocnemius group in man seem to be essentially due to a greater or less separation of the original anlage into independent muscles. The fascial extension of the biceps, semitendinosus and gracilis, which I take to represent the plantaris superficialis medialis (McMurrich) of the amphibian crus, may be muscular instead of tendinous and may be somewhat fused to the gastrocnemius.

2. Development of the Deep Muscles of the Back of the Crus.

a. M. Popliteus.—In an embryo 14 mm. long (Plate IX, Fig. 4) I have been unable to distinguish clearly a popliteus muscle. The anlage of the muscle doubtless lies in the dense tissue posterior to the tibial nerve and proximal to the anlage of the m. tibialis posterior. There is a differentiation of tissue there which indicates this. This tissue is outlined in the drawing. In an embryo of 20 mm. (Plate IX, Fig. 6) the muscle is well defined, has the skeletal relations characteristic of the adult and at its distal border there enters a well marked nerve of supply. Schomburg does not mention this muscle in his article.

In the adult the nerve usually enters the muscle near the center of its distal edge. Often some of the branches of this nerve extend into the posterior surface of the muscle. Rarely a slender second branch enters the superior margin of the muscle (2 in 25 instances).

The place of the popliteus is taken in the lower mammals, the amphibia and reptiles by an interosseous muscle, pronator tibiæ, which passes obliquely from the fibula to the tibia. A popliteus muscle corresponding essentially to that of man is found in nearly all mammals except the monotremes and marsupials. A popliteus in addition to a pronator tibiæ is likewise described for Myrmecobius (Leche). The popliteus is said to be absent in most chiroptera (Leche). In the dog in addition to the popliteus there is a small fibulo-tibial muscle in the proximal part of the interosseous space. A similar muscle (the peroneo-tibialis, Gruber) has been found in a number of mammals and not infrequently as a variation in man (128 times out 860 instances, Gruber). It seems probable that the popliteus is an especially differentiated portion of the fibulo-tibial muscle of the lower vertebrates, and that its origin has extended from the fibula to the lateral condyle of the femur. Eisler, 95, considers it homologous with the brachialis anterior of the arm. According to McMurrich the muscle in the mouse receives two nerve branches, one associated with that for the soleus from the "internal popliteal stem," the other from the deep muscle nerve of the crus. The former is supplied to the more tibial oblique-fibered portion of the muscle, the latter to the more vertical fibular portion. From these facts McMurrich concludes that the popliteus is a compound muscle consisting of a portion derived from the "plantaris superficialis" and a portion which represents a part of the pronator tibiæ of the marsupials and the interosseous of the lower vertebrates. That it is therefore similar to the pronator teres of the arm. While this may be true of the muscle in some of the mammals it does not seem to be true for the muscle as it is found in man. A double innervation is infrequent in man. During embryonic development the muscle appears to come from a single anlage which lies deeper than the tibial nerve. Gordon Taylor and Victor Bonney, 05, conclude that the popliteus is homologous with the deep portion of the pronator teres while the superficial portion of the pronator teres is homologous with the gastrocnemius. Occasionally in man a second head may arise medially from above the lateral condyle. This may possibly be equivalent to the superficial portion of the pronator teres. According to Le Double the m. popliteus biceps coincides frequently with the absence of the plantaris.

b. Deep cruro-pedal group. M. flexor hallucis longus.—The anlage of this muscle is distinct from those of the other muscles of the calf in an embryo of 14 mm. (Plate IX, Figs. 3 and 4). Lateral to the anlage lies the calcaneus, the tendon of Achilles and the distal end of the soleus. On the tibial side it slightly overlaps the anlage of the tibialis posterior. Proximally it extends nearly to the head of the fibula. It lies beneath the n. plantaris lateralis which in this embryo separates high up from the n. plantaris medialis. Distally it terminates in an aponeurosis common to it and the m. flexor digitorum longus. The nerve enters the proximal extremity of the muscle anlage.

In an embryo 20 mm. long (Plate IX, Figs. 5 and 6) the muscle occupies a relatively somewhat more proximal position and is somewhat more under cover of the soleus. It is attached to the blastema of the shaft of the fibula and distally is inserted into the deep surface of the plantar aponeurosis. The nerve runs along and enters the tibial margin of the muscle.

In the adult the nerve or nerves to the muscle run along its tibial margin or deep surface and send twigs into its substance.

M. flexor digitorum longus.—This is differentiated from an anlage medial to that of the m. flexor hallucis longus. In the 14 mm. embryo (Plate IX, Fig. 3) it lies beneath the n. plantaris medialis which gives two branches to the upper extremity of the anlage. The muscle extends into a somewhat irregular plantar aponeurosis of which mention has been made in connection with the m. flexor hallucis longus. The tendons are partially differentiated. The anlage of the muscle nearly covers that of the m. tibialis posterior. Schomburg found in the leg he reconstructed that the tibial side of the muscle had not reached the tibia. In embryo CXLIV this is also true. The tibial attachment has begun to take place in embryo XXII, length 20 mm. (Plate IX, Fig. 5). In this embryo also the pedal aponeurosis has become still further differentiated into tendons, but it is not yet possible to distinguish clearly the tendons belonging to the fibular flexor (flexor hallucis longus) from those belonging to the tibial flexor (flexor digitorum longus). Two nerves enter the muscle on its superficial surface. One of these extends to the fibular side of the muscle, the other to the tibial side. A similar arrangement is usually found in the adult.

M. tibialis posterior.—This muscle is formed from the deeper layer of the tibial portion of the flexor anlage near the lateral portion of the lower half of the tibia (Plate IX, Fig. 4). Its tendon is differentiated early and may be followed to the anlage of the navicular. In subsequent development, as pointed out by Schomburg, it develops in a proximal and lateral direction (Plate IX, Fig. 6). Its nerve enters near the tibial border of the anlage. In the adult the nerve enters the posterior surface of the muscle in its proximal third and gives off one or two branches for the tibial fasciculus. The main trunk descends across the centers of the fasciculi arising from the fibula.

Comparative anatomy of the deep plantar muscles of the crus.—Eisler, 95, and McMurrich, 04, consider that the flexor fibularis (hallucis) is derived from a layer primarily superficial to the layer from which the flexor tibialis (digitorum) and tibialis posterior are derived. McMurrich[23] bases this idea chiefly on the supposition that the flexor fibularis is supplied by the equivalent of the ramus superficialis medialis, while the flexor tibialis is supplied from the ramus profundus. In man, at least, the nerves passing to the two muscles are very frequently bound up for some distance in a common trunk. The flexor tibialis and tibialis posterior seem, however, to be more intimately connected during ontogeny than is either of these muscles with the flexor fibularis. In many mammals the tibialis posterior is absent (Leche). In these it may be undifferentiated from the flexor tibialis. On the other hand in several mammals the tibialis posterior is doubled, the deeper portion sending a tendon to various structures in the tarsus, or even to the base of the first phalanx of the big toe (Le Double, 97). The intimate relations between the tibial and fibular flexors are revealed by the fasciculi which so frequently have been found passing from one to the other as well as by their tendons (see Le Double, 97).

The tibial and fibular flexors are inserted primarily into a deep plantar aponeurosis in which tendons are developed in accordance with varied functions of the foot and digits (Keith, 94). The arrangement of the tendons varies greatly in different forms. In many forms the flexor tibialis is rudimentary. In the chiroptera it is highly developed. For the variation of the tendons in the anthropoids and man see Le Double, 97.

3. Nerve Supply of the Muscles of the Back of the Crus in the Adult.

a. Relation of Muscle Branches to the Spinal Nerves.

The difficulty of tracing these nerves back to their sources from the spinal nerves is so great that no statistical study of the subject has been attempted. It is evident, however, that the main bulk of the nerve fibres distributed to the gastrocnemius-soleus group has in general a somewhat more distal origin than those going to the deep muscles of the calf. The special dissections which I have made serve in the main to support the spinal nerve origins given in Quain's Anatomy. These are as follows: popliteus, 4th and 5th lumbar, 1st sacral; soleus, 5th lumbar, 1st and 2d sacral; gastrocnemius, 1st and 2d sacral; deep musculature of the calf, 5th lumbar, 1st and 2d sacral. The nerve to the plantaris is given as arising from 4th and 5th lumbar and 1st sacral, but the 5th lumbar, 1st and 2d sacral nerves seem to be the more probable sources of supply.

[23] According to McMurrich the flexor tibialis and tibialis posterior of the mammals are represented in the reptiles (Lacertilia) and amphibia (urodeles) by the plantaris profundus I (tibialis posterior of Gadow). The flexor fibularis is according to this author derived from a portion of the plantaris profundis III-II of reptiles (flexor longus digitorum, caput internum, Gadow) and the plantaris profundus II of the urodeles (femoro-fibulæ-metatarsales I-III, Hoffmann).

b. Order of Origin from the Tibial Nerve.

The most proximal branches given off are those to the gastrocnemius, the proximal branch to the soleus and the nerve to the plantaris muscle. Out of 19 instances the nerve to the plantaris was the most proximal branch in 9, the nerves to the gastrocnemius in 9, and in one instance the nerve to the plantaris, in conjunction with the branch to the lateral head of the gastrocnemius and the proximal nerve to the soleus. Usually the nerve to the medial head of the gastrocnemius arises slightly proximal to that to the lateral head. The latter arises near or in conjunction with the proximal nerve to the soleus muscle.

Next distal to the nerves to the plantaris and gastrocnemius muscles and the proximal nerve to the soleus arise the nerves to the popliteus and posterior tibial muscles. These nerves often arise from a common branch. When they arise separately the nerve to the poplitus is the more proximal in the great majority of instances.

Next distal usually comes the distal nerve to the soleus, although this nerve may arise proximal to the nerve to the tibialis posterior or in conjunction with this. Then follow the nerves to the flexor digitorum longus and to the flexor hallucis longus. The two latter frequently arise from a common trunk which may also be combined with the distal nerve to the soleus. The nerve to the flexor hallucis is almost always the most distal in origin of the nerves under consideration, but occasionally a distal branch to the flexor digitorum longus has a more distal origin (in two instances out of 34).

c. Relation to One Another of the Nerves to the Muscles.

Nerve to plantaris.—In all but one out of 21 instances the nerve to the plantaris muscle arose independently from the tibial nerve. In this instance it arose in conjunction with the nerve to the lateral head of the gastrocnemius and the proximal nerve to the soleus muscle. In one instance two nerves could be traced to the plantaris.

Nerve to medial head of gastrocnemius.—In one instance out of 35 two separate parallel branches passed into this head. Occasionally near its origin from the tibial nerve the nerve to the medial head of the gastrocnemius is bound up for a short distance with that to the lateral head.

Nerve to the lateral head of the gastrocnemius.—Out of 35 instances in 20 this nerve arose independently or in conjunction with that to the medial head from the posterior tibial; in 14, in conjunction with the proximal nerve to the soleus and in one in conjunction with the proximal nerve to the soleus and the nerve to the plantaris.

Proximal branch to soleus.—Out of 35 instances in 20 this branch arose independently, in 14 it arose in conjunction with the nerve to the lateral head of the gastrocnemius, and in one in conjunction with the nerve to the lateral head of the gastrocnemius and the nerve to the plantaris.

The above nerves form a group, the trunks of which may be more or less united with one another, but not with those of the following set.

Nerve to the popliteus.—This nerve arose independently in 15 out of 26 instances. In 10 instances it arose in conjunction with the nerve to the tibialis posterior and in one, with the distal nerve to the soleus and the nerve to the tibialis posterior. In two instances a secondary branch entered the superior edge of the muscle.

Halbertsma, 47, described a nerve which arises in the popliteal space, gives rami to the popliteus and posterior tibial muscles, and is continued distally, partly in the substance of the interosseous membrane, to the inferior tibio-fibular articulation. It gives branches to the superior tibio-fibular articulation, to the tibia and the interosseous membrane. When the nerves to the popliteus and tibialis posterior arise separately this nerve is continued distally either from nerve to the popliteus or, more rarely, from that to the tibialis posterior. McMurrich, 04, considers this branch to represent the important ramus profundus of amphibia and reptiles. This supplies the deep muscles of the plantar surface of the crus and is continued into the foot as the internal plantar nerve. In the lower mammals it ends at the ankle. In man another nerve arises from the nerve to the deep muscles and passes distally along the course of the peroneal vessels to the ankle. It gives branches to the shaft of the fibula and the medullary artery.[24]

Nerve to the tibialis posterior.—Out of 38 instances in 20 the nerve arose independently, in 5 it arose in conjunction with the nerve to the popliteus. In 5 instances it arose in two branches, one of which in each instance was associated with the nerve to the popliteus while the other in one instance was independent, in one was associated with the nerve to the flexor digitorum longus and in three with the distal nerve to the soleus muscle. In 4 instances the nerve to the tibialis posterior was associated with the distal branch to the soleus, in 3 with the nerves to the flexor digitorum longus and flexor hallucis longus muscles, and in one instance with the distal nerve to the soleus and with the nerve to the flexor digitorum and flexor hallucis.

Distal nerve to the soleus.—Out of 37 instances, in 20 this nerve arose independently. In 7 it arose in conjunction with a nerve to the posterior tibial muscle; in 4, in conjunction with one to the flexor digitorum longus

[24] Rauber, cited by G. D. Thane, Quain's Anatomy, 10th ed.

and flexor hallucis longus muscles; in 3, in conjunction with the nerve to the flexor hallucis muscle; in one in conjunction with that to the flexor digitorum; in one, in conjunction with that to the popliteus and posterior tibial muscles; and in one in conjunction with a nerve to the posterior tibial, flexor digitorum and flexor hallucis muscles.

Nerve to the flexor digitorum longus. Out of 36 instances, in 20 the nerve arose independently, in 6 of these by two separate branches; in 6 instances it arose in conjunction with the nerve to the flexor hallucis muscle; in 4 others, in conjunction with this and the distal nerve to the soleus. In three instances it arose in conjunction with the nerve to the flexor hallucis and that to the tibialis posterior muscle; in one, in conjunction with that to the tibialis posterior; in one, in conjunction with the distal nerve to the soleus; and in one, with the nerve of the tibialis posterior and flexor hallucis and the distal nerve to the soleus.

Nerve to the flexor hallucis muscle.—Out of 35 instances, in 18 the nerve arose independently, in two of these by two separate branches. In six instances the nerve arose in conjunction with the nerve to the flexor digitorum longus muscle; and in 4 other instances, in conjunction with this and the distal nerve to the soleus. In three instances it arose in conjunction with the distal nerve to the soleus; in three, in conjunction with the nerve to the flexor digitorum and tibialis posterior; and in one, in conjunction with the distal nerve to the soleus and the nerves to the tibialis posterior and flexor digitorum longus.

4. Development and Innervation of the Muscles Supplied by the Lateral Plantar Nerve.

To this group belong the quadratus plantæ, the abductor, flexor brevis, and opponens digiti quinti, the interossei, and the three lateral lumbrical muscles.

M. quadratus plantæ.—The anlage of this muscle appears in a 14 mm. embryo (Plate IX, Fig. 4) medial to the lateral plantar nerve as this curves about the tuber calcanei. Schomburg, 00, describes it in about the same position, but fused with the flexor hallucis longus at a nearly corresponding stage. In the 14 mm. embryo the nerve to the muscle is not distinct but in a 20 mm. embryo (Plate IX, Fig. 6) a well marked nerve enters its superficial surface from the deep surface of the lateral plantar nerve as this crosses the muscle. The muscle can readily be traced from the calcaneus to the deep surface of the plantar aponeurosis.

In the adult the nerve to the quadratus plentæ arises from the lateral plantar nerve near the medial margin of the muscle and crosses on or near the superficial surface of the muscle about midway between its origin and insertion and parallel with the tendon of the flexor digiti quinti longus. I have never seen the nerve for this muscle arise from the medial plantar nerve as described in the anatomy of Poirier and Charpy.

In the adult this muscle is frequently reinforced by a fasciculus which may arise from either of the bones of the crus, from one of the deeper muscles of the crus, from the deep muscle fasciæ, or from the calcaneus, Le Double, 97. The muscle may be inserted into any of the digital tendons, but most frequently into the 2d, 3d, and 4th; into that to the 5th toe less frequently; into that to the great toe rarely.

McMurrich, 04, on phylogenetic grounds thinks that the quadratus plantæ is differentiated from the distal end of the same deep layer of crural muscles from which are derived the tibialis posterior and the flexor digitorum (tibial flexor). Schomburg, on the other hand, considers it more intimately related to the flexor fibularis, a point of view strengthened by the fusion which he found between the quadratus plantæ and the flexor hallucis longus in a young embryo. As mentioned above, I did not find this connection in the 14 mm. embryo. Nor does the nerve supply of the muscle indicate a close union between it and the tibialis posterior or either the tibial or the fibular flexor.

The quadratus plantæ "is clearly represented in the lacertilia where it is supplied by a branch of the ramus profundus." (McMurrich, 04).

In monotremes it arises from the calcaneus (Leche). In the majority of marsupials it is probable that it exists in a rudimentary condition (McMurrich). In edentates it is absent in some forms, well marked in others. In some insectivora it is fused with the abductor metacarpi digiti minimi. In the higher mammals it is absent in some forms and well developed in others (*i. e.*, dog and cat). In some apes it is fused with the flexor digitorum tibialis (Leche).

M. abductor digiti quinti.—In the 14 mm. embryo (Plate IX, Fig. 4) the anlage of this muscle may be seen immediately distal to the tuber calcanei and lateral to the n. plantaris lateralis. In an embryo of a corresponding age Schomburg, 00, pictures the muscle as extending to the 4th metatarsal, but I have found no corresponding condition in the embryos I have studied. In embryo XXII, length 20 mm. (Plate IX, Fig. 6) the muscle extends to the base of the 5th metatarsal and has a more lateral position than in the 14 mm. embryo. At this stage a nerve may be seen extending into the medial margin of the muscle from the deep surface of the lateral plantar nerve.

In the adult the muscle is developed medially so as partially to overlap the lateral head of the m. quadratus plantæ. It varies greatly in structure. The main bulk of the fibre bundles usually extends somewhat obliquely from the calcaneus, the plantar fascia and the tendinous aponeurosis on the lateral side of the muscle near its origin to a tendon which extends high on the medial side of the deep surface of the muscle. Fibre bundles may also run from the calcaneus to the tuberosity of the fifth matatarsal and from this to the tendon of insertion. The more lateral and distal fibre bundles are those least frequently developed.

The nerve may be distributed either near the deep or near the superficial surface of the muscle. The former appears to be the case when the muscle is slightly developed. The chief muscle branches then extend across the middle third of the constituent muscle bundles near the deep surface. In case the calcaneo-metatarsal bundles are well developed a special branch may be sent to these. When the muscle is well developed the nerve enters the proximal margin of the muscle and its chief branches extend across the middle third of the more superficial muscle bundles finally terminating in those most distal bundles which lie on the lateral side of the fifth metatarsal. Other modes of distribution are also found but they agree in general features with those described.

Flexor brevis and opponens digiti quinti.—Beyond the anlage of the abductor digiti quinti the lateral plantar nerve in the 14 mm. embryo (Plate IX, Fig. 4) lies superficial to an ill-defined mass of tissue in which no segmentation into muscles can be made out. In the 20 mm. embryo (Plate IX, Fig. 6) a nerve branch extends from the lateral plantar nerve to the base of the 5th metatarsal and near the tip of this two slightly defined areas of partially differentiated tissue probably represent the anlages of the two muscles under consideration. According to Schomburg the anlage of these muscles lies at first in the area between the 4th and 5th metatarsals but for this statement I find no support in the embryos studied. According to Ruge, **78**, and Schomburg, **00**, the flexor brevis and opponens muscles arise from a common anlage which becomes later differentiated into the two muscles.

In the adult a single nerve is commonly distributed across the middle third of the bellies of each muscle.

Mm. interossei.—Ruge, **78**, called attention to the fact that the interosseous muscles with the possible exception of the first dorsal have a plantar origin and that later the dorsal interossei wander between the metatarsals to the dorsal surface. Schomburg, **00**, has confirmed this observation and has also shown that the dorsal interosseous I is originally plantar in position. In later embryonic stages Schomburg describes the dorsal interosseous II as extending on the plantar surface somewhat like the plantar interossei while the plantar interosseus I shows a tendency to wander dorsally like a dorsal interosseous.

The first signs of the interossei muscles which I have seen are ill-defined anlages in an embryo of 20 mm. (Plate IX, Fig. 6). To the proximal extremity of each anlage branches are given from the lateral plantar nerve. The later stages of development I have not followed out carefully.

M. adductor hallucis.—This arises, as pointed out by Ruge, from an anlage at the base of the 2d metatarsal and from here wanders into its adult position. The anlage of the muscle is shown in Plate IX, Fig. 6. The later development of the muscle I have not followed. According to Ruge, **78**, the transverse head of the adductor comes from the same anlage as the oblique, while Schomburg, **00**, considers that the latter muscle arises from a separate anlage. According to Poirier the nerves of the two portions of the adductor arise from a common trunk which would be in favor of Ruge's view. I have found the nerves arising usually from quite distinct branches of the lateral plantar nerve. One nerve enters the caput obliquum near the proximal end of the middle third; and the other, the caput transversum near its centre.

Lumbricales.—In neither embryo CXLIV, length 14 mm., nor in embryo XXII, length 20 mm., are the lumbricales clearly differentiated. In the latter embryo, Plate IX, Fig. 5, however, the anlage of the lumbrical muscle of the 2d toe is just beginning to appear and to it a slight nerve twig may be traced from the medial plantar nerve. As pointed out by Schomburg the lumbrical muscles appear during the second half of the second month as separate anlages near the distal extremity of the metatarsal bones and from here wander toward their attachments to the tendons of the flexor digitorum longus. The three lateral lumbrical muscles were found supplied by the lateral plantar nerve and the medial by the medial plantar in 9 out of 10 instances by Brooks, **87**, while the two medial muscles were supplied both by the medial and lateral plantar nerves in one instance. He considers that the lumbrical muscles belong primitively to the medial plantar territory.

5. Development and Innervation of the Muscles Supplied by the Medial Plantar Nerve.

To this group belong the flexor digitorum brevis, abductor hallucis, the flexor hallucis brevis and the medial lumbrical muscle. This last has been considered in connection with the muscles of the preceding group.

M. flexor digitorum brevis.—This muscle develops comparatively late. In the 14 mm. embryo I have been able to determine no distinct signs of the muscle. In a 20 mm. embryo (Plate IX, Fig. 5) the anlage of the muscle may be made out on the surface of the aponeurosis of the long flexor muscles above the region of the middle cuneiform bone. Differentiation is just beginning so that no distinct muscle fibres may be made out. A small nerve may be traced into its medial margin. The tendons have not begun to develop. Soon after this stage the muscle undergoes rapid development. Proximally it extends to the tuber calcanei, distally it sends forth tendons to the toes.

In the adult the chief variations are those marked by a reduction of the muscle, especially that portion belonging to the fifth toe. The muscle is supplied by a nerve which enters the medial margin.

M. abductor hallucis.—This muscle is not distinctly visible in embryo CXLIV (length 14 mm.). It can be distinguished in embryo XXII (length 20 mm.), although differentiation is not here well marked. (Plate IX, Fig. 6). The muscle arises on the medial edge of the plantar surface of the foot over the navicular, first cuneiform, and the base of the 1st metatarsal bones and at a considerable distance from the tuber calcanei. It arises in close association with the m. flexor hallucis brevis. With the torsion of the foot which carries the calcaneus in a medial direction the anlage of the abductor extends proximally to be attached to the tuber calcanei.

In the adult a branch from the medial plantar nerve usually enters near the middle of the lateral border of the muscle. The relation of the nerve to the muscle anlage in embryo XXII is shown in the figure.

Flexor hallucis brevis.—Like the other muscles of this group this muscle is not distinguishable in embryo CXLIV, length 14 mm. Even in embryo XXII, length 20 mm. (Plate IX, Fig. 6), it is only beginning to appear. The cells of the anlage are closely packed together. To the anlage a nerve branch is given. I find the anlage somewhat more medially placed on the base of the first metatarsal than that shown by Schomburg, 00. The anlage is incompletely divisible into two portions, a medial and a lateral. During further development the lateral belly approaches the adductor hallucis. The medial belly in embryo XXII is associated with the abductor hallucis, although according to Schomburg it is brought into association with this muscle later than the lateral head is brought into association with the adductor hallucis.

In the adult the nerve enters between the two bellies of the muscle and spreads out into branches which pass between the constituent muscle bundles. It is only rarely that the lateral head of the muscle is supplied by the lateral plantar nerve.

Comparative anatomy of the intrinsic plantar muscles.—According to McMurrich, 04, the muscles of the crus terminate primarily at the ankle either on the plantar aponeurosis or the tarsus. The tendons whereby the long flexors of the toes are attached to the digits he looks upon as a differentiation of a deep plantar aponeurosis. According to this view the foot, in which but one set of crural muscles is attached through tendons to the digits, is to be looked upon as more primitive than the hand, in which superficial and deep forearm flexors are thus attached. In the foot there are to be distinguished several layers of intrinsic muscles, the more superficial of which, the flexor digitorum brevis and the lumbricales, arise in man from or in connection with the plantar aponeurosis or its derivatives, while the deeper layers arise from the tarsus and metatarsus.

The deeper intrinsic muscles of the hand and foot are considered by Cunningham, 82, and Brooks, 87, to have been derived from three primary layers, a superficial layer of four muscles primarily adductors, an intermediate layer of bicipital short flexors, one for each digit, and a deep layer of six abductors. The lateral plantar nerve crosses between the superficial and the intermediate layer.[25]

McMurrich, 03, differs greatly from Cunningham in the layers to which he would ascribe the muscles of the hand. Thus he recognizes the following layers:

Flexor brevis superficialis: Palmaris brevis, abductor digiti quinti, opponens digiti quinti, flexor brevis digiti quinti, abductor pollicis, opponens pollicis, flexor pollicis brevis.

Flexor brevis medius, stratum superficiale: The lumbricales.

Flexor brevis medius, stratum profundum: The adductor pollicis.

Flexor brevis profundus: The interossei volares, interossei dorsales (in part).

Intermetacarpals: The interossei dorsales (in part).

McMurrich has not yet published his paper on the phylogeny of the muscles of the foot, so that his views as to the origin of these muscles cannot be given, but doubtless the layers there, from his point of view, resemble those of the hand.

The subject of the comparative anatomy of the plantar muscles is too intricate to be entered upon here at length. Leche gives a brief summary of the conditions found in the mammalian series.

From the standpoint of embryological development the division of the deep plantar muscles adopted by Ruge, 78, is of the greatest value. He recognizes a medial group consisting of the abductor and the flexor brevis hallucis, innervated by the medial plantar nerve, and two groups innervated by the lateral plantar nerve, a more superficial group of "contrahentes" which lie plantarwards from the deep branch of the nerve and a group of "interossei" which lie deeper than this nerve. He also points out that in many of the mammals the interossei have permanently a plantar position which corresponds with the early embryonic condition in man.

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[25] See Quain's Anatomy 10th ed., Vol. II, Pt. II, p. 276.

6. *The Muscle Branches of the Plantar Nerves.*

While it is certain that the set of spinal nerves supplying the lateral plantar nerve as a group are more distally situated than those supplying the medial plantar nerve, the difficulties of tracing the nerves supplied to the muscles of the sole back to the sacral plexus make it impossible at present to give the spinal nerve supply of these muscles.

Compared with the other nerves of the leg the plantar nerves seem to be unusually constant in their mode of distribution of branches. The difficulties of accurate dissection of the nerves of the intrinsic muscles of the sole of the foot, however, make it more difficult than in other regions to utilize the work of students in getting reliable charts of this nerve supply. In general the descriptions given in the various anatomies agree pretty well. In the anatomy of Poirier and Charpy the supply of the quadratus plantæ is given as coming from the medial plantar. In a large number of dissections which I have followed this branch arose in every case from the lateral plantar, usually proximal but sometimes distal to the branch to the abductor of the fifth toe. This is the situation usually described for it in the text-books. The dissections which I have followed also serve to substantiate the statement given in Quain's Anatomy (10th edition) that the lateral plantar nerve only occasionally gives a branch to the lateral head of the m. flexor brevis hallucis and to substantiate the statement of Brooks, 87, that in about one in ten instances the medial as well as the lateral plantar nerves supply both the first and second lumbrical muscles. There is, however, considerable variation in the way in which the different nerves to the interosseous and lumbrical muscles and the transversales pedis are bound for a distance in common trunks.

XI. SUMMARY AND CONCLUSIONS.

The intrinsic musculature of the inferior extremity in man is differentiated from the blastema of the limb-bud. No processes from the myotomes are sent into the limb from the lumbar or sacral myotomes. After the differentiation of the myotomes from the somites the myotomes are bounded on the external surface, the sides and ends by a clearly marked membrane which is retained until after the lumbo-sacral nerves have extended well into the limb-bud.

Soon after the lumbo-sacral spinal nerves begin to extend into the limb-bud tissue differentiation takes place in the blastema of the bud.

At the center a core of scleroblastema, on each side of this a thick layer of myoblastema, at the periphery of the limb-bud a thinner layer of dermoblastema are differentiated. This differentiation begins near the anlage of the hip joint and extends proximally and distally.

The myoblastema represents the anlage of the muscles and of the skeletal framework of the musculature, including the fasciæ and the tendons.

The spinal nerves which grow into the limb-bud fuse to form a plexus and from this the nerves of the limb arise. At the time these nerves extend distally and give off branches the myoblastema becomes differentiated into anlages for specific groups of muscles and each of these anlages becomes further differentiated into the anlages of the specific muscles which compose the group. The main nerve trunks grow as a rule in regions which lie between the anlages of muscle groups, the main branches to each of the groups between the anlages of the muscles which constitute the group, and the intramuscular branches in the intramuscular septa which appear between the differentiating bundles of muscle fibres. Finally the terminal branches for the individual muscle fibres are given off. The site of entry of a nerve marks the region of earliest differentiation in the muscle. In many instances, at least, the distribution of the nerve in an adult muscle indicates the course of development of that muscle. (Nussbaum, 94).

The development of muscles from the muscle anlages consists essentially of a differentiation of the, at first, apparently nearly homogeneous tissue of the anlage, into muscle cells and into the connective tissue framework which serves to hold these in place and harness them to the structures on which they are to act. The adult architecture of a muscle must be understood before its development can be intelligently followed.

In the simplest muscles in the adult the muscle fibres are bound by the endomysium into bundles which are inserted at each end of the muscle into a tendon. As a rule neither the muscle-fibres nor individual bundles of fibres extend the entire distance from tendon to tendon.[26] The fibre bundles anastomose in such a way that they form a long-meshed network, such as that diagrammatically represented in Fig. 7 b.

The muscle-fibres either take a nearly parallel course from one tendon to the other, Fig. 7 c, or they diverge from one tendon toward the other, Fig. 7 d. In the majority of simple muscles the distance from tendon

[26] In some short mammalian muscles, like the segments of the rectus abdominis of the mouse, the muscle-fibers run from tendon to tendon. On the segmental musculature of elasmobranches and urodeles, see Bardeen, 03.

to tendon along lines parallel with the muscle fibres is approximately the same in all parts. There are, however, numerous exceptions, the most marked of which are found in larger sheet-like muscles such as the oblique and transverse muscles of the abdomen. Frequently in case of exceptions of this nature, as for instance in case of the abdominal muscles, the adult

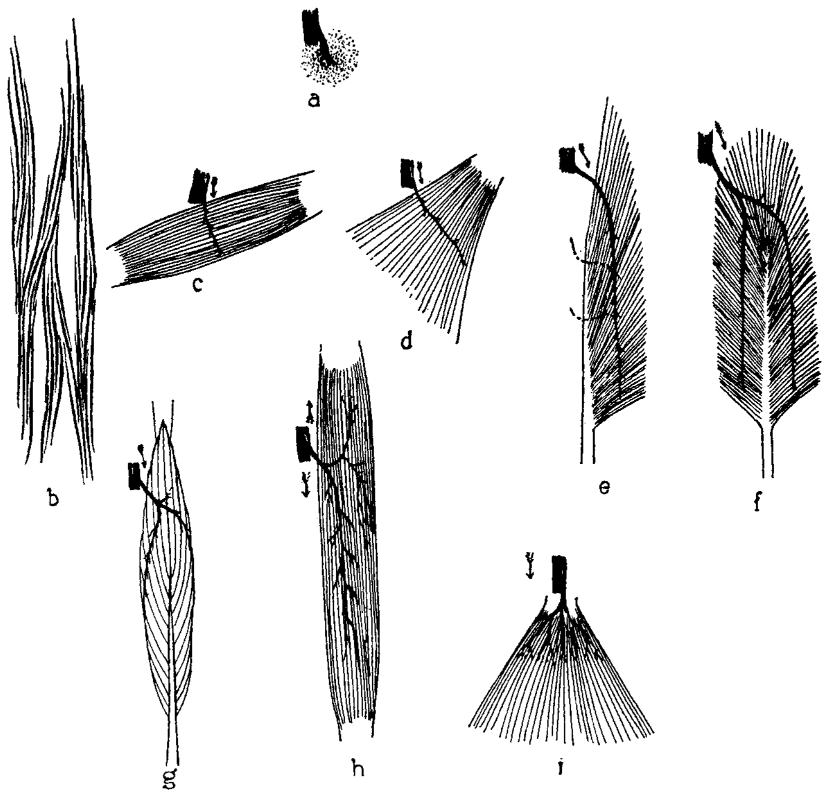

FIG. 7. Diagrams to illustrate nerve-muscle development. *a*. Embryonic muscle anlage. *b*. Anastomosing bundles of muscle fibers. *c*. Band-like muscle developed transverse to course of main nerve trunk. *d*. Triangular muscle developed transverse to course of main nerve trunk. *e*. Pennate muscle developed parallel with course of main nerve trunk. *f*. Bipennate muscle developed parallel with course of main nerve trunk. *g*. Fusiform muscle. *h*. Band-like muscle developed parallel with course of main nerve trunk. *i*. Triangular muscle developed in direction with course of main nerve trunk.

human muscle represents a combination of several simpler muscles in each of which the general rule holds good in the embryo or in some of the lower mammals. For the architecture of the abdominal muscles in the mammals, see Bardeen, 03.

Since the more complex muscles are usually capable of being analyzed into parts the structure of which resembles that of the simpler muscles, we shall consider here the development merely of several simpler types of muscle. The structural units of the more complex muscles develop in a similar manner.

The nerve usually enters the anlage of a muscle near the center of the side toward the main trunk from which its special nerve arises, Fig. 7 a. The relation of the chief branch or branches of the nerve of the muscle to the fibre-bundles depends on whether the course of the muscle fibres is transverse to or parallel with the main trunk from which the nerve arises.

If the fibre bundles of the muscle take a direction directly or obliquely transverse to the course of the main nerve trunk the nerve to the muscle, or its chief branches, usually passes for some distance across the fibre bundles about midway between the tendons and give off rami on each side from which in turn an intramuscular nerve plexus arises, Fig. 7 c-g. The direction of the course of the main nerve branches on or in an adult muscle of this nature indicates the course of growth of the muscle from the anlage in a direction transverse to the long axis of the muscle fibres. This growth is relatively slight in case of ribbon-like muscles, Fig. 7 c, somewhat greater in case of triangular muscles, Fig. 7 d, and extensive in case of muscles like the intercostal muscles and pennate or bipennate muscles, Fig. 7, e, f. Two or more branches may enter muscles of these latter types at different levels from the main nerve trunk, dotted lines Fig. 7 e.

It is at first difficult to recognize that in most fusiform muscles the distance from tendon to tendon along the course of the muscle-fibres is approximately equal. The course of the muscle-fibres in such muscles is diagrammatically represented in Fig. 7, g. It will be noted that the course of the chief branches of the nerve to the muscle is approximated midway between the tendons to which the fibre-bundles are attached.

If the long axes of the fibre-bundles of a muscle are developed in a direction somewhat parallel with the course of the main trunk from which the chief branches to the muscle arise, the branches usually enter the proximal third of the belly of the muscle and extend distally parallel with the muscle fibres, at the same time giving off rami from which an extensive intramuscular plexus is formed. The course of the chief rami within a muscle of this type indicates the course of growth of the muscle in a direction parallel with the muscle fibres. See Fig. 7, h and i.

Metameric segmentation in the innervation of the limb muscles is due not to the ingrowth into the limb of myotomes accompanied by nerves, but to the fact that a given region in the developing musculature is in the more direct path of fibres extending into the limb from one or two specific spinal nerves. The number of spinal nerves contributing to the innervation of the inferior extremity in man varies from six to nine, the number contributing to the innervation of the musculature probably varies from five to eight. The number as well as the position of the spinal nerves serving to innervate a given muscle varies greatly in different individuals.

With a few exceptions it is difficult or impossible to trace back to their origin from the plexus the fibres composing the nerve of supply of a given muscle in the inferior extremity in man. The path of fibre bundles in a nerve is quite different from that of the nerve fibres composing the nerve. The connective tissue which serves to hold together the nerve fibres and to distribute blood vessels to the nerve does not form continuous sheets about continuous bundles of nerve fibres. On the contrary it forms enveloping layers which are continued for but a short distance about a given group of fibres and then breaks up and becomes fused with similar enveloping sheets about other groups of fibres. The nerve fibres take a much more direct course in a nerve than any bundles that can be dissected from the nerve. A study of the origin of the branches of a nerve and the variation in the relation of these branches to one another makes it possible to construct a schematic cross section of a nerve trunk in which the relations of the nerve fibres in the trunk are more accurately revealed than in mere dissection of the branches back into the component fibre bundles of the nerve. On pages 308, 316, and 322 I have shown such schematic diagrams of the femoral, obturator and sciatic nerves. The nerve fibres of contiguous areas may branch off in a common trunk, but nerve fibres in discontinuous areas never do. On Plate III I have shown schematically the probable regions occupied by the fibres destined for the chief branches of the main nerves of the inferior extermity in the nerve trunks near the pelvis at the period when the segmental relations of the spinal nerves to the limb are becoming established.

In the adult nerves variation is frequent and extensive. The main nerve trunks are fairly constant in position, the greatest variation being found in the course of the peroneal nerve in the thigh. This nerve is frequently separated from the tibial nerve by a part or the whole of the piriformis muscle. In one instance I have seen it separated by a part of the short head of the biceps, p. 293. In the embryo the peroneal and tibial nerves in the thigh are separated by a considerable amount of dense tissue.

There is much variation in the number and position of the spinal nerves which supply the main nerve trunks of the limb as well as in those which supply the smaller branches which pass directly from the plexus to the gluteal muscles and the piriformis. There is also great variation in the number, course and distribution of the branches which pass from the main nerve trunks to the muscles and the skin. No correlation has been discovered between variation in the source of supply and variation in peripheral distribution of the intrinsic nerves of the limb, with the exception of the cutaneous border nerves. No marked correlations have been discovered between either sort of variation and race, sex, or side of body.

While the development of the musculature is fairly direct, there is probably as much correlation between the ontogeny and phylogeny of the muscles of the leg as between the ontogeny and phylogeny of the skeleton.

D. PERINEAL MUSCULATURE AND THE NERVES OF THE PUDIC GROUP.

a. Embryonic Development.

In an embryo of 11 mm. (Plate III, Fig. 1) the sacral plexus is fully formed and several branches may be seen extending out toward the cloaca and viscera. These branches indicate the developing pudic and visceral nerves, but differentiation has not proceeded sufficiently far to make it possible to determine with certainty what each of the branches represents. The myotomes of the sacro-coccygeal region are distinct. No specific differentiation of the perineo-caudal musculature is apparent. The relations of the pubic nerves to the nerves of the leg are shown schematically in Plate III, Fig. 3.

In a slightly older embryo (Plate X, Fig. 1) the main branches of the pudic and visceral nerves have appeared. The dorsal nerve of the penis arises in the main from the 3d sacral nerve. The perineal nerves arise from the (2d), 3d, and 4th sacral nerves. The hemorrhoidal nerve arises from the 3d and 4th sacral nerves. About the region of the cloaca there is some condensation of tissue, but there is no distinct differentiation of muscle. From the 3d and 4th sacral nerves branches are given to a highly developed visceral plexus in which a large amount of chromophile tissue is apparent. This tissue mass lies lateral to the intestine and extends nearly to the urachus. Anteriorly it is continued into a similar mass extending down from the region of the suprarenal gland.

In company with the visceral branch from the 4th sacral nerve there arises a nerve which extends out into a differentiating mass of tissue which probably represents the levator ani muscle. There is no good evidence to show that this muscle arises from the myotomes. The coccygeal musculature which lies dorsal and lateral to the levator ani seems, however, evidently to arise from the ventral tips of the caudal myotomes. Into it extend nerves from the 4th and 5th sacral and possibly from the caudal nerve. This, as also in embryo CIX, is relatively at this stage very large.

In embryo XXII, length 20 mm. (Plate X, Fig. 2) conditions similar to those just described may be found. The direction in which the sections are cut makes a reconstruction of the region somewhat imperfect. The results have been controlled by study of another somewhat older embryo, CXLV, length 33 mm. The plexus is of a more anterior type than that of 144. The dorsal nerve of the penis and perineal nerves apparently arise largely from the 2d sacral nerve and the 4th sacral nerve seems not to enter into the pudic plexus. The perineal musculature is undergoing specific differentiation, but no attempt has been made to determine definitely the boundaries of the various muscles. The levator ani muscle is well differentiated. The visceral plexus is even more extensive than in the preceding stage.

For comparison of embryonic conditions with the distribution of the pudic nerves in the adult male, the well-known illustration of Hirschfeld and Léveillé may be used. It is to be noted that previous to the outgrowth of the pudic nerves the cloaca and urachus occupy a more distal position relative to the spinal column (Fig. CIX) than they do at the period when these nerves are developed (Plate X, Figs. 1 and 2). Later, the external genitalia shift again distally.

The paths taken by the growing nerves are fairly direct. That of the dorsal nerve of the penis is most so. The perineal nerves bend more in a distal direction. The nerve of the levator ani muscle takes a course at right angles to the path of the main trunk from which it arises. It may readily be seen that the most anterior root fibres of the pudendal nerve enter the dorsal nerve of the penis, the most posterior the hæmorrhoidal nerve. Cutaneous branches also arise from the caudal nerve.

According to Popowsky, **99**, at a period when the cloaca is still present a sheet of muscle forms a sphincter around its opening. Later, when the rectal becomes separated from the urogenital portion of the cloaca the sphincter is divided, the posterior portion becoming the sphincter ani

TABLE

Types of Origin of Pudic Nerves from Spinal Nerves.			Frequency of		
			A	B	C
N. Pudendus.	Separate N. Hæmorr-hoidalis.	Separate N. Dorsalis Penis.	XXIV XXVI	XXIV XXVII	XXIV XXVIII
XXVI, XXVII			1	1	
XXVII				2	
XXVI, XXVII	XXVIII			1	
XXVII	XXVIII			1	
XXVI, XXVII, XXVIII				2	4
XXVII, XXVIII		XXVII[27]		11	37
XXVII, XXVIII	XXVIII			3	1
XXVIII					1
XXVI, XXVII, XXVIII	XXVII, XXVIII, XXIX				1
XXVII, XXVIII	XXVIII, XXIX	XXVII, XXVIII[28]		1	2
XXVII, XXVIII, XXIX		XXVII[29]		1	7
XXVIII, XXIX	XXVIII, XXIX	XXVIII[30]			
XXVIII, XXIX		XXVIII[31]		1	8
XXVIII, XXIX	XXX				
XXVIII, XXIX, XXX					
Number of Instances			1	24	61

[27] In three instances: W. F. R; W. F. L; W. M. R.
[28] In one instance: W. M. R.
[29] In two instances: W. M. L; B. M. L.
[30] In two instances: B. F. R; B. M. L.
[31] In one instance: B. M. R.

XXIX.

Association with Various Types of Plexuses.					Race, Sex, and Side of Body.							
D	E	F	G		White.				Negro.			
XXIV	XXIV, XXV	XXIV	XXIV, XXV	Furcal N.	Male.		Female.		Male.		Female.	
XXVIII	XXVIII	XXIX	XXIX	Most Distal Nerve to Limb.	R	L	R	L	R	L	R	L
				No. of Inst.								
				2						1		1
				2		1						1
				1	1							
				1		1						
1				7	2	1			2	2		
34	3			85	13	10	1	4	20	18	11	8
				4			1		2		1	
3				4			1				2	1
				1	1							
1	1			5	1	2				1	1	
22	1	5	3	39	6	7	1		8	6	3	8
5	1	1		7					2	2	2	1
37	8	6	15	75	7	6	2	1	18	20	11	10
		1		1						1		
			1	1					1			
103	19	13	14	235	31	28	6	5	53	51	31	30

TABLE XXX.

Type of Plexus from which the Chief Nerve to the M. Levator Ani arises.				Frequency of Origin of Nerve to M. Levator Ani from:					
Type.		Furcal Nerve.	Most Distal Spinal Nerve to Limb.	Nn. Sp. XXVII XXVIII	Nn. Sp. XXVIII	Nn. Sp. XXVIII XXIX	Nn. Sp. XXIX	Nn. Sp. XXIX	Total Number.
Ant.	A	XXIV	XXVI						
	B	XXIV	XXVII	1	4				5
	C	XXIV chiefly to sacral plexus	XXVIII		9	3	14		26
Norm.	D	XXIV chiefly to lumbar plexus	XXVIII		1	4	29		34
Post.	E	XXIV-XXV, or XXV	XXVIII		1	1	5		7
	F	XXIV	XXIX			1			1
	G	XXIV-XXV, or XXV	XXIX			1	6	1	8
Total Number..........				1	15	10	54	1	81

TABLE XXX.—*Continued.*

Race, Sex, and Side of Body.			Frequency of Origin of Nerve to M. Levator Ani from:					
			Nn. Sp. XXVII XXVIII	Nn. Sp. XXVIII	Nn. Sp. XXVIII XXIX	Nn. Sp. XXIX	Nn. Sp. XXIX	Total Number.
White.	Male.	R	1	1	3	5		10
		L		4	1	7		12
	Female.	R		2		2		4
		L		3		1		4
Negro.		R			4	10		14
		L		1	1	14		16
		R		2		6	1	9
		L		2	1	9		12

while the anterior portion becomes differentiated into the various perineal muscles. The details of this process I have not followed.

For the comparative anatomy of the perineal muscles, see H. Eggeling, **96**, M. Holl, **96**.

b. Nerve Variation in the Adult.

There is considerable variation in the origin and distribution of the nerves of the perineal region in man. Commonly the hæmorrhoidal and the perineal nerves and the dorsal nerve to the penis (clitoris) are branches of a common trunk, the pudic nerve, which arises from the 27th and 28th spinal (2d and 3d sacral) or the 28th and 29th spinal (3d and 4th sacral) nerves. The origin may, however, be from the 26th and 27th; the 27th; the 26th, 27th, and 28th; the 28th; the 27th, 28th, and 29th; or from the 28th, 29th, and 30th spinal nerves. In the accompanying table the frequency of these various modes of origin is shown.

Not infrequently (in 20 out of 235 instances, 8.5%) the hæmorrhoidal branch has a separate origin from the plexus, usually from the 28th, or 28th and 29th spinal nerves.

Less frequently the dorsal nerve of the penis (clitoris) has an independent origin (in 9 out of 235 instances, 3.9%). In such instances the nerve arises from the 27th; 27th and 28th; or 28th spinal nerves (see Table XXIX).

The chief nerve to the levator ani muscle arises usually in conjunction with viscereal branches from the 29th spinal (4th sacral) nerve. It may arise from the 27th and 28th; the 28th; the 28th and 29th; or the 29th and 30th spinal nerves (see Table XXX). Other small branches are also frequently given to this muscle.

The nerves to the coccygeus muscle arise from the last spinal nerve contributing to the pudic plexus and also usually from the next more distal spinal nerve.

The visceral branches usually arise from the last two spinal nerves entering the pudic plexus and also often from the next most distal spinal nerve.

The charts which I have show great variation in the peripheral course and distribution of all of these nerves. The difficulties of making thoroughly accurate dissections and charts of the nerves of the perineal region make it seem inadvisable to try to use these charts for statistical purposes. In general the distribution corresponds with that given in the anatomies of Poirier and Charpy and Quain, and with those pictured in the atlases of Toldt and Spalteholz.

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DESCRIPTION OF PLATES.

PLATE I.

Two figures, repeated from this journal (Vol. I, Plate II), to illustrate early stages in the differentiation of the inferior extremity.

FIG. 1. Embryo II, length 7 mm., age about four weeks.

FIG. 2. Embryo CLXIII, length 9 mm., age about four and a half weeks.

For description of figures see text, p. 264.

PLATE II.

Four sections through the base of the posterior limb to illustrate different stages in the development of the nerves and musculature.

FIG. 1. Section passing through the right limb-bud in embryo II, length 7 mm., age 26 days. The tips of the neighboring myotomes do not extend into the mass of tissue of which the limb-buds are composed and in which as yet no specific differentiation is visible. 33 diam.

FIG. 2. Secton passing transversely through the base of the right limb-bud of embryo CIX, length 11 mm., age about five weeks. At the center of the limb-bud the acetabular region of the skeleton appears as a condensed mass of tissue. About this the femoral, obturator, and sciatic nerves may be seen extending into the limb bud. Myogenous tissue is fairly well marked near the femoral and sciatic nerves. 25 diam.

FIG. 3. Transverse section passing through the acetabular region of left leg of embryo CXLIV, length 14 mm., age about five and one-half weeks. The femoral, obturator, gluteal, and sciatic nerves may be seen extending into the limb bud, and in the vicinity of these nerves the anlages of the iliopsoas, pectineus, adductor, hamstring, and gluteal muscles. 25 diam.

FIG. 4. Transverse section passing through the acetabular region of embryo CXLV, length 33 mm., age about two months. The femoral, obturator, inferior gluteal, and sciatic nerves may be seen entering the limb. The chief fasciculi of the iliopsoas, pectineus, adductor, and gluteus maximus muscles are separated by an amount of connective tissue relatively greater than in the adult. 10 diam.

PLATE III.

Three figures to illustrate the skeletal, muscular, and nervous apparatus of the right posterior extremity of embryo CIX, length 11 mm., age about five weeks. The nerves are represented black; the muscle anlages by stippling; the skeletal structures, light grey; the skin of the leg, transparent. About 17 diam.

FIG. 1. Median view. The urachus is shown in outline.

FIG. 2. Lateral view.

FIG. 3. Ventral view showing the relation of the pelvis to the boay wall and the main nerve trunks. At the right the outline of the peritoneal membrane is shown. The division of the main nerve trunks into branches is diagrammatic.

PLATE IV.

Medial and lateral views showing the relations of the nerves of the abdominal wall and posterior limb to the abdominal musculature and the skeleton of embryo CXLIV, length 14 mm., age about five and one-half weeks. The skin of the thigh and leg is represented transparent. About 17 diam.

FIG. 1. Medial view.

FIG. 2. Lateral view.

PLATE V.

Medial and lateral views showing the relations of the nerves of the abdominal wall and posterior limb to the abdominal musculature and the skeleton of embryo XXII, length 20 mm., age about seven weeks. The skin of the leg is represented transparent. About 13 diam.

FIG. 1. Medial view.

FIG. 2. Lateral view.

PLATE VI.

Figures showing the nerves of the abdomen and the nerves and muscles of the extensor side of the thigh.

FIG. 1. Embryo CXLIV, length 14 mm., age about five and one-half weeks. The abdominal musculature has been partially removed to show the course of the main nerve trunks. About 17 diam.

FIG. 2. Embryo XXII, length 20 mm., age about seven weeks. The ventral portion of the abdominal wall has been removed. About 13 diam.

FIGS. *a* and *b*. Branches of the femoral nerve to the quadriceps femoris muscle in embryo CXLIV and in embryo XXII. The muscle in each instance is represented semitransparent. About 15 diam.

PLATE VII.

Two diagrammatic outline sketches to illustrate the distribution of the cutaneous nerves of the inferior extremity in the adult.

FIG. 1. Front view of the left and medial view of the right leg. The dotted line on the right leg represents approximately the proximal margin of the embryonic limb-bud.

FIG. 2. Back of the left leg and lateral side of the right leg. The dotted line represents approximately the distal margin of the embryonic limb-bud.

PLATE VIII.

Figures to illustrate the early differentiation of the adductor, hamstring, tensor fasciæ latæ, gluteal, obturator internus, and quadratus femoris muscles and the short head of the biceps and the nerves supplied to these. 25 diam.

FIG. 1. Adductor and hamstring muscles in embryo CXLIV, length 14 mm., age about five and a half weeks. In order that the adductor longus and brevis may be seen, merely the outline of the gracilis muscle is shown.

FIG. 2. Adductor group in embryo XXII, length 20 mm., age about seven weeks. The adductor brevis and the gracilis muscles are shown cut out a short distance from their attachments. In "a" the relation of the nerve to the belly of the gracilis muscle is shown; in "b" that to the belly of the adductor brevis. The muscles are represented as semitransparent so that the intramuscular course of the main nerve trunks may be followed.

FIG. 3. The hamstring group in embryo XXII. The belly of the semitendinosus has been cut out so as to show the deeper structures.

FIG. 4. The gluteal and obturator internus muscle groups in embryo CXLIV. The gluteus maximus muscle, except at its attachment to the femur, is represented merely by an outline. The central portion of the belly of the gluteus medius has been cut out to reveal the gluteus minimus. The tibial nerve is cut off near the plexus, the peroneal nerve more distally.

FIG. 5. The gluteal and obturator internus muscle groups in embryo XXII. The m. gluteus maximus and the lig. sacrotuberosum are shown in outline. The central part of the belly of the gluteus medius is cut out. The tibial nerve is cut off near the plexus.

PLATE IX.

Six figures to illustrate the early differentiation of the musculature of the crus and pes. 25 diam.

FIG. 1. Peroneal and extensor muscles and nerves of the crus and pes of embryo CXLIV, length 14 mm., age about five and a half weeks. The peroneal muscles and the m. extensor digitorum longus are made semitransparent in order to reveal the deeper muscles and nerves.

FIG. 2. Peroneal and extensor muscles and nerves of the crus and pes of embryo XXII, length 20 mm., age about seven weeks. The peroneal muscles and the m. extensor digitorum longus are represented semitransparent.

FIG. 3. Superficial plantar musculature and nerves of the crus and pes of embryo CXLIV.

FIG. 4. Deep plantar musculature and nerves of embryo CXLIV. The gastrocnemius and flexor digitorum longus and the main trunk of the medial plantar and a part of that of the lateral plantar nerves have been removed.

FIG. 5. The superficial plantar muscles and nerves of the crus and pes of embryo XXII.

FIG. 6. The deep plantar muscles and nerves of the crus and pes of embryo XXII. The gastrocnemius and flexor digitorum longus muscles and the greater part of the tibial nerve have been removed.

PLATE X.

Two figures to illustrate the early stages in the development of the pudic nerves and the distal portion of the sympathetic system.

FIG. 1. Medial view of the right half of the distal portion of embryo CXLIV, length 14 mm., age about five and a half weeks. Enough of the surrounding undifferentiated mesenchyme has been removed to reveal the course of the nerves and the neighboring blood-vessels. The intestines are not represented. 25 diam.

FIG. 2. Similar view of the right half of the distal portion of embryo XXII, length 20 mm., age about seven weeks. 20 diam.

ABBREVIATIONS USED IN LETTERING FIGURES.

abd. musc. .... abdominal musculature.
acet. .... acetabulum.
ao. .... aorta.
A. .... artery.
  fem. .... femoralis.
  il. ext. .... iliaca externa.
  d. penis .... dorsalis penis.
  isch. .... sciatic.
  popl. .... poplitea.
  tib. ant. .... tibialis anterior.
  tib. post. .... tibialis posterior.
  umb. .... umbilical.
calc. .... calcaneus.
ch. d. .... chorda dorsalis.
cœl. .... cœlom.
costa .... rib.
fe. .... femur.
fi. .... fibula.
ft. pl. .... foot plate.
gl. suprar. .... glandula suprarenalis.
il. .... ilium.
isch. .... ischium.
lig. sac. tub. .... ligamentum sacrotuberosum.
lig. ing. .... ligamentum inguinale.
meson. .... mesonephros.
metan. .... metanephros.
metat. .... metatarsus.
M. .... musculus (li).
  abd. V .... abductor digiti quinti
  abd. hal. .... abductor hallucis
  add. .... adductor group.
  add. br. .... adductor brevis.
  add. hal. .... adductor hallucis.
  add. l. .... adductor longus.
  add. magn. .... adductor magnus
  add. min. .... adductor minimus.
  bi. .... biceps femoris.
    cap. br. .... short head.
    cap. l. .... long head.
  coccyg. .... coccygeus.
  cr. ant. .... crurales anteriores.
  cr. post. prof. .... crurales posteriores profundi.
  cr. post. supf. .... crurales posteriores superficiales.
  ext. dig. l. .... extensor digitorum longus.
  ext. dig. br. .... extensor digitorum brevis.
  ext. hal. l. .... extensor hallucis longus.
  ext. dig. V .... extensor digiti quinti brevis.

fem. post.	hamstring group of muscles.
flex. dig. br.	flexor digitorum brevis.
flex. dig. V br.	flexor digiti quinti brevis.
flex. dig. l.	flexor digitorum longus.
flex. hal. br.	flexor hallucis brevis.
flex. hal. l.	flexor hallucis longus.
gastroc.	gastrocnemius.
gem.	gemelli.
gl. max.	gluteus maximus.
gl. med.	gluteus medius.
gl. min.	gluteus minimus.
gr.	gracilis.
il.	iliacus.
il. cost.	iliocostales.
il. ps.	iliopsoas.
interos. dors.	interossei dorsales.
interos. plant.	interossei plantares.
obl. abd. ext.	obliquus abdominis externus.
obl. abd. int.	obliquus abdominis internus.
obt. ext.	obturator externus.
obt. int.	obturator internus.
opp. V	opponens digiti quinti.
pect.	pectineus.
peron.	peroneal.
peron. br.	peroneus brevis.
peron. l.	peroneus longus.
pirif.	piriformis.
plant.	plantaris.
popl.	popliteus.
ps. mj.	psoas major.
quadr. fem.	quadratus femoris.
quadr. lumb.	quadratus lumborum.
quadr. pl.	quadratus plantæ.
quadri. fem.	quadriceps femoris.
r. abd.	rectus abdominis.
rect. fem.	rectus femoris.
sart.	sartorius.
semim.	semimembranosus.
semit.	semitendinosus.
sol.	soleus.
tens. fasc. lat.	tensor fasciæ latæ.
tib. ant.	tibialis anterior.
tib. post.	tibialis posterior.
trans. abd.	transversus abdominis.
vastus lat.	vastus lateralis.
vastus interm.	vastus intermedius.
vastus med.	vastus medialis.

myo. .... myotome.
  l. .... lumbar.
  s. .... sacral.
  t. .... thoracic.
N.[32] .... nervus (vi).
  caud. .... caudalis.
  clun. inf. .... clunium inferiores.
  clun. med. .... clunium mediales.
  clun. sup. .... clunium superiores.
  cut. ant. .... cutaneus femoris anterior.
  dig. plant. .... digitales plantares propr.
  cut. lat. .... cutaneus femoris lateralis.
  cut. med. .... cutaneus femoris anterior, medial branch.
  cut. post. .... cutaneus femoris posterior.
    r. perin. .... perineal branch.
  cut. suræ lat. .... cutaneus suræ lateralis.
  cut. suræ med. .... cutaneus suræ medialis.
  d. penis .... dorsalis penis.
  fem. .... femoralis.
  g. .... genital.
  g. f. .... genitofemoral.
  gl. s. .... gluteus superior.
  gl. i. .... gluteus inferior.
  hæmorrh. med. .... hæmorrhoidalis medialis.
  hæmorrh. inf. .... hæmorrhoidalis inferior.
  hypog. .... hypogastricus.
  il. .... iliacus.
  ing. .... inguinalis.
  isch. .... ischiadicus (sciatic).
  l. .... lumbalis.
  l. ing. .... lumbo-inguinalis.
  obt. .... obturatorius.
  perin. .... perinei.
  peron. .... peroneus.
  peron. sup. .... peroneus superficialis.
  peron. prof. .... peroneus profundus.
  plant. .... plantaris.
  plant. l. .... plantaris lateralis.
  plant. m. .... plantaris medialis.
  pl. symp. .... sympathetic plexus.
  pud. .... pudendus.
  R. dors. l. .... lateral cutaneus branch of the dorsal (posterior) division of a spinal nerve.
  R. dors. m. .... medial cutaneus branch.
  s. .... sacralis.

[32] For abbreviations of terms applied to nerves going to muscles, see under muscle, *M.*

saph. .... saphenus.
sp. .... spinalis.
sural. .... suralis.
t. .... thoracicus.
tib. .... tibialis.
tr. symp. .... truncus sympathicus.
visc. .... visceral.
pat. .... patella.
perit. .... peritoneum.
proc. vag. .... processus vaginalis.
pub. .... pubis.
sp. ant. sup. .... spina anterior superior.
sp. post. sup. .... spina posterior superior.
symph. .... sympathetic nervous system.
tars. .... tarsus.
T. .... tendon.
test. .... testicle.
ti. .... tibia.
ur. .... ureter.
urach. .... urachus.
vert. .... vertebra.
V. .... vena.
card. .... cardinalis.
d. penis .... dorsalis penis.
fem. .... femoralis.
hypog. .... hypogastrica.
il. ext. .... iliaca externa.
isch. .... sciatic.
W. d. .... Wolffian duct.

Fig. 1

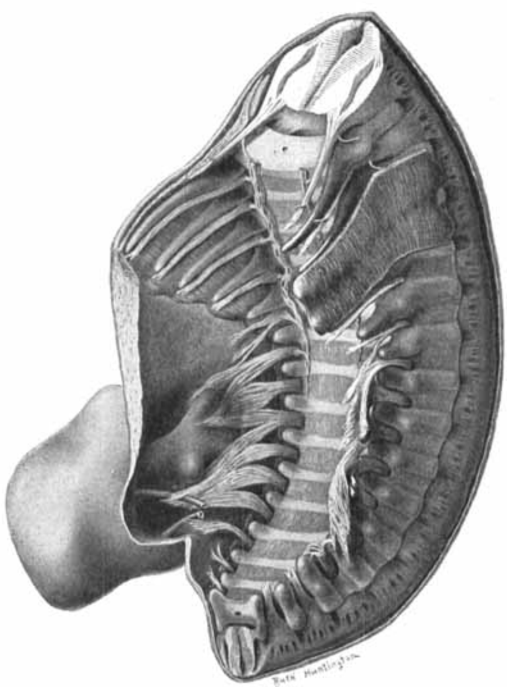


Fig. 2

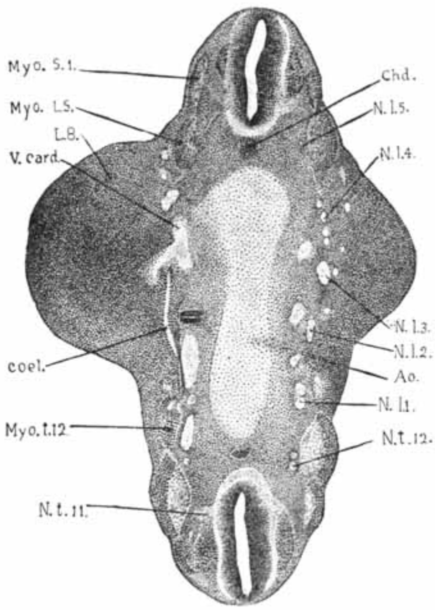


Fig. 1

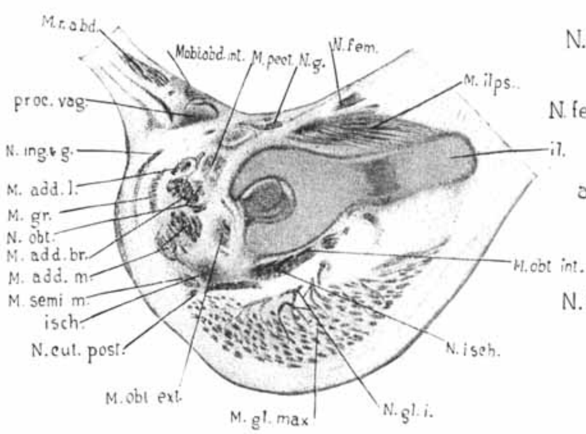


Fig. 4

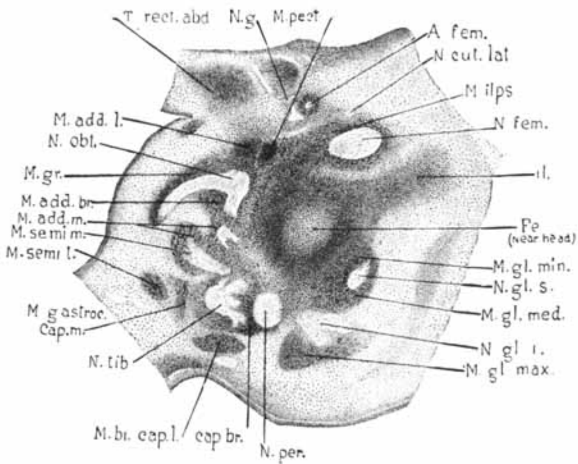


Fig. 3

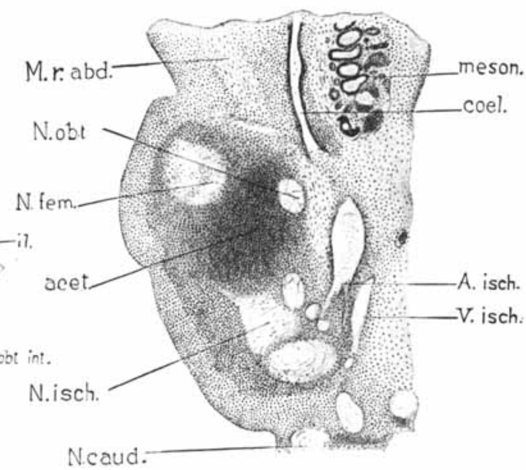


Fig. 2

PLATE III
(Fig. 1)

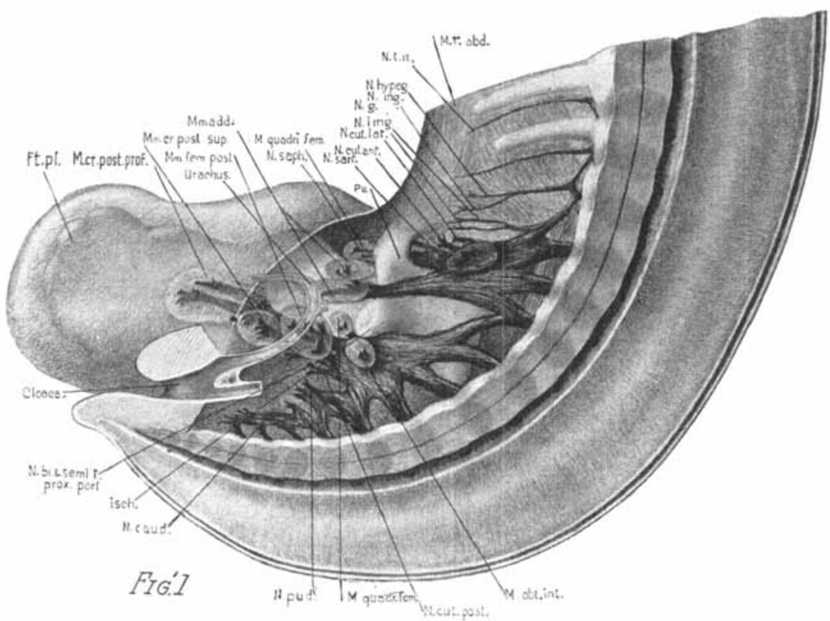


FIG. 1

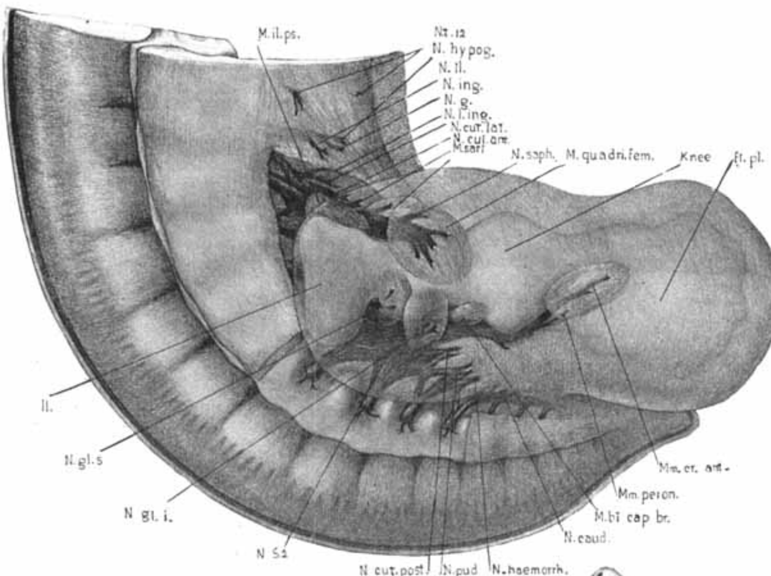

M. il. ps.
Nt. 12
N. hypog.
N. il.
N. ing.
N. g.
N. l. ing.
N. cut. lat.
N. cut. ant.
M. sart
N. saph.
M. quadri. fem.
Knee
ft. pl.
Il.
N. gl. s
N gl. i.
N S2
N cut. post.
N. pud
N. haemorrh.
N. caud.
M. bi cap br.
Mm. peron.
Mm. ex. ant.

Fig. 2

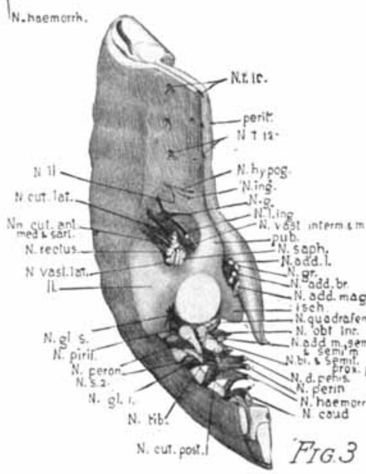

N. t. 1c.
perit.
N T 12
N il
N cut. lat.
Nn cut. ant. med & sart.
N. rectus
N vast. lat.
Il.
N. hypog.
N. ing.
N. g.
N. l. ing
N. vast interm & m
pub.
N. saph.
N. add. l.
N. gr.
N. add. br.
N. add. magn
isch
N. quadrafem.
N. obt inr.
N. add m., semit & semi'm
N. bi. & semit. prox. port
N. d. penis.
N. perin
N. haemorrh.
N. caud
N. gl s.
N. pirif.
N. peron.
N. S. 2.
N. gl. i.
N. tib.
N. cut. post. l

Fig. 3

PLATE IV
(Fig. 1)

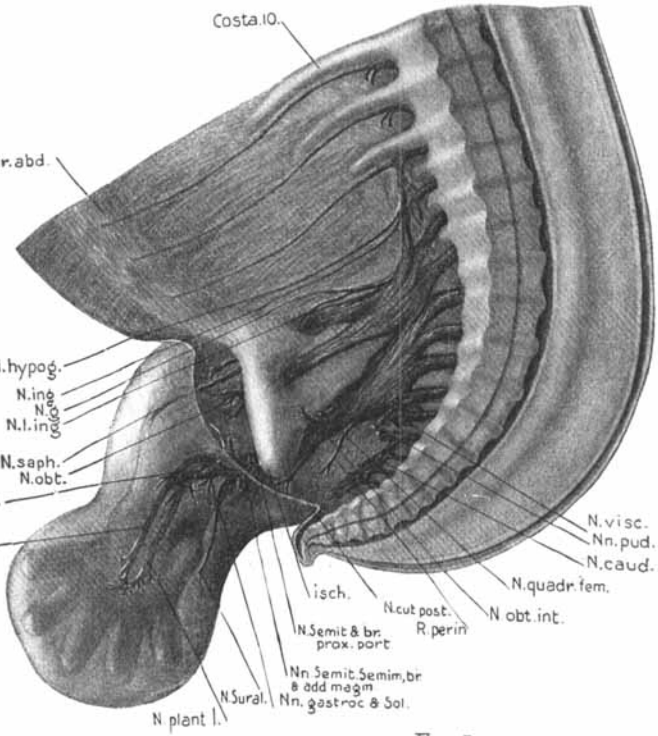
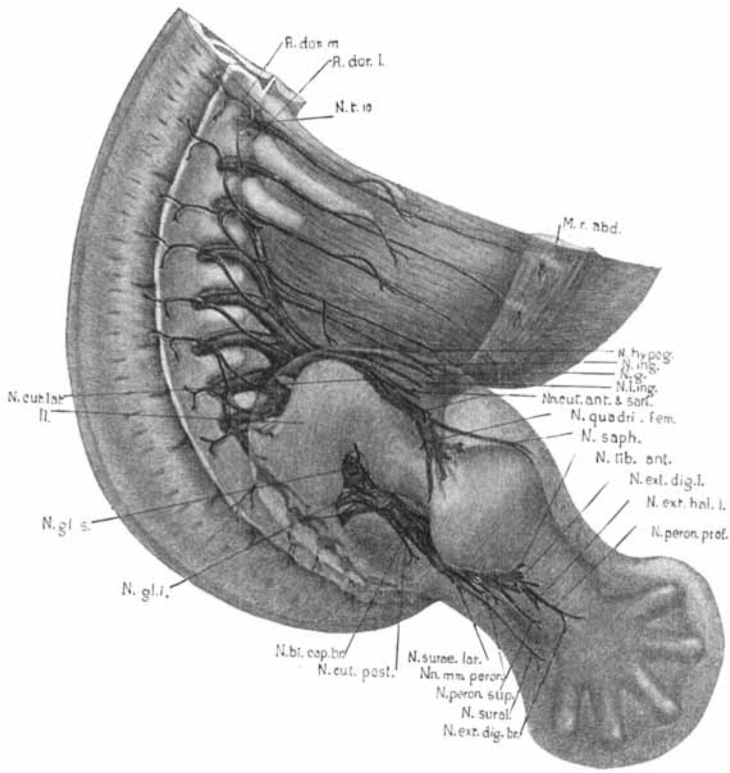


FIG. 1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R. dor. l.
N. t. 10
M. r. abd.
N. hypog.
N. ing.
N. g.
N. l. ing.
Nn. cut. ant. & sart.
N. quadri. fem.
N. saph.
N. tib. ant.
N. ext. dig. l.
N. ext. hal. l.
N. peron. prof.
N. cut. lat.
Il.
N. gl. s.
N. gl. i.
N. bi. cap. br.
N. cut. post.
N. surae. lat.
Nn. mm. peron.
N. peron. sup.
N. sural.
N. ext. dig. br.

Fig. 2

PLATE V
(Fig. 1)

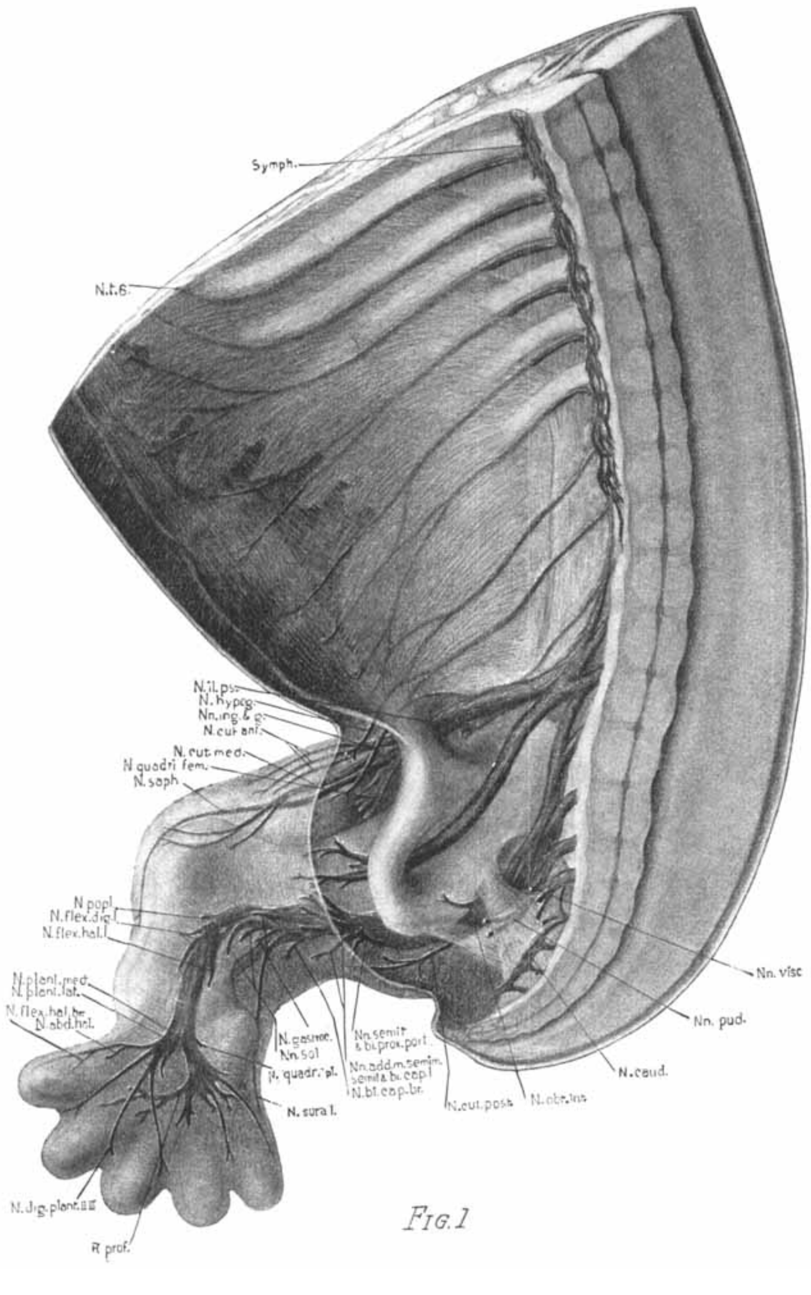

Fig. 1

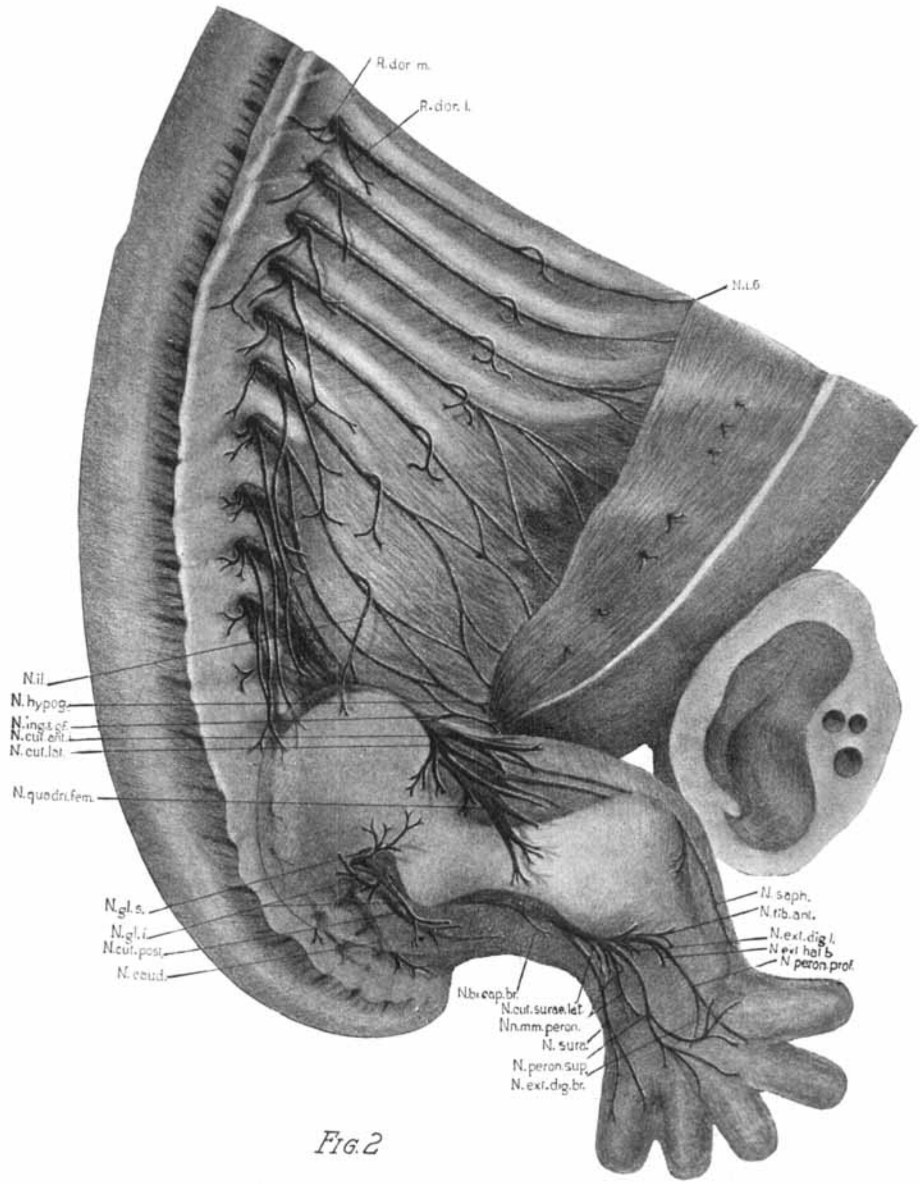
R. dor. m.
R. dor. l.
N. i. 6
N. il.
N. hypog.
N. ing. & cf.
N. cut. ant. i.
N. cut. lat.
N. quadri. fem.
N. gl. s.
N. gl. i.
N. cut. post.
N. caud.
N. saph.
N. tib. ant.
N. ext. dig. l.
N. ext. hal. b.
N. peron. prof.
N. bi. cap. br.
N. cut. surae. lat.
Nn. mm. peron.
N. sura.
N. peron. sup.
N. ext. dig. br.

FIG. 2

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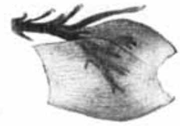

Fig. a

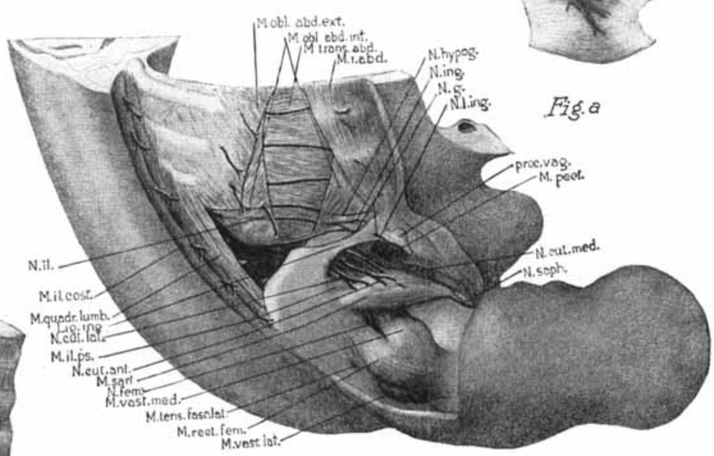

FIG. 1

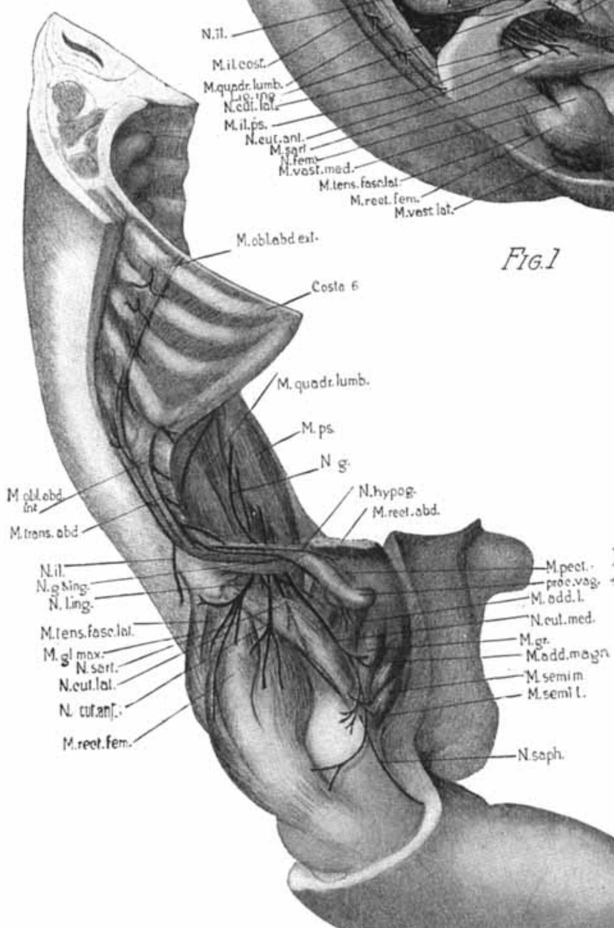

FIG. 2

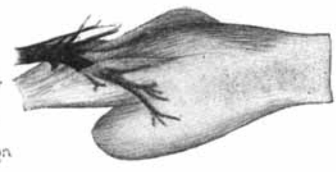

Fig. b.