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The Gross Morphology of the Internal Tendons of the Muscles of the Human Lower Extremity

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Loyola University Chicago

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THE GROSS MORPHOLOGY OF THE INTERNAL TENDONS OF THE MUSCLES OF THE HUMAN LOWER EXTREMITY

by

Nadhi Gagnantadilok

A Dissertation Submitted to the Faculty of the Graduate School of Loyola University of Chicago in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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VITA

The author, Nadhi Gagnantadolok, is the son of Yee-Hooy and Wah (Fah) Gagnantadolok. He was born on February 6, 1935, in Surasthanee, in the Southern part of Thailand.

His elementary education was obtained in government school at his birth place, and his secondary education at Mansri and Wat Suthi-Wararam High School, Bangkok, Thailand, where he was graduated in 1956.

In May, 1956, he entered Chulalongkorn University, and in April, 1962, received a second class honor in the degree of Bachelor of Science with a major in Zoology. While attending Chulalongkorn University, he assisted in teaching comparative anatomy for four years. In 1960, he was elected as a class representative.

In 1962, he began his graduate studies in the Department of Anatomy, and was granted a government scholarship at the University of Medical Science, in Bangkok, Thailand. During his graduate studies, he also assisted in teaching vertebrate and comparative anatomy. He was awarded the degree of Master of Science in April, 1964.

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graduate studies in the Department of Anatomy, Michigan State University, and transferred to the Department of Anatomy, Loyola University of Chicago, Maywood, Illinois, in September, 1970, where he was awarded a Basic Science Fellowship from 1971 through 1975.

Nadhi Gagnantadilok was married to Penchan Supachit on December 17, 1971.

In October, 1976, he was appointed Assistant Professor in the Department of Biology, Chulalongkorn University, Bangkok, Thailand.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>ii</td>
</tr>
<tr>
<td>VITA</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REVIEW OF RELATED LITERATURE</td>
<td>5</td>
</tr>
<tr>
<td>MATERIALS AND METHODS</td>
<td>16</td>
</tr>
<tr>
<td>MATERIALS</td>
<td>16</td>
</tr>
<tr>
<td>PROCEDURE</td>
<td>18</td>
</tr>
<tr>
<td>TERMINOLOGY</td>
<td>23</td>
</tr>
<tr>
<td>RESULTS</td>
<td>27</td>
</tr>
<tr>
<td>MUSCLES OF THE HIP</td>
<td>27</td>
</tr>
<tr>
<td>MUSCLES OF THE THIGH</td>
<td>49</td>
</tr>
<tr>
<td>MUSCLES OF THE LEG</td>
<td>74</td>
</tr>
<tr>
<td>MUSCLES OF THE FOOT</td>
<td>98</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>148</td>
</tr>
<tr>
<td>SUMMARY AND CONCLUSIONS</td>
<td>187</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>191</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>List of muscles dissected</td>
</tr>
<tr>
<td>2</td>
<td>Abbreviations used</td>
</tr>
<tr>
<td>3</td>
<td>The formulae of the external and internal tendons</td>
</tr>
<tr>
<td></td>
<td>of origin and of insertion</td>
</tr>
<tr>
<td>4</td>
<td>The degree of the complexity of the arrangements</td>
</tr>
<tr>
<td></td>
<td>of the internal tendons</td>
</tr>
<tr>
<td>5</td>
<td>The ratio of the number of internal tendons of insertion to that of origin</td>
</tr>
<tr>
<td>Figure Number</td>
<td>Muscle</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Diagram of the internal structures</td>
</tr>
<tr>
<td>2 - 10</td>
<td>Iliacus</td>
</tr>
<tr>
<td>11 - 16</td>
<td>Gluteus maximus</td>
</tr>
<tr>
<td>17 - 24</td>
<td>Gluteus medius</td>
</tr>
<tr>
<td>25 - 30</td>
<td>Gluteus minimus</td>
</tr>
<tr>
<td>31 - 37</td>
<td>Tensor fascia lata</td>
</tr>
<tr>
<td>38 - 44</td>
<td>Piriformis</td>
</tr>
<tr>
<td>45 - 56</td>
<td>Obturator internus</td>
</tr>
<tr>
<td>45 - 46</td>
<td>Gemellus superior</td>
</tr>
<tr>
<td>52 - 57</td>
<td>Gemellus inferior</td>
</tr>
<tr>
<td>58 - 61</td>
<td>Quadratus femoris</td>
</tr>
<tr>
<td>62 - 69</td>
<td>Obturator externus</td>
</tr>
<tr>
<td>70 - 78</td>
<td>Sartorius</td>
</tr>
<tr>
<td>79 - 88</td>
<td>Quadriceps femoris</td>
</tr>
<tr>
<td>85</td>
<td>Articularis genus</td>
</tr>
<tr>
<td>89 - 94</td>
<td>Biceps femoris</td>
</tr>
<tr>
<td>95 - 103</td>
<td>Semitendinosus</td>
</tr>
<tr>
<td>104 - 112</td>
<td>Semimembranosus</td>
</tr>
<tr>
<td>Figure Number</td>
<td>Muscle</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>113 - 118</td>
<td>Pectineus</td>
</tr>
<tr>
<td>119 - 124</td>
<td>Gracilis</td>
</tr>
<tr>
<td>125 - 129</td>
<td>Adductor longus</td>
</tr>
<tr>
<td>130 - 135</td>
<td>Adductor brevis</td>
</tr>
<tr>
<td>136 - 142</td>
<td>Adductor magnus</td>
</tr>
<tr>
<td>143 - 148</td>
<td>Tibialis anterior</td>
</tr>
<tr>
<td>149 - 153</td>
<td>Extensor hallucis longus</td>
</tr>
<tr>
<td>154 - 159</td>
<td>Extensor digitorum longus</td>
</tr>
<tr>
<td></td>
<td>Peroneus tertius</td>
</tr>
<tr>
<td>160 - 165</td>
<td>Peroneus longus</td>
</tr>
<tr>
<td>166 - 170</td>
<td>Peroneus brevis</td>
</tr>
<tr>
<td>171 - 176</td>
<td>Gastrocnemius</td>
</tr>
<tr>
<td>177 - 178</td>
<td>Soleus</td>
</tr>
<tr>
<td>182 - 188</td>
<td>Plantaris</td>
</tr>
<tr>
<td>189 - 195</td>
<td>Popliteus</td>
</tr>
<tr>
<td>196 - 203</td>
<td>Tibialis posterior</td>
</tr>
<tr>
<td>204 - 210</td>
<td>Flexor digitorum longus</td>
</tr>
<tr>
<td>211 - 217</td>
<td>Flexor hallucis longus</td>
</tr>
<tr>
<td>218 - 225</td>
<td>Extensor digitorum brevis</td>
</tr>
<tr>
<td></td>
<td>Extensor hallucis brevis</td>
</tr>
<tr>
<td>226 - 232</td>
<td>Flexor digitorum brevis</td>
</tr>
<tr>
<td>233 - 239</td>
<td>Quadratus plantae</td>
</tr>
</tbody>
</table>
List of Figures - continued

<table>
<thead>
<tr>
<th>Figure Number</th>
<th>Muscle</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>240 - 246</td>
<td>Abductor hallucis</td>
<td>296 - 298</td>
</tr>
<tr>
<td>247 - 255</td>
<td>Lumbricals</td>
<td>299 - 302</td>
</tr>
<tr>
<td>256 - 261</td>
<td>Abductor digiti minimi</td>
<td>303 - 305</td>
</tr>
<tr>
<td>262 - 268</td>
<td>Flexor digiti minimi brevis</td>
<td>306 - 308</td>
</tr>
<tr>
<td>269 - 283</td>
<td>Adductor hallucis</td>
<td>309 - 314</td>
</tr>
<tr>
<td></td>
<td>Flexor hallucis brevis</td>
<td></td>
</tr>
<tr>
<td>284 - 290</td>
<td>First plantar interosseus</td>
<td>315 - 317</td>
</tr>
<tr>
<td>291 - 297</td>
<td>Second plantar interosseus</td>
<td>318 - 320</td>
</tr>
<tr>
<td>298 - 303</td>
<td>Third plantar interosseus</td>
<td>321 - 322</td>
</tr>
<tr>
<td>304 - 311</td>
<td>First dorsal interosseus</td>
<td>323 - 326</td>
</tr>
<tr>
<td>312 - 317</td>
<td>Second dorsal interosseus</td>
<td>327 - 328</td>
</tr>
<tr>
<td>318 - 322</td>
<td>Third dorsal interosseus</td>
<td>329 - 330</td>
</tr>
<tr>
<td>323 - 330</td>
<td>Fourth dorsal interosseus</td>
<td>331 - 334</td>
</tr>
</tbody>
</table>
INTRODUCTION

Muscles are readily recognizable as distinct structures which are enclosed by a connective tissue sheath, the epimysium. Each end of a muscle is in continuity with a tendon which attaches to a bone or some other structures. This tendon may be very long, short, or not observable grossly and the muscle appears then to be directly attached to the bone.

The expansion of this tendon onto the muscle surfaces is generally termed an aponeurosis. Both the tendon and the aponeurosis are considered as the external tendon. On the other hand, the "internal tendon" (Heinze, 1969), earlier also named "internal tendinous structure" (Jager and Moll, 1951), or "intramuscular tendon" (Markee, et al., 1955; Iordansky, 1964) arises from the external tendon, and courses within the muscle.

Quain's Anatomy presents as early as 1892 the following description of the internal tendons: "the tendinous bands frequently run to a considerable length either on the surface of a muscle or between its fibers. There is indeed great variety in the relation of the muscular and tendinous portions, and but few muscles are entirely destitute of some tendinous elements in their composition". Other old classic textbooks, such as Piersol's Human Anatomy (1919), and
Rauber's Lehrbuch der Anatomie des Menschen (1919) present some, albeit very little, information about internal tendons. The new comprehensive textbooks, such as Morris' Human Anatomy (1953), Cunningham's Textbook of Anatomy (1972), and Gray's Anatomy of the Human Body (1973), have deleted any reference to this subject.

Internal tendons have been observed as early as the nineteenth century. Cleland (1867) while investigating muscular variations, noted "longitudinal tendinous septa" in the coraco-radialis muscle of a horse. These tendinous septa give origin to obliquely coursing muscle fibers, and thus produce a multipennate arrangement. McMurrich (1902-03) observed a tendon which is embedded in the substance of the condyloulnaris muscle of the cat. This buried tendon originates as a continuation of the tendon on the ventral surface of the ulnaris muscle. He also observed in 1905 a thin "sagittal aponeurotic plate" which "appears" to divide the lateral head of the gastrocnemius of the cat. Inferiorly, this aponeurotic plate joins to the tendons of the medial head of the gastrocnemius and of the soleus which contribute to the formation of the typical tendo Achillis. Bardeen (1906-07) observed in mammals, but rarely in man, that the tendon of insertion of the tibialis anterior extends into its muscle belly.

The morphology of the internal tendons of the muscles of mastication have been extensively studied in the crocodile by Lubosch (1914), Poglayen-Neuwall (1953), and Iordansky (1964), in mammals by Heinze (1963a, b; 1964a) and Yoshikawa and Suzuki (1969), and in man by Schumacher (1961), Herring and Scapino (1973), and Herring and Herring (1974). These investi
Investigators proposed different interpretations of their observations. Some suggested a "lamination" theory, according to which the internal tendons divide the muscle mass into many laminae. Others proposed a "polypinna-tion" theory, according to which the internal tendons provide attachments for multiple feather-like arrangements of the muscle fibers.

Extensive studies on the internal tendons of domestic mammals have been done on the posterior limbs of the horse (Kadletz, 1931), and on the anterior and posterior limbs of the swine (Heinze, 1972a, b, c). The observed internal tendons were presented in two-dimensional diagrams. Such a presentation has inherent limitation for the visualization of the three-dimensional structures. This limitation restricts an analysis of the internal tendons to relatively simple arrangements.

In the human, the internal tendons of the soleus (Reid, 1918; Druner, 1926; Hains, 1931-32; Cummins et al., 1946; Loetzke and Trzenschik, 1969), gastrocnemius and plantaris (Cummins et al., 1946) muscles were studied.

The previous studies of the internal structures of the jaw and limb muscles had revealed some of the complexities of the morphology of the internal tendons. These investigators employed simple cross- and longitudinal sectioning techniques which are inadequate for the elucidation of the complex three-dimensional structures.

The terminology employed by early investigators has been confusing and inconsistent. Although, later investigators used more consistent terminologies, none employed one based upon rigorous definitions.

Studies of the internal tendons of the muscle of the human have
been limited to the few examples cited. The results of these investigations showed moderately complex arrangements of the internal tendons.

It has been felt that a thorough investigation of a large, functionally related group of muscles of the human may be of interest. The muscles of the human lower extremity were selected for this study.

It seemed necessary that a new methodological approach, going beyond the previously used sectional techniques, had to be employed. An improved teasing technique has been introduced.

The previously used presentation of the results in two-dimensional diagrams has been inadequate for the visualization as well as for the analysis of any complex arrangement of the internal tendons. To allow the analysis and the visualization of such complex arrangements, three-dimensional models of the internal tendons have been built. The results of these studies are presented by photographs of the dissected specimens upon which these models are based.
REVIEW OF THE RELATED LITERATURE

The studies of the muscular system in man during the nineteenth century and at the turn of this century were mostly concerned with anomalies of individual muscles. Numerous variations of human muscles had been recorded in these extensive investigations. Representatives of this early period of investigation are: Wood(1867), and Macalister(1867), who studied the coraco-brachialis, and Turner(1867), who focused his attention on the sternalis muscle. Turner(1873a), in the first of his review articles entitled: "Report on the Progress of Anatomy", cites the studies of Macalister on "A Descriptive Catalogue of Muscular Anomalies", of Gruber on the "Record of Muscular Variations", and of Humphry on the "Observations in Myology". Turner, in his second review article(1873b), reports on the variations in the arrangements of the human muscles as recorded by Perrin and his associates.

Some of these earlier investigators observed also the internal tendinous structures within the muscles while studying muscular variations. Cleland(1867) described many longitudinal tendinous septa within the coraco-radialis muscle of the horse which corresponds to the biceps brachii in man. These tendinous septa give origin to obliquely coursing muscle fibers of varying lengths, thus producing an arrangement which he named "compound pennate fashion". McMurrich
(1902-03) observed a tendon which is embedded in the substance of the condylo-ulnaris muscle of the cat, which corresponds to a portion of the flexor digitorum sublimis in man. This buried tendon originates as a continuation of the tendon on the ventral surface of the ulnaris muscle. In 1905, he described a thin "sagittal aponeurotic plate" which "appears" to divide the upper part of the lateral head of the gastrocnemius of the cat. This aponeurotic plate extends inferiorly in the leg, and joins the tendons of the medial head and of the soleus, thus contributing to the formation of a typical tendo Achillis.

Bardeen (1906-07) observed in many mammals that the tendon of insertion of the tibialis anterior extends into the muscle belly. According to Le Double (1897) as cited by Bardeen (1906-07), only rarely can such an internal tendon be observed in the tibialis anterior of man. Although these authors observed the presence of the internal tendons, none studied their finer morphology.

The majority of the investigations of the internal tendons during the last sixty years were done on the muscles of mastication. Lubosch (1914), Poglayen-Neuwall (1953), and Iordansky (1964) studied extensively the internal tendons in crocodiles. Lubosch (1914) divided the muscles of mastication into masseter, temporalis and pterygoidei. The thin, two layered temporalis muscle has two insertions. One is by a short and strong tendon into the complementale. The other insertion is into an intermediate tendon (Zwischensehne). Muscle fibers which originate from this intermediate tendon were classified on account of their nerve supply as belonging to the
pterygoideus posterior.

Poglayen-Neuwall(1953) arrived at a different nomenclature for the muscles of mastication in the crocodile through considerations of the topography, the directions of the muscle fibers, and the innervations. He distinguished M. adductor mandibularis externus, M. adductor mandibularis intermediate, and M. adductor mandibularis internus; M. constrictor I dorsalis; and M. intra mandibularis. The M. adductor mandibularis externus is further subdivided into pars superficialis, pars media, and pars profunda. The pars profunda is described as having a weak internal tendinous structure within the muscle. This structure is responsible for a bipennate arrangement of the muscle fibers in the alligator, but not in the crocodile. This internal tendon, which he describes to be synonymous with the intermediate tendon observed by Lubosch(1914), inserts into a powerful stem tendon.

Iordansky(1964) studied the jaw muscles in the crocodile and his interpretation of the results is different from the previous authors. Mainly, he distinguishes only two separate muscles, the adductor externus profunda, and the musculus intramandibularis instead of eight individual muscles as named by Pogalyen-Neuwall(1953). Iordansky's thesis is that only fascial planes can be used for the identification of individual muscles. No internal tendon can serve as a landmark for such separation of muscles. Iordansky describes in detail those internal tendons which attach to the skull, and those which attach to the mandible.

Obviously, there is disagreement among these authors in the descriptions and interpretations of the internal tendons of the muscles.
of mastication in the crocodile.

Heinze (1961, 1963a, b; 1964a), Yoshikawa and Suzuki (1969), Herring (1972), and Herring and Scapino (1973) have extensively studied the internal tendons in mammals. Yoshikawa and Suzuki (1969) studied the comparative anatomy of the masseter of various mammals. They divided the masseter muscles into two groups: the proper and improper masseter. The former group is further divided into pars superficialis and pars profunda. The pars superficialis is subdivided into the first superficialis, the second superficialis, and the intermediate masseter. The pars profunda is subdivided into a pars anterior, and a pars posterior. The improper masseter is divided into the maxillo-mandibularis, and the zygomatico-mandibularis. Only two of these muscular divisions seem to be based upon a naturally occurring fascial plane. The partes superficialis and profunda of the proper masseter are separated by "thick connective tissue". The authors describe a nerve coursing in this tissue, and one can reasonably assume that it is a fascial plane separating these two parts. The other divisions and subdivisions of these muscles are the result of the dissection of the muscle mass. A circumferential cut has been made along the origin and insertion. Then this first cut is extended to the depth of the internal tendon, and the superficial part of the muscle is removed. This same procedure is repeated again and again, until the muscle is divided into the previously described parts. The authors interpreted these parts as laminae, and consequently, the muscle has been described as having different laminae. This "fundamental laminar
pattern" is based upon the interpretation of the internal tendons as boundaries between different parts of the muscle.

Heinze studied extensively the internal structures of the muscles of mastication in the pig (1961), in the cattle, goat, and sheep (1963a), in the horse (1963b), and in the dog, cat, and rabbit (1964a). He employed sections of muscles in different planes for the study of the arrangement of the internal tendons. Additional dissection was used for the determination of the directions of the muscle fibers. Sometimes, diagrams of serial sections were used for the presentation of the results. Mainly, however, he used for the presentation what he called "the muscle diagram". Such a muscle diagram combines and presents in one hypothetical plane all the observations on serial sections throughout the muscle. Heinze stated that such a muscle diagram was not a perfect way for the presentation of the arrangement of the internal tendons. This was especially evident in those cases when the internal tendons did not traverse the entire width of a muscle, or when the internal tendons had an oblique course. Heinze found that the temporalis muscle usually had the simplest arrangement of the internal tendons.

Only one internal tendon branched off from either the tendon of origin, or the tendon of insertion. The most complex arrangement of the internal tendons had been observed in the lateral pterygoid of the horse. Seven internal tendons were associated with the tendon of origin, and eight with the tendon of insertion. It appeared that the internal tendons may be interconnected within each of these two groups. Furthermore, Heinze observed a slanting course of muscle fibers
between two internal tendons. He perceived a kind of pennate arrangement of the muscle fibers. Therefore, Heinze postulated that the fibers course obliquely from one internal tendon to the other. He spoke of a "polypinnation system" of the arrangement of fibers within the lateral pterygoid muscle.

Heinze considered the internal tendons as a functional element of a single muscle mass. He believed that it is arbitrary to consider the internal tendons as a boundary layer between different portions of a muscle. Such a concept led only to the classification of artificial muscles.

Most recently, Herring and Scapino (1973) studied the anatomy of the muscles of mastication of the miniature pig by the gross sectional method. These authors described in detail the arrangements of the internal tendons of origin and of insertion, as well as the directions of the muscle fibers between the internal tendons. The internal structures of the zygomatico-mandibularis, the temporalis, and the lateral pterygoid muscles were fairly simple and pinnation was only occasionally observed. The masseter and the medial pterygoid had the most complex arrangements of the internal tendons and pinnation was almost universally present. For example, the medial pterygoid had two U-shaped "internal tendon sheets" of origin, which were enclosed one within the other. The large outer U-shaped sheet divided into seven "septa". The smaller inner U-shaped "aponeurosis" divided into two separate "septa:. The internal tendons associated with the tendon of insertion consist of four "overlapping aponeuroses". Most of these
aponeuroses gave off a septum. In addition, there were three small "insertion tendons" which were nothing else but internal tendons of insertion. The results of this study were presented in a series of three-dimensional diagrams, which demonstrated (1) the aponeuroses and septa of origin, (2) the aponeuroses and septa of insertion, (3) the relation between the internal tendons of origin and insertion, and (4) the arrangement of the superficial muscle fibers. The authors accepted the pinnation theory without discussing the relative merits of this theory or the lamination theory.

These authors described the morphology of the internal tendons using an inconsistent terminology. For example, the term aponeurosis was used interchangeably with the term (internal) tendon. No definition of the relationship between aponeurosis and septa (internal tendons) was given. Equally, no clarifying nomenclature had been adopted and adhered to concerning the type of branching of the septa (internal tendons).

Summing up, these investigators interpreted differently their observations of the internal structures of the jaw muscles in mammals. Some suggested the lamination theory. According to it, the internal tendons divided the muscle into different, individual parts (Yoshikawa and Suzuki, 1969). Others suggested the polypinnation theory. According to it, the internal tendons, which provided additional area for the attachment of muscle fibers, were considered as an integral part of the muscle (Heinze, 1961; 1963a, b; 1964a; and Herring and Scapino, 1973).
The morphology of the internal structures of the muscles of mastication in man had been extensively studied in various age groups ranging from the newborn to young children by Schumacher, 1961. His observations were based on a two step dissection. First, he divided the muscle into layers, which were bounded by internal tendons. Secondly, he teased away the muscle fibers. The temporalis and the lateral pterygoid muscles had simple internal structures, whereas the masseter and the medial pterygoid had the most complex ones. There were six layers of internal tendons of origin and of insertion in the masseter, and there were five layers of internal tendons of origin and of insertion in the medial pterygoid muscle. Some of these layers were further subdivided by lamellae. For instance, the second layer of the masseter was subdivided by four lamellae, whereas the second, the third, and the fourth layers of the medial pterygoid were subdivided by four, three, and two lamellae respectively. Schumacher presents his observations by "reconstructional" diagrams of longitudinal sections of the muscles which projected into one plane all layers and lamellae. He concluded that there was an increase in the polypinnation from the newborn to the young children.

The morphological investigation of the internal tendons of the limb muscles were quite extensive. Kadletz’s (1931) comprehensive study of the morphology of the muscles of the posterior limb of the horse and bovine concerned itself also with internal tendons. He employed the technique of teasing the muscle fibers with very fine pointed forceps. His findings concerning the internal tendons were shown in
many pictorial representation. He utilizes an external view of the muscles with surface projections of the internal tendons, view of the internal aspects of the muscles, diagramatic longitudinal and cross sections, and three-dimensional diagramatic reconstructions of muscles.

These four different ways of presentation of the results convey only a general idea of the complexity of the internal tendons. Details of their intricate arrangements cannot be visualized.

Recently, the internal structures of the muscles have been extensively studied in the posterior limb of the giraffe (Heinze, 1964b), in the triceps surae and the flexor digitorum pedis superficialis of the beaver, rabbit, dog, cat, pig, cattle, sheep, goat, and horse (Heinze, 1969), in the anterior and posterior limbs of the pig (Heinze, 1972a, b), in the posterior limbs of the rabbit (Heinze and Beetz, 1972), and in the anterior limb of the dog (Heinze, et al., 1972). These authors employed the cross- and longitudinal section method. The results of their findings were presented by means of "ideal" cross- and longitudinal sections called "muscle diagrams". These present in one plane all internal tendons of origin in white with numerical labelling, and all the internal tendons of insertion in black with letter labelling. The directions of the muscle fibers are not given. The muscle mass is represented by a gray background.

The diagramatic representation of the intricate spatial arrangements of the internal tendons in one plane inevitably introduces inaccuracies. A real visualization of complex three-dimensional arrangements of the internal tendons cannot be perceived from these
diagrams.

Other morphological studies of the internal structures include that of the soleus muscle of the rat (Close, 1964), the soleus and the flexor digitorum longus muscles of the cat (Close and Hoh, 1967; Rack and Westbury, 1969; Al-Amood and Pope, 1972), and the tibialis anterior of the rabbit (Crawford, 1973).

In man, the investigation of the internal structures of the lower extremity are limited to the soleus (Reid, 1918; Druner, 1926; Loetzke and Trzenschik, 1969), the triceps surae (Cummins, et al., 1946), and the plantaris (Daseler and Anson, 1943). The studies also employed the cross-sectional technique. These authors were mainly interested in the variations of the internal and external structures of these muscles. The greatest variability was observed in the soleus muscle (Loetzke and Trzenschik, 1969). Again, the descriptions of the internal tendons by these authors were not detailed enough to allow a real three-dimensional visualization.

This overview of the literature shows that, generally, more studies of the internal tendons have been done on muscles of animals than of man. With respect to the internal tendons of the muscles of the lower extremity, again, more studies have been done on muscles of animals than of man. There is no uniformity in the terminology used for the description of the internal structures of the muscles. The presentation of the results is mostly by diagrams of the longitudinal and cross section of the muscles. Occasionally, based upon special dissections, diagrams of the internal structures are constructed,
giving somewhat better overall views. Generally, no real visualization of the three-dimensional structures of the internal tendons is possible, and one wonders whether the authors ever intended to make available such a visualization.

It is interesting to note that in spite of the many physiological and clinical studies of the muscles of the lower extremity in man, no detailed investigation of the internal structures of these muscles has ever been undertaken. Therefore, I decided to study the morphology of the internal structures of the lower extremity of man with the following aims: (1) rigorous application of a suitable terminology, allowing clear definitions and descriptions without ambiguity, and (2) presentation of the results in a way which permits a three-dimensional visualization, and an analysis of even the most intricate structures.
MATERIALS AND METHODS

Materials

The lower extremities of human male and female cadavers have been collected from the School of Dentistry, Loyola University of Chicago. The specimens have been stored and kept moist in plastic bags until dissection. Table 1, shows the muscles studied:

TABLE 1
MUSCLES DISSECTED FOR INTERNAL TENDONS

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Iliacus</td>
<td>11 Obturator externus</td>
</tr>
<tr>
<td>2  Gluteus maximus</td>
<td>12 Sartorius</td>
</tr>
<tr>
<td>3  Gluteus medius</td>
<td>13 Quadriceps femoris</td>
</tr>
<tr>
<td>4  Gluteus minimus</td>
<td>14 Articularis genus</td>
</tr>
<tr>
<td>5  Tensor fascia lata</td>
<td>15 Biceps femoris</td>
</tr>
<tr>
<td>6  Piriformis</td>
<td>16 Semitendinosus</td>
</tr>
<tr>
<td>7  Obturator internus</td>
<td>17 Semimembranosus</td>
</tr>
<tr>
<td>8  Gemellus superior</td>
<td>18 Pectineus</td>
</tr>
<tr>
<td>9  Gemellus inferior</td>
<td>19 Gracilis</td>
</tr>
<tr>
<td>10 Quadratus femoris</td>
<td>20 Adductor longus</td>
</tr>
<tr>
<td>Muscle</td>
<td>Muscle</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>21  Adductor brevis</td>
<td>39  Quadratus plantae</td>
</tr>
<tr>
<td>22  Adductor magnus</td>
<td>40  Abductor hallucis</td>
</tr>
<tr>
<td>23  Tibialis anterior</td>
<td>41  First lumbrical</td>
</tr>
<tr>
<td>24  Extensor hallucis longus</td>
<td>42  Second lumbrical</td>
</tr>
<tr>
<td>25  Extensor digitorum longus</td>
<td>43  Third lumbrical</td>
</tr>
<tr>
<td>26  Peroneus tertius</td>
<td>44  Fourth lumbrical</td>
</tr>
<tr>
<td>27  Peroneus longus</td>
<td>45  Abductor digiti minimi</td>
</tr>
<tr>
<td>28  Peroneus brevis</td>
<td>46  Flexor digiti minimi brevis</td>
</tr>
<tr>
<td>29  Gastrocnemius</td>
<td>47  Flexor hallucis brevis</td>
</tr>
<tr>
<td>30  Soleus</td>
<td>48  Adductor hallucis</td>
</tr>
<tr>
<td>31  Plantaris</td>
<td>49  First plantar interosseus</td>
</tr>
<tr>
<td>32  Popliteus</td>
<td>50  Second plantar interosseus</td>
</tr>
<tr>
<td>33  Tibialis posterior</td>
<td>51  Third plantar interosseus</td>
</tr>
<tr>
<td>34  Flexor digitorum longus</td>
<td>52  First dorsal interosseus</td>
</tr>
<tr>
<td>35  Flexor hallucis longus</td>
<td>53  Second dorsal interosseus</td>
</tr>
<tr>
<td>36  Extensor hallucis brevis</td>
<td>54  Third dorsal interosseus</td>
</tr>
<tr>
<td>37  Extensor digitorum brevis</td>
<td>55  Fourth dorsal interosseus</td>
</tr>
<tr>
<td>38  Flexor digitorum brevis</td>
<td></td>
</tr>
</tbody>
</table>

A total of two hundred and twenty seven muscles from right and left lower extremities have been dissected during this investigation.
Procedure

In order to facilitate the taking of the numerous photographs, a simple boxlike wooden frame (size 2'x 3'x 2') had been built which held the floodlights of 200 watts. The bottom of this box is a plexiglass plate in which had been etched a grid of square centimeters. The photographs were taken against a mat black background with the specimens and models lying on this grid. A 35 mm. SLR camera was used with either a wide angle lens or a special macro lens for reproductions in the actual size (1:1) in conjunction with a neutral filter.

Typically, each muscle was dissected first in situ, and its fascia was removed. Special care was taken to delineate the origins and insertions. Then a sketch and a photograph was made of the muscle in situ. The muscle was then removed from the lower extremity. The superficial and deep aspects of the isolated muscle were recorded by sketches and by photographs. Most previous authors used a sectional technique (cross- and longitudinal sections) for the study of the course and extent of the internal structures of the muscles. This method may be adequate for simple internal structures but it is by no means adequate for an analysis of the complex internal structures in their entirety. Vastly better, but very time consuming, is the teasing technique which had been used by some investigators (Druler, 1926; Kadletz, 1931; Schumacher, 1961; and Heinze, 1963b).

We employed the teasing method for this study. In essence, each individual muscle fiber was first isolated with the aid of a
pair of very fine, straight forceps. Then, each fiber was followed as far as possible to its attachment on an aponeurosis or internal tendon of origin or of insertion. Next, each muscle fiber was removed after it was cut off close to its attachment. Often, this had not been possible, because the muscle fiber had one of its attachments on the underside of an internal tendon, thus placing this attachment out of reach. In such case, the muscle fiber was first cut as close as possible to its accessible attachment. Then this procedure was repeated on as many fibers as necessary to free the internal tendon and to lift it upward. Then these fibers were cut close to their formerly hidden attachments and removed. This see-saw like procedure was then repeated until all muscle fibers could be removed from the internal tendons. Photographs were made during these individual stages of the dissection. Supplementary sketches were made when warranted due to the complex arrangements of the internal tendons. This painstaking dissection permitted the complete isolation of the internal tendons, their branchings, and their filamentous terminations. The isolated internal tendons of each muscle had been stored in plastic containers containing a 4% formaldehyde solution.

Previous investigators presented their results either by means of diagrams of sections of muscles, or a few times by "graphic diagrams" conveying a three-dimensional image. Our dissections had revealed many details about the internal tendons which had not been previously reported. Especially, the divisions of the internal tendons into tertiary, quartery, and even quintary branches had not been observed
earlier. In view of this complexity of the arrangements of the internal tendons, the mode of presentation of the results used by previous authors, is clearly inadequate.

Therefore, it was decided to construct models of the internal tendons of each muscle for presentation of the results. Such models had to display the shape and size of the area of the internal tendons, as well as the angulations between all their ramifications. In addition, the course and direction of the muscle fibers between the ramifications of the internal tendon should be indicated. It had been felt that the latter information may allow at a later date some mechanical analysis of the internal structures of the muscles. Finally, the models should be stable enough to retain the interrelationships between these internal structures.

The internal tendons of the models were cut from sheets of easily malleable zinc alloy. 16 gauge soft copper wire was used for the representations of the course of the muscle fibers. These component parts of the models were soldered together, thus producing a stable complete model.

The sketches and photographs obtained so far of the internal tendons and the directions of the fibers gave valuable, but incomplete, information for the construction of the models. These data allowed a perception of the overall plan of the internal structures. However, it had not been possible to extract sufficiently accurate values of the angulation between the branchings of the internal tendons, and of their three-dimensional curvatures. In order to obtain these values, a
second dissection of the internal structures of each muscle become necessary. It was done on the muscles of a left lower extremity. The previously used teasing technique was employed again. Also sketches were made, and serial photographs were taken.

The dissection proceeded from superficial to deep. Superficially located internal tendons were first visualized, and deeply located ones later. A replica of each individual internal tendon was cut and formed from the zinc alloy sheet as soon as the complete size and shape could be determined. Especial care was taken to transfer the correct angulations between the internal tendons from this dissection to the models.

The assembly of the models proceeded, following the dissection, from superficial to deep. To avoid blocking access to deeper aspects of the models, those copper wires indicating the course of the superficial fibers had to be left off initially. Therefore, after the dissection and the concomitant building of the model had been completed, the contour of the superficial aspect of the model as expressed by copper wires had to be added. This information about the contour had been gained from muscles which had been removed after a third dissection in situ. Great care had been taken to select for this dissection a lower extremity which was as nearly as possible identical in shape to the one used for the construction of the models.

It may be added here that no gross variations of the internal tendons could be observed during the repeated dissections of the same muscle in different extremities.
Most models have been constructed in the actual sizes of the muscles. A twice linear enlargement has been used for small muscles, such as the piriformis, quadratus femoris, tensor fascia lata, pectineus, plantaris, popliteus, and the intrinsic muscles of the foot.

It should be realized, however, that some of the models made to the real size of the muscles are actually slightly enlarged due to the technical requirements of the construction of the models. Very acute angles between internal tendons had to be slightly enlarged in the models in order to place solder between the metal sheets representing the internal tendons. However, the presentation of the overall layout of the internal structures has not been affected by these slight local enlargements. The models were photographed against the same grid as the one used for the photography of the muscles.
THE TERMINOLOGY

The necessity for a new terminology of the internal tendons became evident after up to forty of these had been observed in some of the muscles. Such a terminology should be logical, and should be free of ambiguity.

Kadletz (1931) and Heinze (1969) distinguished between primary and secondary laminae without, however, giving definitions of these terms.

The concept of naming the internal tendons according to their mode of branching is sound. Our terminology follows and expands this concept. The definitions of the subdivisions of the internal tendons are given in the following with the aid of a diagram (fig. 1 p. 26).

The external tendon is that structure which attaches the muscle to bones, ligaments, intermuscular septa, interosseous membranes, or other tendons. It is at either end of the muscle. These external tendons are further defined following the accepted usage as tendon of origin (0), and tendon of insertion (I).

The (tendinous) aponeurosis, often present, is usually an extension of varying length of the tendon on the surface of the muscle. Such an aponeurosis may arise directly from bone or any other structure without the interposition of an external tendon. The
aponeurosis is considered a part of the external tendinous structure. An aponeurosis of origin (Ao) is distinguished from an aponeurosis of insertion (Ai). Subscripts are added for further distinction in the presence of several aponeuroses, such as: Ao₁, Ao₂, or Ai₁, Ai₂.

The internal tendon generally is an expansion of the external tendinous structures within the muscle mass. These expansions form tendinous laminae which can occur singly or in multiples. They are classified according to their branching. Muscle fibers originate or insert on both sides of these laminae.

The primary lamina branches off from either the (external) tendon or from the tendinous aponeurosis, or directly from bone. The primary laminae of origin (Po) are distinguished from those of insertion (Pi). Again, in the case of multiple laminae, subscripts are added for further distinction, such as: Po₁, Po₂, or Pi₁, Pi₂. Muscle fibers originate or insert on both sides of these laminae.

The secondary, tertiary, quartery, and quintary laminae The secondary laminae arise from a primary lamina, and the tertiary lamina from a secondary one. Aside from these, quartery and quintary laminae have been observed. Generally, these arise from laminae with the next lower number. Again, distinctions are made between laminae associated with the origin and those associated with the insertion. In the case of multiple laminae, additional subscripts are added,
as has been shown for the primary laminae. This terminology allows the construction of a formula of all internal tendons associated with either the origin or the insertion of a muscle. Such a formula gives an overview of all internal tendons and their deviations. Again, muscle fibers originate or insert on both sides of all these laminae. The following table 2 shows the abbreviations used.

**TABLE 2**

**ABBREVIATIONS USED IN TEXT AND PICTURES**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>tendon of origin</td>
</tr>
<tr>
<td>Ao</td>
<td>aponeurosis of origin</td>
</tr>
<tr>
<td>Po</td>
<td>primary lamina of origin</td>
</tr>
<tr>
<td>So</td>
<td>secondary lamina of origin</td>
</tr>
<tr>
<td>To</td>
<td>tertiary lamina of origin</td>
</tr>
<tr>
<td>Qao</td>
<td>quarterly lamina of origin</td>
</tr>
<tr>
<td>Qio</td>
<td>quintary lamina of origin</td>
</tr>
<tr>
<td>I</td>
<td>tendon of insertion</td>
</tr>
<tr>
<td>Ai</td>
<td>aponeurosis of insertion</td>
</tr>
<tr>
<td>Pi</td>
<td>primary lamina of insertion</td>
</tr>
<tr>
<td>Si</td>
<td>secondary lamina of insertion</td>
</tr>
<tr>
<td>Ti</td>
<td>tertiary lamina of insertion</td>
</tr>
<tr>
<td>Qai</td>
<td>quarterly lamina of insertion</td>
</tr>
<tr>
<td>Qii</td>
<td>quintary lamina of insertion</td>
</tr>
</tbody>
</table>
Fig. 1 Diagram of the internal structures of a muscle

- tendon
- aponeurosis
- primary lamina
- secondary lamina
- tertiary lamina
- quartery lamina
- quintary lamina
- muscle contour

---

0  Po3  Ao  Po2  So1  To  Qao  Qio  Pi2  Pi1  Qi1  Qi1  Ti  Si  A11  A12  I
RESULTS

The muscles of the lower limb are arranged for descriptive purposes in four groups. This arrangement is based on the regional relationship of the muscles to the hip, thigh, leg, and foot.

The description of each muscle is in four parts. An introductory general description of the muscle is followed by analytical descriptions of the internal tendons of origin and of insertion. A description of the course of the muscle fibers is given in the last part. This information is added because the numbers, locations, and sizes of the internal tendons determine the arrangements of the muscle fibers.

The Muscles of the Hip

There are the following eleven muscles. The psoas muscles have been eliminated because the specimens available do not include their origins from the posterior abdominal wall:

1 Iliacus
2 Gluteus maximus
3 Gluteus medius
4 Gluteus minimus
5 Tensor fascia lata
6 Piriformis
7 Obturator internus
8 Gemellus superior
9 Gemellus inferior
10 Quadratus femoris
11 Obturator externus
Iliacus

General Description (figs. 2,3)

The iliacus is a large fan shaped muscle that arises from the upper half of the internal surface of the iliac fossa. Its fibers converge to its tendon of insertion, which in turn, inserts together with that of the psoas muscle, into the lesser trochanter.

Internal Tendons of Origin (figs. 2,3)

Formula: $A_0_1, A_0_2$.

The muscle arises by a fleshy origin, without any visible tendon of origin. There are two small aponeuroses of origin, the anterior and posterior aponeuroses. The anterior aponeurosis of origin ($A_0_1$) is on the lateral part of the anterior surface of the muscle (fig. 2). The posterior aponeurosis of origin ($A_0_2$) is on the lowest part of the lateral side of the posterior surface of the muscle (fig. 3).

Internal Tendons of Insertion (figs. 4,5,6,7)

Formula: $A_i, P_i_1, P_i_2, P_i_3, S_i$.

The tendon of insertion joins the tendon of psoas major and forms a strong, thick, common tendinous cord. This common tendon of insertion ($I$) inserts on the lesser trochanter. The tendon is flattened from lateral to medial. Its medial surface twists anteriorly close to the fleshy part. The aponeurosis of insertion ($A_i$ in fig. 6) extends on the posterior surface of the muscle, and lies against the superior ramus of the pubis. This aponeurosis ($A_i$) is as thick as the tendon of insertion, and it is proximally continuous with the intramuscularly
located first primary lamina (Pi₁, figs. 4, 5, 6, 7). This primary lamina (Pi₁) terminates with two poorly deliniated lobular extensions. A secondary lamina (Si, figs. 4, 5, 6, 7) arises at an angle from the middle of the anterior surface of the first primary lamina Pi₁. Si extends to, and is partially continuous with the lateral margin of a lamina (Pi) of insertion of the psoas major muscle. A second primary lamina Pi₂ arises from the middle of the anteriorly convex surface of the aponeurosis Ai. This lamina (Pi₂) curves laterally forming about a half circle, and it is thicker at its free margin (figs. 4, 5, 6, 7). A third, very small primary lamina Pi₃, arises from the anterior border of the tendon of insertion (I) close to its bony attachment (figs. 4, 5). It terminates in three small saw teeth-like extensions, whose tips are successively arranged in a step-like fashions (figs. 5, 7).

The Arrangement of the Muscle Fibers

The muscle fibers of the central part of the anterior surface arise from the iliac crest, converge and insert on the anterior surface of the first primary lamina Pi₁ of insertion, and on both surfaces of the secondary lamina (Si). The muscle fibers which arise from the medial and lateral sides converge to the front of the psoas major muscle generally forming a penniform structure (fig. 2). Specifically, the fibers from the medial side insert only on the medial half of the anterior surface of the aponeurosis Ai. Most of the fibers from the lateral side which arise from Ao₁ insert on the lateral half of the anterior surfaces of the aponeurosis Ai, and of the second primary lamina Pi₂. Some of the lateral fibers extend more inferiorly and insert on the superficial surface of the third primary lamina Pi₃.
The majority of the muscle fibers on the posterior surface arise from the iliac fossa, converge and insert on the posterior surfaces of the first (Pi₁) and the second (Pi₂) primary laminae of insertion. A small muscle bundle from the posterior aponeurosis of origin (Ao₂) passes downward parallel to the anterior border of the aponeurosis of insertion and inserts on the deep surface of the third primary lamina Pi₃.

**Gluteus maximus**

**General Description** (figs. 11, 12)

The gluteus maximus is a large, thick, coarse fibered quadrilateral muscle. Its fibers arise from the rough area of the external surface of the ilium behind the posterior gluteal line, from the posterior sacro-iliac joint, and from the posterior surface of the sacro-tuberous ligament. Its superficial fibers are parallel and pass obliquely downward and laterally to its broad tendon of insertion, which in turn, inserts with two parts into the ilio-tibial tract and into the gluteal tuberosity of the femur.

**Internal Tendons of Origin** (fig. 13)

**Formula:** Ao₁, Ao₂, Po₁, Po₂.

There is no tendon of origin. Two aponeuroses arise together from the rough surface of the ilium. The superficial aponeurosis Ao₁ is small and thick (fig. 13), and it is connected to the deep aponeurosis Ao₂. The contour of the distal free edge resembles villi. There are seven of these very small extensions (fig. 13). The deep aponeuro-
sis Ao₂ is large, thick, quadrilateral and ends with a brush-like border. From its deep aspect arise two broad, thin, and fish tail-like primary laminae(Po₁, Po₂), which course parallel to each other. Their borders are directed superiorly and laterally. Also, the line of attachments of these primary laminae divide the deep aponeurosis Ao₂ into three nearly equal areas.

**Internal Tendons of Insertion (fig. 14)**

**Formula:** Ai₁, Ai₂, Pi₁, Pi₂, Pi₃, Pi₄, Pi₅, Pi₆, Pi₇, Pi₈, Pi₉, Pi₁₀, Pi₁₁.

The tendon of insertion is broad, thick, and strong, and consists of two parts. The large and flat upper part(I₁) inserts into the ilio-tibial tract, and the lower, thick, and cord-like part(I₂) inserts into the gluteal tuberosity.

From the upper part of the tendon arise two aponeuroses. One is large and superficial(Ai₁), the other one is small and deep(Ai₂).

The superficial aponeurosis Ai₁ is thick and strong. From its deep surface arise ten primary laminae(Pi₁, Pi₂, Pi₃, Pi₄, Pi₅, Pi₆, Pi₇, Pi₈, Pi₉, Pi₁₀) of varying sizes and shapes(fig. 14). When numbering these beginning from inferior; the second, third and six primary laminae(Pi₂, Pi₃, Pi₆) are large, curved, and arise perpendicular to the aponeurosis. They have, with the exception of the third, a serrated border. The eight, ninth, and tenth primary laminae(Pi₈, Pi₉, Pi₁₀) are of medium size, and form an acute angle with the aponeurosis Ai₁. Their smooth and curved inferior borders overlap each other from superior to inferior. The remaining primary laminae(Pi₁, Pi₄, Pi₅, Pi₇)
are very small, and resemble small ridges which arise from the aponeurosis $A_{i1}$.

The deep aponeurosis $A_{i2}$ is small and short (fig. 14), and arises from the deep surface of the tendon of insertion (I). This aponeurosis terminates into a primary lamina $P_{i11}$.

The Arrangement of the Muscle Fibers (figs. 15, 16)

The most superficial fibers arise from the proximal muscle-tendon junction of origin, from the posterior sacro-iliac joint, and from the sacrum. These fibers pass in a parallel fashion obliquely downward and laterally, and insert on the distal muscle-tendon junction of insertion. The deeper fibers arise from the deep aspect of the deep aponeurosis $A_{o2}$, its primary laminae ($P_{o1}$, $P_{o2}$), from the sacrum, and also from the sacro-tuberous ligament. These fibers course in the same manner as the superficial fibers, and insert on the deep aspect of the superficial aponeurosis $A_{i1}$ and its primary laminae ($P_{i1}$, $P_{i2}$, $P_{i3}$, $P_{i4}$, $P_{i5}$, $P_{i6}$, $P_{i7}$, $P_{i8}$, $P_{i9}$, $P_{i10}$), on the deep aspect of the deep aponeurosis $A_{i2}$ and on its primary $P_{i11}$.

Gluteus medius

General Description (figs. 17, 18)

The gluteus medius is a quadrilateral muscle. The upper part of the muscle is covered by the gluteal fascia, whereas its lower part is covered by the gluteus maximus. The lateral part of its deep surface is connected to the superficial surface of the aponeurosi of insertion of the gluteus minimus by three small, thin slips of muscle
fibers (fig. 25). The gluteus medius arises from the rough area of the external surface of the ala of the ilium between the anterior and the posterior gluteal lines. It inserts with a strong, short tendon into the posterior and upper surface of the greater trochanter. This insertion is partially fused with the tendon of the gluteus minimus (fig. 25).

Internal Tendons of Origin (figs. 19, 20)

Formula: $Ao_1, Ao_2, Ao_3, Po_1, Po_2, Po_3, Po_4, Po_5, Po_6, Po_7, Po_8, Po_9, Po_{10}, Po_{11}, Po_{12}, Po_{13}$.

There is no tendon of origin. The muscle fibers arise directly from bone. There are one superficial and two deep aponeuroses of origin. The superficial aponeurosis ($Ao_1$) is very large. It covers the upper half of the superficial surface of the muscle. Twelve primary laminae arise from the deep aspect of the aponeurosis (fig. 20). From its lateral side, arise the first two primary laminae ($Po_1, Po_2$). They are rather large and extend from the aponeurosis to its distal border. Another set of very small primary laminae is arranged in two vertical rows. The laminae of the lateral row are named $Po_3, Po_4, Po_5$, and those of the medial row are named $Po_{10}$ and $Po_{11}$. The very small primary laminae $Po_6, Po_7, Po_8, Po_9$, and $Po_{12}$ arise from the distal border and medial part of the aponeurosis $Ao_1$.

On the deep surface of the muscle are two deep aponeuroses. One deep aponeurosis $Ao_2$ arises together with the superficial aponeurosis $Ao_1$. The former ends with a dentate border, and its lateral part becomes a primary lamina $Po_{13}$. The other deep aponeurosis $Ao_3$ arises from the anterior gluteal line. There is no primary lamina arising
from this aponeurosis.

**Internal Tendons of Insertion** (figs. 19, 21, 22)

**Formula:**\[A_{11}, A_{12}, P_{11}, P_{12}, P_{13}, S_{11}, S_{12}, S_{13}, S_{14}, S_{15}, S_{16}, S_{17}, S_{18}, S_{19}, S_{20}, S_{21}, S_{22}, S_{23}\]

The external tendon of insertion is strong and short. There is one triangular shaped (\(A_{11}\)) and one lunar shaped (\(A_{12}\)) aponeuroses (figs. 19, 21). The proximal part of the triangular aponeurosis (\(A_{11}\)) terminates as a small primary lamina (\(P_{11}\), figs. 21, 22). From the lunar shaped aponeurosis (\(A_{12}\)), arise two large quadrilateral primary laminae, the middle (\(P_{12}\)), and the medial (\(P_{13}\)) primary laminae. The tendinous fibers of the middle primary lamina (\(P_{12}\)) are parallel, and its anterior deep surface (fig. 21) is smooth, whereas its posterior surface (fig. 22) gives rise to a series of five small secondary laminae (\(S_{11}, S_{12}, S_{13}, S_{14}, S_{15}\)). The tendinous fibers of the medial primary lamina (\(P_{13}\)) radiate fan-like. It has a medial portion which is curved, and a lateral portion which is flat. On its anterior (or deep) surface, arises a series of secondary laminae of varying sizes (\(S_{16}, S_{17}, S_{18}, S_{19}, S_{20}, S_{21}, S_{22}, S_{23}\)).

The Arrangement of the Muscle Fibers (figs. 23, 24)

The arrangements and directions of the muscle fibers on the superficial (or posterior) surface are different from those on the deep (or anterior) surface.

The arrangement of the fibers on the superficial part of the
muscle is different on the lateral, and on the medial portions. The muscle fibers on the lateral portion arise from the deep aspect of the superficial aponeurosis Ao₁ (fig. 23), and pass downward in a parallel fashion. They insert on the posterior surface of the triangular aponeurosis Ai₁, and the posterior surface of the middle primary lamina Pi₂ and its secondary laminae (Si₁, Si₂, Si₃, Si₄, Si₅). The muscle fibers on the medial portion arise from two areas, the deep aspect of the superficial aponeurosis Ao₁, and the most medial portion of the ilium. The fibers from these two areas insert on the posterior surface of the medial primary lamina Pi₃ in such a way that a groove is formed between them. Thus the appearance of a pennate arrangement is created, without actually being in existence.

On the deep surface of the muscle are three different arrangements of the fibers. First, the muscle fibers on the medial part arise from a small aponeurosis Ao₃, pass obliquely and insert on the anterior surface of the medial primary lamina Pi₃, and its secondary laminae (Si₆, Si₇, Si₈, Si₉, Si₁₀, Si₁₁, Si₁₂, Si₁₃, Si₁₄, Si₁₅, Si₁₆, Si₁₇, Si₁₈, Si₁₉, Si₂₀, Si₂₁, Si₂₂, Si₂₃). Secondly, the muscle fibers on the medial part, form a series of six well separated muscle fibers (fig. 18) which arise from the deep aspect of the deep aponeurosis Ao₂. These fibers insert on the anterior surface of the middle lamina Pi₂. Thirdly, the muscle fibers on the lateral part arise from the primary lamina Po₁₃, and the deep aspect of the superficial aponeurosis Ao₁. These fibers converge downward and insert on the superficial, and deep surfaces of the primary lamina Pi₁. In addition, there are three small,
thin muscular slips (fig. 25) that arise from the primary lamina Po₁₃ pass downward and insert on the superficial surface of the superficial aponeurosis Ai of the gluteus minimus.

**Gluteus minimus**

**General Description** (figs. 25, 26)

The gluteus minimus is a fan-shaped muscle that arises with a fleshy origin from the external surface of the ala of the ilium between the anterior and inferior gluteal lines. The muscle fibers converge and insert on the anterior surface of the greater trochanter. The insertion is partially fused with that of the lateral part of the gluteus medius (fig. 25).

**Internal Tendons of Origin** (fig. 27)

Formula: Ao, Po₁, Po₂, Po₃, Po₄, Po₅, Po₆, Po₇, Po₈, So₁, So₂.

There is no visible external tendon of origin. A small aponeurosis Ao is on the deep surface of the muscle (fig. 26). It terminates within the muscle as five primary laminae (Po₁, Po₂, Po₃, Po₄, Po₅) which end in five irregularly shaped slips (fig. 27). Two secondary laminae (So₁, So₂) arise perpendicular to the deep surfaces of the second and third primary laminae (Po₂, Po₃). These secondary laminae extend beyond the boundaries of the primary laminae. Another three very small primary laminae (Po₆, Po₇, Po₈) arise directly from, and perpendicular to the ala of the ilium. They are too small to be preserved.

**Internal Tendons of Insertion** (fig. 28)

Formula: Ai₁, Ai₂, Pi₁, Pi₂, Pi₃, Pi₄, Pi₅, Pi₆, Pi₇.
The external tendon is strong and thick. A superficial aponeurosis \( A_{1} \) which extends fan-shape like arises from this external tendon. This aponeurosis covers the distal half of the superficial surface of the muscle. A broad band-like primary lamina \( P_{1} \) (fig. 28) arises from the deep aspect of this aponeurosis \( A_{1} \), and extends upward half the length of the aponeurosis \( A_{1} \). \( P_{1} \) divides the aponeurosis into a medial and a lateral part. A series of four small primary laminae \( P_{2}, P_{3}, P_{4}, P_{5} \) arise from the deep aspect of the medial part of the aponeurosis. Two small, thin primary laminae \( P_{6}, P_{7} \) arise from the deep aspect of the lateral part of the aponeurosis \( A_{1} \).

A small deep aponeurosis \( A_{2} \) arises from the external tendon on the deep surface of the muscle. It curves nearly perpendicular towards medial, and thus forms together with the external tendon an inverted L-shaped structure.

**The Arrangement of the Muscle Fibers** (figs. 29, 30)

The arrangements and the directions of the muscle fibers on the superficial surface are different from those on the deep surface.

The fibers on the superficial surface (figs. 25, 29) arise directly from the ilium and converge toward the proximal and deep aspect of the superficial aponeurosis \( A_{1} \), and its primary laminae \( P_{1}, P_{2}, P_{3}, P_{4}, P_{5}, P_{6}, P_{7} \). As already described, three small, thin slips arise from the anterior(or deep) surface of the primary lamina \( P_{13} \) of the gluteus medius, pass downward and insert on the posterior(or superficial) surface of the superficial aponeurosis \( A_{1} \) of the gluteus minimus (fig. 25).
The muscle fibers on the deep surface (figs. 26, 30) course differently in the medial and in the lateral parts. The medial part has parallel fibers. They arise from the aponeurosis Ao and its primary laminae Po₃, Po₄, Po₅ and secondary lamina So₂, pass downward and insert on the deep aspect of the deep aponeurosis Ai₂. The muscle fibers of the lateral part form a true pennate arrangement. The fibers which originate from the primary and secondary laminae (Po₁, Po₂; and So₁) on the one side, and from the ilium and three small primary laminae (Po₆, Po₇, Po₈) on the other side, converge, and insert on the primary lamina Pi₁.

Tensor fascia lata

General Description (figs. 31, 32)

The tensor fascia lata is a flat, strap-like muscle. It arises with a small, short tendon from the outer lip of the iliac crest adjacent to the anterior superior iliac spine. The muscle fibers of the superficial surface pass downward and slightly posteriorly, whereas the fibers of the deep surface pass downward and somewhat anteriorly. These deep fibers (fig. 31) are shorter than those on the superficial surface (fig. 32). The muscle inserts with a barely identifiable tendon on the ilio-tibial tract.

Internal Tendons of Origin (figs. 33, 34)

Formula: Ao₁, Ao₂, Ao₃, Ao₄, Ao₅, Po₁, Po₂, Po₃, Po₄, Po₅, Po₆, Po₇.

The external tendon of origin is very short and thick. There are three narrow aponeuroses, Ao₁, Ao₂, Ao₃, on the superficial surface.
of the muscle (fig. 33). These decrease in size from anterior to posterior. The superficial anterior aponeurosis $A_{o1}$ is long. Its proximal medial part is fused with the deep anterior aponeurosis $A_{o5}$, and it terminates as the primary lamina $P_{o1}$. The middle aponeurosis $A_{o2}$ has a triangular shape, and terminates as the very short primary lamina $P_{o2}$. The superficial posterior aponeurosis $A_{o3}$ is fused with the deep posterior aponeurosis $A_{o4}$ and it terminates as the very short primary lamina $P_{o3}$.

There are two broad aponeuroses $A_{o4}$ and $A_{o5}$ on the deep surface of the muscle (fig. 34). The deep posterior aponeurosis $A_{o4}$ is long and terminates into a long fish tail-like primary lamina $P_{o4}$. The deep anterior aponeurosis $A_{o5}$ is broader than $A_{o4}$ and it terminates as three short primary laminae $P_{o5}$, $P_{o6}$, $P_{o7}$ which are separated from each other by two very narrow clefts.

**Internal Tendons of Insertion** (fig. 35).

Formula: $A_{i1}$, $A_{i2}$.

The barely identifiable tendon of insertion immediately inserts on the ilio-tibial tract, and then divides into a superficial ($A_{i1}$) and a deep ($A_{i2}$) aponeuroses. The superficial aponeurosis $A_{i1}$ is shorter than the deep one ($A_{i2}$). Each aponeurosis terminates with a fringe-like border.

**The Arrangement of the Muscle Fibers** (figs. 36, 37)

The course of the fibers arising from the superficial aponeuroses $A_{o1}$, $A_{o2}$, $A_{o3}$ and the primary laminae $P_{o1}$, $P_{o2}$, $P_{o3}$ is slightly different from that of the fibers arising from the deep aponeuroses
Ao4, Ao5, and the primary laminae Po4, Po5, Po6, Po7. The more superficial fibers pass downward and slightly posteriorly (fig. 36). The fibers on the deep surface pass also downward, but somewhat anteriorly (fig. 37). Superficial and deep fibers insert on the aponeuroses without a discernable pattern.

Piriformis

General Description (figs. 38, 39)

The piriformis is a flat, elongated, triangular shaped muscle. Its origin is from the internal surface of the sacrum and the sacro-tuberous ligament. The muscle passes laterally and slightly downward, and inserts on the medial surface of the upper end of the greater trochanter.

Internal Tendons of Origin (fig. 40)

Formula: Ao, Po1, Po2, Po3, Po4, Po5, Po6, Po7, Po8, Po9, Po10, Po11,
                Po12, Po13, Po14.

There is no tendon of origin. The aponeurosis Ao of origin forms a nearly complete ring around the muscle. It is broader on the anterior (or deep) surface than on the posterior (or superficial) surface. This aponeurosis arises from the internal surfaces of the sacrum and the sacro-tuberous ligament. It continues and terminates as nine primary laminae (Po1, Po2, Po3, Po4, Po5, Po6, Po7, Po8, Po9), each of which has a dentate outline. Additional five primary laminae Po10, Po11, Po12, Po13, Po14 arise from the deep (or internal) aspect of this aponeurosis Ao. Po10 forms a large V-shaped lamina (fig. 40). Its two leaves arise from the internal aspect of Ao. These two leaves meet
and bound, together with the aponeurosis, a small triangular compartment. The other four small primary laminae \( P_{01}, P_{02}, P_{03}, P_{04} \) form small ridges, which arise from the internal aspect of the anterior portion of the aponeurosis \( A_o \).

**Internal Tendons of Insertion** (figs. 41, 42)

*Formula:* \( P_{i1}, P_{i2}, S_{i1}, S_{i2}, S_{i3}, S_{i4}, S_{i5} \).

The tendon of insertion(I) is boot-like and flattened. It divides and continues as two primary laminae. One of these is the anterior primary lamina \( P_{i1} \), and the other is the posterior primary lamina \( P_{i2} \). The posterior primary lamina \( P_{i2} \) (fig. 41) is short and it terminates with two triangular extensions. The larger extension overlaps the smaller one. The anterior primary lamina \( P_{i1} \) is very long, and extends as far as the aponeurosis of origin. There are five secondary laminae which arise from both of its surfaces. Three small secondary laminae \( S_{i1}, S_{i2}, S_{i3} \) arise from the anterior surface (fig. 42) and two small secondary laminae \( S_{i4}, S_{i5} \) arise from the posterior surface.

**The Arrangement of the Muscle Fibers** (figs. 43, 44)

The most superficial fibers arise from the superficial aspect of the primary laminae \( P_{01}, P_{02}, P_{03}, P_{04}, P_{05} \). These fibers converge and extend as far as to the muscle-tendon junction of insertion. The deeper fibers arise from the deep aspect of the aponeurosis of origin \( A_o \) and its primary laminae \( P_{01}, P_{02}, P_{03}, P_{04}, P_{05} \) and insert on the proximal border of the primary lamina \( P_{i2} \) of insertion and its extensions, the secondary laminae \( S_{i4}, S_{i5} \). Generally the fibers are
staggered in such a way that the superficial fibers extend more distally than the deeper fibers.

On the deep surface, the superficial fibers arise from the superficial aspect of the primary laminae (Po6, Po7, Po8, Po9). These fibers converge and insert on the deep aspect of Pi1 and its secondary laminae Si1, Si2, Si3. The deeper fibers arise from the deep (or internal) aspect of the aponeurosis Ao, and the primary laminae (Po6, Po7, Po8, Po9). They insert on the proximal part of Pi1.

**Obturator internus**

**General Description** (figs. 45, 46)

The obturator internus is a fan-shaped muscle. It arises from the internal surface of the obturator membrane and the adjacent borders of the obturator foramen. The muscle fibers converge and form a tendon, which turns sharply at the lesser sciatic foramen. This tendon passes laterally and inserts on the lower medial surface of the greater trochanter.

**Internal Tendons of Origin** (figs. 47, 48, 49, 50)

Formula: Ao1, Ao2, Po1, Po2, Po3, Po4, Po5, Po6, Po7, Po8, Po9, Po10, Po11, Po12, Po13, Po14, Po15, Po16, Po17.

There is no visible external tendon. A superficial and a deep aponeuroses are present. The superficial aponeurosis Ao1 is broad and of irregular shape. Its lateral and medial ends bent sharply and extend towards the deep surface of the muscle. This aponeurosis Ao1 (fig. 47) terminates and divides into ten teeth-like primary laminae.
(Po1, Po2, Po3, Po4, Po5, Po6, Po7, Po8, Po9, Po10). Four additional primary laminae (Po11, Po12, Po13, Po14) arise from the deep aspect of the superficial aponeurosis Ao1 (figs. 47, 48). Of these, Po11, Po12, and Po13 arise with an acute angle, and Po14 arises parallel to the aponeurosis Ao1.

The deep aponeurosis Ao2 (figs. 49, 50) lies on the deep surface of the muscle between the medial and lateral ends of the superficial aponeurosis which is reflected around the muscle. The deep aponeurosis terminates and divides into two small (Po15, Po16) and one large (Po17) tooth-like primary laminae.

Internal Tendons of Insertion (figs. 51, 52, 53)

Formula: Ai1, Ai2, Ai3, Ai4, Ai5, Ai6, Ai7, Ai8, Pi1, Pi2, Pi3, Pi4, Pi5, Pi6, Pi7, Pi8, Si1, Si2.

The tendon of insertion (I) is strong and thick. This tendon continues as eight aponeuroses (fig. 51), which bend and conform to the general contour of the muscle. The aponeuroses terminate in eight primary laminae (Pi1, Pi2, Pi3, Pi4, Pi5, Pi6, Pi7, Pi8) which radiate like the feathers of a bird of paradise (figs. 52, 53). The third, the fourth, the fifth, the sixth, and the seventh of these laminae twist and penetrate almost vertically into the muscle. Broad and thin secondary laminae (Si1, Si2) arise from the superficial margins of the third and the fourth primary laminae (fig. 52).

The Arrangement of the Muscle Fibers (figs. 54, 55, 56)

The most superficial fibers arise from the deep aspect of the superficial aponeurosis Ao1 and its primary laminae, and from the
adjacent borders of the obturator foramen. These fibers converge and insert on the superficial aspects of the primary and secondary laminae of insertion ($P_{1}$, $P_{2}$, $P_{3}$, $P_{4}$, $P_{5}$, $P_{6}$, $P_{7}$, $P_{8}$, $S_{1}$, $S_{2}$). Some fibers extend on the posterior surface of the aponeurosis beyond the sharp turn at the lesser sciatic foramen. The deeper fibers arise from the obturator membrane, from the deep aponeurosis $A_{0}$, and the adjacent borders of the obturator foramen. These fibers converge and insert on the deep aspect of the primary and secondary laminae ($P_{1}$, $P_{2}$, $P_{3}$, $P_{4}$, $P_{5}$, $P_{6}$, $P_{7}$, $P_{8}$, $S_{1}$, $S_{2}$).

Gemelli

General Description (fig. 57)

There are two small gemelli muscles, the gemellus superior and the gemellus inferior (fig. 57). The gemellus superior arises from the external surface of the ischial spine and the gemellus inferior arises from the ischial tuberosity. The gemellus superior is parallel to the superior border of the obturator internus muscle, and the gemellus inferior is partially posterior and partially inferior to the tendon of insertion of the obturator internus muscle. They insert on the tendon of insertion of the obturator internus muscle close to its bony attachment.

Internal Tendons of Origin

There are no external and internal tendons of origin.

Internal Tendons of Insertion (fig. 56)

Formula: $P_{1}$, $P_{2}$.
There are two thin primary laminae, one superior ($\Pi_1$) and one inferior ($\Pi_2$), which arise from the superior and inferior borders of the tendon (I) of insertion of the obturator internus close to its attachment. The superior one is a little smaller than the inferior one.

**The Arrangement of the Muscle Fibers (fig. 56)**

The fibers are parallel in both muscles. They arise from the external surfaces of the ischial spine and ischial tuberosity, and insert in each muscle on both surfaces of their primary laminae ($\Pi_1$, $\Pi_2$). The posterior fibers of the gemellus inferior extend further to the posterior surface of the tendon of insertion of the obturator internus.

**Quadratus femoris**

**General Description (figs. 58, 59)**

The quadratus femoris in situ appears as a small, short and quadrilateral muscle. However, it becomes evident, when the muscle is isolated, that there is a small triangular aponeurotic extension ($A_0_1$) of the visible quadrilateral part (fig. 58). This extension originates from the ischial tuberosity which hides this triangular part from view. The muscle fibers pass laterally and insert on the posterior surface of the femur along a vertical line extending from the middle of the intertrochanteric crest.

**Internal Tendons of origin**

Formula: $A_0_1$, $A_0_2$. 
There is no tendon of origin. The first aponeurosis Ao₁ arises directly from the lateral half of the ischial tuberosity and adjacent parts. It is large, and has a triangular shape. This aponeurosis expands on the posterior surface of the muscle which is normally hidden from view. It is difficult to preserve during dissection because it is not very tendinous, but rather more like a thick fascia. The second aponeurosis Ao₂ is smaller. It arises on the superior surface of the muscle, and its beginning is very close to the terminal tip of the first aponeurosis Ao₁.

**Internal Tendons of Insertion**

**Formula:** Ao₁, Ao₂, Ai₁, Ai₂, Ai₃.

There is no tendon of insertion. One large quadrilateral and two small triangular aponeuroses are present. These arise from the posterior surface of the femur along a vertical line from the intertrochanteric crest. The large quadrilateral aponeurosis Ao₁ expands on the lower half of the anterior surface of the muscle. The other two small triangular aponeuroses Ai₂ and Ai₃ are located on the upper half of the anterior surface of the muscle.

**The Arrangement of the Muscle Fibers (figs. 6o, 61)**

The muscle fibers on the posterior and anterior surfaces of the muscle are arranged slightly different. The muscle fibers on the anterior surface are roughly separated into three bundles (fig. 59). The fibers of the upper two muscular bundles arise from the deep aspect of the aponeurosis Ao₂, pass laterally and insert on the deep aspect of the two small triangular shaped aponeuroses Ai₂ and Ai₃. The fibers of the
Lower muscular bundle arise from the proximal part of the deep aspect of the triangular aponeurosis A01. They first diverge, and then converge toward their insertion on the proximal part of the deep aspect of the quadrilateral aponeurosis A11.

The muscle fibers on the posterior surface arise from the distal end of the deep aspect of the triangular aponeurosis A01, pass laterally in a parallel fashion, and insert on the distal end of the deep aspect of the quadrilateral aponeurosis A11. On the lower part, the muscle fibers curve gently to reach their insertion (figs. 60, 61).

**Obturator externus**

**General Description (figs. 62, 63)**

The obturator externus is a fan-shaped muscle which arises from the external surface of the obturator membrane and from the adjacent borders of the obturator foramen. It inserts on the trochanteric fossa of the femur.

**Internal Tendons of Origin (fig. 64)**

**Formula:** A01, A02, A03, A04, Po1, Po2, Po3, Po4.

There is no visible tendon of origin. A series of four small aponeuroses A01, A02, A03, A04 are visible on the superficial surface of the muscle. Their terminal parts become primary laminae. The first of these (Po1) is broad and wide. Its anterior border curves upon itself and thus the lamina becomes bilaminated. The second primary lamina Po2 is long and narrow with a pointed terminal part. The third primary lamina Po3 is short and narrow. It has also a pointed terminal part.
The fourth primary lamina Po₄ is broad and short with tooth-like terminations.

**Internal Tendons of Insertion (figs. 65, 66)**

Formula: Ai₁, Ai₂, Pi, Si₁, Si₂, Ti₁, Ti₂, Qai, Qii.

The external tendon is thick and strong. The internal tendons form a very complex structure, which are connected to the aponeurosis on the surface of the muscle. The naming of these internal tendons proceeds from the surface to the deep aspect of the muscle.

There are two aponeuroses, one on the superficial surface, and the other one on the deep surface. The aponeurosis Ai₁ terminates with a primary lamina Pi(fig. 65). This lamina has seven tooth-like extensions. From the deep aspect of this lamina arise the anterior and posterior secondary laminae Si₁ and Si₂. Their adjacent borders are continuous with each other. These two laminae form with each other an obtuse angle. Each of these two secondary laminae terminates with four teeth-like extensions. Two tertiary laminae Ti₁ and Ti₂ which are directed superiorly arise from the deep aspects of these secondary laminae(fig. 66). The first tertiary lamina Ti₁ is long and thin. It arises from the deep aspects of the two adjoining borders of the secondary laminae Si₁ and Si₂. The anterior border of the Ti₁ attaches to the deep aspect of the deep aponeurosis Ai₂. This tertiary lamina Ti₁ terminates with asymmetric fish tail-like extensions. The second tertiary lamina Ti₂ is small and curved. It extends between the posterior margins of the secondary lamina Si₂ and the quartery lamina Qai. This tertiary lamina Ti₂ terminates with a fringe-like border.
The quarterly lamina Qai (fig. 66) arises from the deep aspect of the first tertiary lamina Ti₁. It is directed posteriorly and attaches to the deep margin of the second tertiary lamina Ti₂, as previously described. This quarterly lamina terminates with a fringe-like border. From the deep aspect of this lamina (Qai) arises a quintary lamina Qii of irregular shape.

On the deep surface of the muscle, an aponeurosis Ai₂ arises from the external tendon. This aponeurosis terminates with two extensions. The outer extension fuses with the deep aspect of the secondary lamina Si₂ (fig. 66). The inner extension attaches to the extero-lateral border of the tertiary lamina Ti₁.

**The Arrangement of the Muscle Fibers** (figs. 67, 68, 69)

Generally, the muscle fibers of the superficial surface are slightly different from those of the deep surface.

The fibers of the anterior half of the superficial surface course differently from those of the posterior half. The fibers of the anterior half arise from the superficial aspect of the two primary laminae Po₁ and Po₂. The anterior fibers fold and thus form a bilamina. These fibers insert on the superficial aspect of the secondary lamina Si₁. The fibers of the posterior half of the muscle arise from the superficial aspect of the two primary laminae Po₃ and Po₄. They insert on the superficial aspect of the secondary lamina Si₂. The deeper fibers which arise from the deep aspect of the primary lamina Po₃ and Po₄ insert on the proximal part of both surfaces of the secondary laminae Si₂.
The muscle fibers on the deep surface arise from the external surface of the obturator membrane, converge, and insert on both surfaces of the tertiary, quarteny and quintary laminae ($T_{11}$, $T_{12}$, $Q_{ai}$, $Q_{ii}$), and the corresponding aspect of the aponeurosis $A_{i2}$. The directions of the muscle fibers do not conform to any of the classified patterns.

The Muscles of the Thigh

The muscles of the thigh are divided into three groups according to their locations:

1. **The Anterior (or Extensor) Group:**
   - (1) Sartorius
   - (2) Quadriceps femoris
   - (3) Articularis genus

2. **The Posterior (or Flexor) Group:**
   - (1) Biceps femoris
   - (2) Semitendinosus
   - (3) Semimembranosus

3. **The Medial (or Adductor) Group:**
   - (1) Pectineus
   - (2) Gracilis
   - (3) Adductor longus
   - (4) Adductor brevis
   - (5) Adductor magnus
The Anterior (or Extensor) Group

The muscles of the anterior or extensor group are post-axial and are located on the front of the thigh.

Sartorius

General Description (figs. 70, 71, 74, 75)

The sartorius is a long, strap-like muscle that crosses obliquely from supero-lateral to infero-medial. It arises from the anterior superior iliac spine with a very short external tendon, and it inserts into the proximal part of the medial surface of the upper part of the tibia.

Internal Tendons of Origin (figs. 72, 73)

Formula: \( Ao_1, Ao_2, Ao_3, Po_1, Po_2, Po_3, So, To \).

The external tendon is very short and thick with triangular outline in cross section. There are three aponeuroses, anterior \( (Ao_1) \), postero-medial \( (Ao_2) \), and postero-lateral \( (Ao_3) \). Each of these aponeuroses arises from a corresponding part of the external tendon. These aponeuroses terminate as primary laminae \( (Po_1, Po_2, Po_3) \) which have fringe-like borders. At the angle between the anterior and postero-lateral primary laminae \( Po_1 \) and \( Po_3 \) arises a long, thin secondary lamina \( So \) (figs. 72, 73). It also has a fringe-like border. On the deep surface of this secondary lamina \( So \) arises at a nearly right angle, a small, tertiary lamina \( To \) (fig. 73).

Internal Tendons of Insertion (fig. 76)

Formula: \( Pi \).
The external tendon is broad and thin. It terminates as the broad, thin primary lamina Pi which has a fringe-like border (fig. 76).

The Arrangement of the Muscle Fibers (figs. 77, 78)

The muscle fibers arise from the deep aspects of each of the three aponeuroses and both surfaces of the primary laminae (Po₁, Po₂, Po₃), the secondary lamina So, and the tertiary lamina To. They extend downward, flatten, and insert on both surfaces of the primary lamina Pi where the most superficial fibers insert distal to the deeper fibers. There is no twisting of the fibers where the cross section of the muscle changes from triangular to flattened ovoid below the upper one fourth.

Quadriceps femoris

General Description (figs. 79, 85)

Generally, the quadriceps femoris is described as having four heads of origin, the rectus femoris, and the three vasti, i.e. vastus lateralis, vastus intermedius, and vastus medialis. The three vasti are, with the exception of their most proximal parts, inseparable. The rectus femoris is completely separated from the three vasti and arises with two heads. The straight head arises from the anterior inferior iliac spine. The reflected head arises from above the rim of the acetabulum. These two heads immediately join together and form a short tendon of origin.

The three vasti arise from a large area of bone and the adjacent intermuscular septa. The lateral part arises with a very short tendon from the anterior and inferior borders of the greater trochanter, and
with a large fleshy mass from the lateral intermuscular septum, and the entire lateral surface of the body of the femur. The middle part also arises with a large fleshy mass from the anterior surface of the body of the femur. The medial part arises with a very short tendon from the inferior border of the lesser trochanter, and with a large fleshy mass from the medial intermuscular septum, and the medial surface of the body of the femur.

Both, the tendon of the rectus femoris, and the tendon of three vasti fuse together into the broad quadriceps femoris tendon which covers the patella, and becomes continuous with the ligamentum patellae which, in turn, inserts into the tuberosity of the tibia.

Internal Tendons of Origin (figs. 81, 82, 83)

Formula of the rectus femoris: $A_0_1$, $P_0_1$, $P_0_2$.

The external tendon is strong and short. It arises with two heads. The straight head originates from the anterior inferior iliac spine. The reflected head originates from the superior rim of the acetabulum. An aponeurosis $A_0_1$ continues from the external tendon on the middle of the anterior surface of the proximal third of the muscle. The margins of this aponeurosis penetrate into the muscle as primary lamina $P_0_1$. In addition, another primary lamina $P_0_2$ arises at an angle of 45 degree from the deep aspect of the aponeurosis $A_0_1$. It extends inferiorly close to the insertion.

Formula of the vastus lateralis: $A_0_2$.

There is a very short external tendon which arises from the anterior and inferior borders of the greater trochanter. A very large
and broad aponeurosis $A_{o_2}$ arises from this tendon and covers most of the antero-lateral surface of the muscle(fig. 80). Its lateral border is thick and fuses with the lateral intermuscular septum(fig. 82).

Formula of the vastus intermedius: none.

The vastus intermedius has neither an external tendon nor an aponeurosis of origin. The muscle fibers arise with fleshy origin from the anterior surface of the body of the femur.

Formula of the vastus medialis: $A_{o_3}$.

There is a very short external tendon which arises from the inferior border of the lesser trochanter. A small, thin aponeurosis $A_{o_3}$ arises from the external tendon, and extends over the medial half of the muscle(fig. 84). Its medial border is continues with the medial intermuscular septum(fig. 83).

Internal Tendons of Insertion (fig. 84)

Formula: $A_{i_1}, A_{i_2}, P_{i_1}, P_{i_2}$.

The external tendon of the quadriceps femoris has two parts: (1) the proper quadriceps femoris tendon which inserts into the upper and lateral borders of the patella, and (2) the ligamentum patellae which arises from the lower border of the patella and inserts on the tibial tuberosity. The external tendon covers a large sesamoid bone, the patella. The upper part of this tendon is easily separated into two layers, a superficial layer which is continuous with the external tendon of the rectus femoris, and a deep layer which appear to be continuous with the fleshy parts of the three vasti.
The superficial layer of the quadriceps tendon is continuous with the external tendon of the rectus femoris (tendo musculi recti femoris). It is short and narrow. A long aponeurosis Ai$_1$ arises from this tendon which covers nearly the entire posterior surface of the rectus femoris (fig. 80). It terminates about 2 cm. from its origin. This aponeurosis is shaped like a large anteriorly open trough.

The deep layer of the quadriceps tendon is broad and has three parts: (1) the primary lamina of the vastus lateralis, Pi$_1$, (2) the aponeurosis of the vastus intermedius Ai$_2$, and (3) the primary lamina of the vastus medialis Pi$_2$.

The primary lamina Pi$_1$ is large and has a flipper-like outline. It arises from the supero-lateral border of the external tendon and from the lateral border of the aponeurosis Ai$_2$ of the vastus intermedius.

The aponeurosis Ai$_2$ is long and narrow. It arises from the middle of the deep layer of the external tendon of the quadriceps femoris. A deep fascia separates this aponeurosis from the aponeurosis Ai$_1$ of insertion of the rectus femoris. The lateral and medial borders of Ai$_2$ continue with the primary lamina of the vastus lateralis Pi$_1$ and of the vastus medialis Pi$_2$.

The primary lamina Pi$_2$ is small, narrow, and of irregular outline. It arises from the supero-medial border of the external tendon and from the medial border of the aponeurosis Ai$_2$ of the vastus intermedius.

**The Arrangement of the Muscle Fibers** (figs. 86, 87, 88)

The most superficial fibers of the upper half of the rectus femoris which arise from the margin of the superficial aspect of the
primary lamina \( \text{Po}_1 \), course obliquely downward, diverge, and insert on the margins of the proximal half of the aponeurosis \( \text{Ai}_1 \). The fibers of the lower half of the muscle arise from the long primary lamina \( \text{Po}_2 \) that originates from the deep aspect of the aponeurosis \( \text{Ao}_1 \). It extends further distal and becomes the central tendon of the true pennate muscle. However, it is an inverted form of pennate. The fibers diverge obliquely downward and laterally from this central tendon and insert more distal on the anterior aspect of the lower half of the aponeurosis \( \text{Ai}_1 \). The deeper fibers arise from the deep aspect of the aponeurosis \( \text{Ao}_1 \) and its primary lamina \( \text{Po}_2 \), pass downward, diverge, and insert on the anterior aspect of the proximal half of the aponeurosis \( \text{Ai}_1 \).

The most superficial fibers of the vastus lateralis arise from the medial margin of its aponeurosis \( \text{Ao}_2 \). They pass obliquely downward and medially with a slightly different direction for the upper and for the lower fibers. The upper fibers are more horizontal, whereas the lower fibers are more vertical. These superficial fibers insert on the junction between the aponeurosis \( \text{Ai}_2 \) of the vastus intermedius and the primary lamina \( \text{Pi}_1 \) of the vastus lateralis. The deeper fibers arise from the deep aspect of the aponeurosis \( \text{Ao}_2 \), the lateral intermuscular septum and the lateral surface of the body of the femur. Some of these fibers insert on the most supero-lateral part of the anterior aspect of the primary lamina \( \text{Pi}_1 \); some insert on the lateral part of the posterior aspect of the primary lamina \( \text{Pi}_1 \).

The muscle fibers of the vastus intermedius arise from the anterior surface of the body of the femur, pass obliquely downward and
anteriorly and insert on the posterior aspect of the aponeurosis $A_{12}$ and the adjacent parts of the primary lamina $P_{11}$ of the vastus lateralis and the primary lamina $P_{12}$ of the vastus medialis.

The most superficial fibers of the vastus medialis arise superiorly from the medial intermuscular septum, and inferiorly from the margin of the aponeurosis $A_{03}$. These fibers pass obliquely downward and laterally; the superior fibers are more vertical, and the inferior fibers are more horizontal. All these fibers insert on the junction of the aponeurosis $A_{12}$ of the vastus intermedius and the primary lamina $P_{12}$ of the vastus medialis; some of these fibers insert on the anterior aspect, and some on the posterior aspect of the primary lamina $P_{12}$ of the vastus medialis.

**Articularis genus**

**General Description (fig. 85)**

The articularis genus is a small muscle bundle. It arises from the lower part of the anterior surface of the body of the femur, and inserts partly on the lowest posterior aspect of the aponeurosis $A_{12}$ of the vastus intermedius, and partly on the upper part of the capsule of the knee joint.

**Internal Tendons of Origin and of Insertion**

There is neither an internal tendon of origin nor of insertion.

**The Arrangement of the Muscle Fibers**

The muscle fibers arise from the lower part of the anterior surface of the body of the femur. These fibers insert partly on the
lower part of the posterior aspect of the aponeurosis Ai₂ of the vastus intermedius and partly on the upper part of the capsular ligament of the knee joint.

The Posterior (or Flexor) Group

The muscles of the posterior or flexor group are pre-axial and are located on the back of the thigh. The following muscles are in this group:

1. Biceps femoris
2. Semitendinosus
3. Semimembranosus

Biceps femoris

General Description (figs. 89, 104)

The biceps femoris has a long head and a short head of origin. The long head arises from the lateral half of the ischial tuberosity. The short head originates from the lateral lip of the linea aspera, as well as from the posterior surface of the lateral intermuscular septum. These two heads unite into a common muscle mass at about the lower third of the muscle. The insertion is on the lateral side of the head of the fibula, the lateral condyle of the tibia, and on the fascia of the leg.

Internal Tendons of Origin (figs. 90, 91)

The formula of the long head is: Ao, Po₁, Po₂.

There is a thick and strong tendon of origin which serves as
external tendon of origin for both, the long head of the biceps femoris and the semitendinosus. The distal part of this tendon is separated into two aponeuroses: (1) a small aponeurosis Ao₂ of the semitendinosus (fig. 95) which will be described later, and (2) a broad and long aponeurosis Ao of the long head of biceps femoris(figs. 90, 91). This aponeurosis terminates with a narrow, thin primary lamina Po₁(fig. 91). In addition, another long and thin primary lamina Po₂ arises at an angle of 45 degree from the deep surface of the aponeurosis Ao(fig. 90). This lamina terminates with asymmetric fish tail-like extensions.

There is neither an external nor internal tendon of origin of the short head of the biceps femoris.

Internal Tendons of Insertion (fig. 92)

Formula: Ai, Pi.

The tendon of insertion is short and flat. An aponeurosis Ai continues from this tendon and becomes wider as it extends proximally (fig. 92). This aponeurosis covers the posterior surface of the lower two-thirds of the muscle. A primary lamina Pi arises obliquely at an acute angle from the deep surface of this aponeurosis. It is narrow infero-laterally, but broader supero-medially and terminates again with fish tail-like extensions. This primary lamina Pi divides the aponeurosis Ai into two portions, an upper portion which serves as insertion of the long head, and a lower portion which serves as insertion of the short head.

The Arrangement of the Muscle Fibers (figs. 93, 94)

The arrangements and directions of the muscle fibers of the
long head are different from that of the short head.

The muscle fibers on the superficial surface of the long head course differently from those on the deep surface. On the superficial surface, the most superficial fibers arise from the proximal part of the lateral surface of the common tendon of origin. These fibers pass downward in a parallel fashion, and insert on the deep aspect of the proximal part of the aponeurosis Ai (fig. 93). The deeper fibers arise from the distal part of the lateral surface of the common tendon, and from both surfaces of the primary lamina Po₂. These fibers insert on the deep surface of the proximal half of the aponeurosis Ai and the corresponding surface of its primary lamina Pi. On the deep surface, the muscle fibers arise from the superficial aspect of the posterior margin of the primary lamina Po₁, pass obliquely downward, posteriorly, and insert on the deep aspect of the medial margin of the aponeurosis Ai. The fibers which arise from the anterior margin of the aponeurosis Ao together with the fibers from the terminal part of the primary lamina Po₁ form an inverted pennate-like structure. These fibers insert on the superficial aspect of the primary lamina Pi.

The muscle fibers of the short head pass obliquely downward and posteriorly in a parallel fashion, and insert on the deep surface of the distal half of the aponeurosis Ai.

**Semitendinosus**

**General Description** (figs. 95, 96)

The semitendinosus is a long spindle shaped muscle with an
obliquely directed intervening tendinous inscription which passes from proximo-medially to disto-laterally. This muscle has then two portions. The upper portion arises from the outer side of the ischial tuberosity and from the common tendon which it shares with that of the biceps femoris, and inserts in the tendinous inscription. The lower portion arises from the tendinous inscription and inserts, by means of long, small, and rounded tendon, on the antero-medial surface of the posterior part of the medial condyle of the tibia deep to the tendon of insertion of the gracilis muscle.

Internal Tendons of Origin of the Upper Portion (fig. 97)
Formula: \( A_{o1}, A_{o2} \).

The tendon of origin is very short. There are two aponeuroses (fig. 97) which are proximally continuous with each other. The anterior borders of the proximal parts of both aponeuroses join and form a wedge. One aponeurosis \( A_{o1} \) arises from the tendon and covers the medial surface of the muscle. The other aponeurosis \( A_{o2} \) arises from the distal part of the common tendon, and extends on the lateral surface of the muscle.

Internal Tendons of the Tendinous Inscription (figs. 98, 99)
Formula: \( A, P, S \).

The tendinous inscription completely separates the muscle in upper and lower portions. Following the pattern of description used so far, one can discern an aponeurosis, and primary and secondary laminae. The aponeurosis \( A \) begins on the proximal portion of the lower part of the posterior surface of the muscle. Proximally, this aponeurosis continues as a primary lamina \( P \) which partially traverses the
muscle obliquely from posterior to anterior. Before this lamina terminates with a teeth-like border, a secondary lamina S arises at an acute angle from the anterior aspect. This secondary lamina extends anteriorly and inferiorly through the mass of the muscle until it reaches its anterior surface. Thus, the muscle is completely divided into two portions.

**Internal Tendons of Insertion (fig. 100)**

Formula: \( A_i, P_i \)

The tendon of insertion is long, small, and round. An aponeurosis \( A_i \) continues from this tendon and covers the deep surface of the muscle. Its medial border curves to a small extent around the medial border of the muscle. The lateral and terminal borders penetrate within the muscle as the primary lamina \( P_i \).

**The Arrangement of the Muscle Fibers (figs. 101, 102, 103)**

This muscle is classically considered as a single muscle which consists of two portions, the upper and lower portions. These two portions are attached to the intervening tendinous inscription.

The arrangements and directions of the muscle fibers of these two portions are of the spindle type on the superficial surface, and of the pennate type on the deep surface.

On the superficial surface of the muscle, the fibers of the superficial part of the upper portion arise from the distal border of the deep aspect of the aponeurosis \( A_{o_2} \), pass downward, diverge and insert on the most distal part of the superficial surface of the primary lamina \( P \) of the tendinous inscription (fig. 102). The deeper fibers
arise from the medial surface of the common tendon and insert on the proximal part of the superficial surface of the primary lamina P of the tendinous inscription.

On the deep surface of the muscle (fig. 101), the fibers of the superficial part of the upper portion arise from the distal border of the deep aspect of the deep aponeurosis Ao₁, pass downward and medially, and insert on the outer surface of the margin of the secondary lamina S of the tendinous inscription. The deeper fibers arise from the deep aspect of the aponeurosis Ao₁, and insert on the deep surface of the primary lamina P of the tendinous inscription, proximal to the secondary lamina S.

On the superficial surface of the muscle, the fibers of the superficial part of the lower portion arise from the distal border of the deep aspect of the aponeurosis A of the tendinous inscription. These fibers converge and insert on the posterior aspect of the aponeurosis Ai. The deeper fibers arise from the deep aspect of the primary lamina P below the secondary lamina S, and insert on the proximal part of the posterior aspect of the primary lamina Pi.

On the deep surface of the muscle, the fibers of the superficial part of the lower portion arise from the margin of the secondary lamina S of the tendinous inscription in the same manner and direction as in the upper portion, and converge to insert on the distal border of the anterior aspect of the primary lamina Pi. The deeper fibers arise from the inner surface of the secondary lamina S, insert on the proximal part of the anterior and posterior surfaces of the primary lamina Pi.
Semimembranosus

General Description (figs. 104, 105)

The semimembranosus has a proximal tendinous part and a distal muscular part. It arises from the lateral surface of the posterior aspect of the ischial tuberosity, and it inserts on the back of the medial condyle of the tibia, as well as on the capsule of the knee joint.

Internal Tendons of Origin (figs. 106, 107)

Formula: $Ao, Po_1, Po_2, Po_3, Po_4, So$. 

The external tendon is thick and strong. It becomes wider and thinner as it extends downward to the lateral side of the muscle. This tendon terminates with an aponeurosis $Ao$ which covers the posterior surface of the muscle. This aponeurosis narrows as it continues inferiorly. The margin of this aponeurosis extends on the primary lamina $Po_1$ which has on the medial side a fringe-like border. There are three additional small primary laminae $Po_2$, $Po_3$, $Po_4$ which arise from the deep aspect of the aponeurosis $Ao$ (fig. 106). From the deep aspect of the lateral margin of $Po_1$ arises a long, thin secondary lamina $So$ (figs. 106, 107).

Internal Tendons of Insertion (fig. 108)

Formula: $Ai, Pi_1, Pi_2$.

The round and short tendon of insertion gives rise to the wide and thin aponeurosis $Ai$ (fig. 108). It covers the anterior surface of the muscle. The margin of this aponeurosis penetrates into the muscle.
as the primary lamina Pi₁, which curves anteriorly and terminates with a fringe-like border. The general contour of this aponeurosis and its primary lamina resemble a leave of a willow (lanceolate). In addition, a long and narrow primary lamina Pi₂ arises from the deep aspect of the aponeurosis Ai(fig. 108). Its proximal part is wider than its distal part.

The Arrangement of the Muscle Fibers (figs. 109, 110, 111, 112)

The arrangement and direction of the muscle fibers of the superficial surface is different from that of the deep surface.

The muscle fibers of the superficial surface are arranged in an asymmetric inverted pennate-like structure(fig. 110). The muscle fibers on the medial side arise from the superficial surface of the entire medial border of the primary lamina Po₁, and pass obliquely and medially downward. These fibers insert on the superficial surface of the medial border of the primary lamina Pi₁. The upper medial superficial fibers are more vertical than those of the lower fibers. The muscle fibers on the lateral side arise from the superficial surface of the lateral border of the primary lamina Po₁. They curve laterally towards the deep surface of the muscle and insert on the anterior aspect of the primary lamina Pi₁. They form a thick muscle mass of the inverted asymmetric pennate type.

The muscle fibers on the deep surface(fig. 109) have a semi-pennate arrangement. These fibers arise from the anterior aspect of the aponeurosis Ao and its primary laminae. They pass obliquely downward and medially, and insert on the anterior aspect of the primary
laminae $\Pi_1$ and $\Pi_2$. Again, the upper fibers are more vertical than the lower fibers.

**The Medial (or Adductor) Group**

The muscles of the adductor group are located on the anteromedial part of the thigh. These include the following muscles:

1. Pectineus
2. Gracilis
3. Adductor longus
4. Adductor brevis
5. Adductor magnus

**Pectineus**

**General Description** *(figs. 113, 114)*

The pectineus is an oblong shaped muscle. It arises from the pecten of the pubis, and inserts on the pectineal line on the posterior surface of the femur.

**Internal Tendons of Origin** *(fig. 115)*

**Formula:** $Po_1, Po_2, Po_3, Po_4, Po_5, Po_6, So_1, So_2, So_3$.

The tendon of origin is very short. There is no aponeurosis. A primary lamina arises from the tendon, and enters the muscle. It immediately terminates and divides into six parallel primary laminae $Po_1, Po_2, Po_3, Po_4, Po_5, Po_6$ of different sizes and shapes *(fig. 115)*. On the deep surfaces of the three primary laminae, three very small secondary laminae $(So_1, So_2, So_3)$ arise from the bases of the second, third, and fifth primary laminae.
Internal Tendons of Insertion (fig. 116)

Formula: \( A_{i1}, A_{i2}, A_{i3}, A_{i4}, P_{i1}, P_{i2}, P_{i3}, P_{i4}, P_{i5}, P_{i6}, P_{i7}, P_{i8}, P_{i9} \)

The tendon of insertion is thin and short, and gives rise to the broad and thin superficial aponeurosis \( A_{i1} \) which covers the anterior surface of the muscle. This aponeurosis divides into anterior and posterior parts. Each part terminates in a primary lamina (\( P_{i1}, P_{i2}, \) fig. 116). Both have fringe-like borders. Additional four very small primary laminae (\( P_{i3}, P_{i4}, P_{i5}, P_{i6} \)) arise from the deep aspect of the aponeurosis \( A_{i1} \).

Three small aponeuroses (\( A_{i2}, A_{i3}, A_{i4} \)) which cover the deep surface of the muscle arise from the tendon of insertion. Two aponeuroses (\( A_{i3}, A_{i4} \)) originate from the middle, and one (\( A_{i2} \)) arises from the posterior border of the tendon. Each aponeurosis continues as a primary lamina (\( P_{i8}, P_{i9}, P_{i7} \)) respectively, and each of these has a fringe-like border.

The Arrangement of the Muscle Fibers (figs. 117, 118)

The muscle fibers are generally arranged in a parallel fashion. The fibers on the superficial surface arise from the superficial aspects of the primary laminae, pass obliquely downward and slightly medially, and insert on the superficial aspect of the posterior part of the primary lamina \( P_{i2} \). Some of the most medial fibers turn to the deep surface of the muscle, and insert on the superficial aspect of the primary lamina \( P_{i7} \) which is near the posterior border of the muscle.

The muscle fibers on the deep surface arise from the deep aspects.
of the primary laminae (Po₁, Po₂, Po₃, Po₄, Po₅, Po₆), pass obliquely downward, turn slightly laterally, and insert on the superficial aspects of the primary laminae (Pi₈, Pi₉). Some of the most lateral fibers turn to the superficial surface of the muscle, and insert on the superficial aspect of the anterior part of the primary lamina Pi₁.

**Gracilis**

**General Description (fig. 119)**

The gracilis is a long, flat, and elongated triangular muscle. It arises from the lower pubic symphysis and the superior part of the pubic arch, and inserts on the medial surface of the proximal part of the shaft of tibia, between the insertions of the sartorius and semimembranosus muscles.

**Internal Tendons of Origin (figs. 120, 121)**

**Formula:** Ao₁, Ao₂.

The external tendon is broad and short. A superficial aponeurosis Ao₁ with a finger-like border arises from this tendon and covers the superficial surface of the muscle. A small deep aponeurosis Ao₂ with a fringe-like border (fig. 120) is located on the deep surface of the muscle.

**Internal Tendons of Insertion (fig. 122)**

**Formula:** Ai, Pi₁, Pi₂, Pi₃.

The external tendon is long, small and round. It extends proximally as the long and narrow aponeurosis Ai (fig. 122) on the posterior border of the muscle. This aponeurosis folds into superficial and deep
layers. The terminal part of the superficial layer penetrates into the muscle as the primary lamina \( \text{Pi}_1 \). In addition, two primary laminae, a middle (\( \text{Pi}_2 \)) and a distal (\( \text{Pi}_3 \)) one, arise from the anterior border of the deep layer of the aponeurosis. The middle primary lamina \( \text{Pi}_2 \) is long and narrow, whereas the distal one (\( \text{Pi}_3 \)) is small and wide.

**The Arrangement of the Muscle Fibers** (figs. 123, 124)

Generally, the muscle fibers of both the superficial and deep surfaces course in a parallel fashion. The fibers on the superficial surface (fig. 123) arise from the deep aspect of the superficial aponeurosis \( \text{Ao}_1 \), converge and insert on the superficial aspect of the primary laminae (\( \text{Pi}_1, \text{Pi}_2, \text{Pi}_3 \)). The fibers on the deep surface of the muscle (fig. 124) arise from the deep aspect of the deep aponeurosis \( \text{Ao}_2 \), converge and insert on the deep aspect of the primary laminae (\( \text{Pi}_1, \text{Pi}_2, \text{Pi}_3 \)).

**Adductor longus**

**General Description** (fig. 125)

The adductor longus is long, somewhat triangular shaped muscle with a truncated apex. It arises from the anterior surface of the body and superior ramus of the pubis. Its insertion which is fused posteriorly with that of the adductor magnus, is on the middle third of the inner lip of the linea aspera of the femur.

**Internal Tendons of Origin** (fig. 126)

**Formula:** \( \text{Ao}, \text{Po} \).

The external tendon is very short. An aponeurosis \( \text{Ao} \) arises
from this tendon and covers the anterior and medial surfaces of the muscle. The aponeurosis terminates as the primary lamina Po which has a fringe-like border (fig. 126).

Internal Tendons of Insertion (fig. 127)

Formula: $A_{i1}, A_{i2}$.

The external tendon is broad and thin. Its deep surface fuses with the tendon of the adductor magnus. There are two aponeuroses of irregular shape, one ($A_{i1}$) on the superficial surface (fig. 127), and the other one ($A_{i2}$) on the deep surface of the muscle (fig. 136). Both terminate with fringe-like borders.

The Arrangement of the Muscle Fibers (figs. 128, 129)

Generally, the muscle fibers of both, the superficial and deep surfaces diverge from the narrow area of origin to the wide area of insertion. The fibers on the superficial surface which arise from the anterior aspect of the primary lamina Po, pass obliquely downward and laterally. They insert on the deep aspect of the superficial aponeurosis $A_{i1}$ (fig. 128). The fibers on the deep surface arise from the deep aspect of the aponeurosis $A_{o}$ and its primary lamina Po, pass downward and laterally in the same manner as the fibers of the superficial surface. They insert on the deep aspect of the deep aponeurosis $A_{i2}$. Some of the fibers on the medial surface of the muscle partially insert on the aponeurosis $A_{i}$ of the adductor magnus.

Adductor brevis

General Description (figs. 130, 131)
The adductor brevis is a triangularly shaped muscle. It arises from the inferior ramus of the pubis and inserts on the upper third of the medial lip of the linea aspera of the femur. This insertion is in continuation with the insertion of the upper part of the adductor longus. The insertion on the posterior surface fuses with that of the upper part of the adductor magnus.

Internal Tendons of Origin (fig. 132)

Formula: Ao, Po.

The external tendon is very short, thin, and small. A small aponeurosis Ao is visible on the proximal part of the superficial surface of the muscle (fig. 130). This aponeurosis terminates as the primary lamina Po. It is cone-shaped and has small tooth-like extensions (fig. 132).

Internal Tendons of Insertion (fig. 133)

Formula: Ai₁, Ai₂, Ai₃, Ai₄.

The external tendon is very short and thin, and fuses with the tendon of the upper part of the adductor magnus. Two aponeuroses (Ai₁, Ai₂) are on the superficial surface, and two (Ai₃, Ai₄) are on the deep surface. Those on the deep surface are smaller than those on the superficial surface. All aponeuroses have fringe-like borders.

The Arrangement of the Muscle Fibers (figs. 134, 135)

Generally the directions of the muscle fibers on the superficial surface are slightly different from those on the deep surface. The majority of the fibers on the superficial surface (fig. 134) arise from the superficial aspect of the primary lamina Po, pass obliquely downward
and laterally in a parallel fashion, and then insert on the deep aspect of the lower part of the superficial aponeurosis \(A_{12}\). Some fibers which arise from the superficial aspect of the small tooth-like part of the primary lamina \(P_0\), diverge and insert on the deep aspect of the upper part of the superficial aponeurosis \(A_{11}\).

The majority of the fibers on the deep surface (fig. 135), arise from the deep aspects of the upper part of the primary lamina \(P_0\), and its small tooth-like part. They course in a somewhat parallel fashion, and insert on the deep aspect of the upper part of the deep aponeurosis \(A_{13}\). Some fibers which arise from the deep aspect of the lower part of the primary lamina \(P_0\), diverge and insert on the deep aspect of the lower part of the deep aponeurosis \(A_{14}\).

**Adductor magnus**

**General Description** (fig. 136, 137)

The adductor magnus is a thick and large triangular shaped muscle. The uppermost part of this muscle is easily separated from the lower part. This uppermost part is sometimes called the "adductor minimus". The adductor magnus, together with the adductor minimus, arise from the conjoint ramus of the ischium and pubis. It inserts with two portions. The fleshy fibers of the upper portion join the deep surface of the external tendons of the adductor longus and brevis and insert on the linea aspera. The lower portion inserts by means of a long, flat tendon(I) on the adductor tubercle of the femur.
Internal Tendons of Origin (figs. 138, 139)

Formula: Ao, Po₁, Po₂, Po₃, Po₄, Po₅, Po₆.

The external tendon is very short. The aponeurosis Ao is of oblong shape and bent upon itself (fig. 138). It is visible on the posterior proximal surface of the muscle. This aponeurosis continues as the primary lamina Po₁ which has a fringe-like border. From the upper and lower borders of the aponeurosis Ao, arise the second and third small primary laminae Po₂ and Po₃. Three primary laminae (Po₄, Po₅, Po₆) arise from the deep aspect of the aponeurosis Ao. The fourth primary lamina Po₄ is long, and arises from the lateral and lower border of the aponeurosis Ao. The irregular shaped primary lamina Po₅ arises from the superficial aspect of the aponeurosis Ao, and terminates with six finger-like extensions. The sixth primary lamina Po₆ arises from the proximal part of Ao, and terminates with fish tail-like extensions.

Internal Tendons of Insertion (fig. 140)

Formula: Ai

The external tendon is long and thin. It terminates with a broad aponeurosis Ai, which covers the antero-medial surface of the muscle. This aponeurosis has a fringe-like border. The anterior border of this aponeurosis attaches to the medial border of the aponeurosis Ai₁ of the anterior layer of the adductor longus. Both aponeuroses form almost a right angle with each other.

The Arrangement of the Muscle Fibers (figs. 141, 142)

Generally, the arrangement of the muscle fibers of the anterior surface is slightly different from that of the posterior surface.
The muscle fibers on the anterior surface (fig. 141) arise from the anterior aspect of the primary laminae Po5 and Po6, and pass obliquely downward and laterally. They diverge and insert on the posterior aspect of the aponeurosis Ai, and on the posterior surface of the tendon of insertion of the adductor longus. The uppermost fibers (of the adductor minimus) arise directly from the conjoint ramus of the ischium and pubis. These fibers pass obliquely downward and laterally, and insert on the posterior surface of the external tendon of the insertion of the adductor brevis. These fibers course more horizontally, whereas those of the adductor magnus course more vertically. The deeper fibers of the adductor magnus arise from the deep aspect of the primary laminae Po5 and Po6. These fibers insert on the posterior aspect of the aponeurosis Ai, and on the posterior surface of the external tendon of the insertion of the adductor longus.

The muscle fibers on the posterior surface (fig. 142), arise from the superficial aspect of the primary laminae Po1, Po2, Po3, diverge and form a penniform structure (fig. 137). They insert on the distal part of the aponeurosis Ai and on the posterior aspect of the external tendon of insertion of the adductor longus. The deeper fibers arise from the deep aspect of the aponeurosis Ao and its primary laminae Po1 and Po4. Their insertion is on the proximal part of the aponeurosis Ai and on the posterior surface of the external tendon of insertion of the adductor longus.
The Muscles of the Leg

The muscles of the leg are divided into three groups according to their locations.

1. The Anterior Group:
   (1) Tibialis anterior
   (2) Extensor hallucis longus
   (3) Extensor digitorum longus
   (4) Peroneus tertius

2. The Lateral Group:
   (1) Peroneus longus
   (2) Peroneus brevis

3. The Posterior Group:
   (1) Gastrocnemius
   (2) Soleus
   (3) Plantaris
   (4) Popliteus
   (5) Tibialis posterior
   (6) Flexor digitorum longus
   (7) Flexor hallucis longus

Tibialis anterior

General Description (figs. 143, 144)

The tibialis anterior is a fusiform shaped muscle. It arises from the proximal two-thirds of the lateral surface of the tibia, and
from the adjoining part of the interosseous membrane. The muscle inserts on the medial side of the medial cuneiform, and on the base of the first metatarsal bone.

**Internal Tendons of Origin (fig. 145)**

Formula: $Ao_1, Ao_2$.

There is no visible tendon of origin. A large superficial aponeurosis $Ao_1$ (fig. 145) arises from the tibia and the adjoining part of the interosseous membrane, and fuses with the deep fascia of the leg. It covers the antero-proximal two thirds of the muscle. Another small deep aponeurosis $Ao_2$ arises from the interosseous membrane and fuses with the aponeurosis $Ao_1$.

**Internal Tendons of Insertion (fig. 146)**

Formula: $Ai, Pi, Si$.

The external tendon is long and small. This tendon crosses the anterior lower third of the tibia from supero-lateral to infero-medial. It becomes an aponeurosis $Ai$, which covers the antero-distal surface of the muscle. This aponeurosis terminates with a large primary lamina $Pi$ (fig. 146) which is shaped like a lanceolate with a serrulate margin. Both lateral and medial borders curve and thus form a posteriorly open shallow trough. The lamina extends superiorly and separates the muscle into superficial and deep portions. The secondary lamina $Si$ arises from the distal border of the primary lamina $Pi$.

**The Arrangement of the Muscle Fibers (figs. 147, 148)**

The muscle fibers of the superficial portion (fig. 148) arise from the margin and terminal part of the aponeurosis $Ao_1$, pass downward,
converge and insert on the distal part of the superficial aspect of the primary lamina Pi. Somewhat deeper fibers arise from the deep aspect of the aponeurosis Ao₁ and insert on the proximal part of the superficial aspect of the primary lamina Pi.

The fibers of the deep portion arise from the deep aponeurosis Ao₂ and the interosseous membrane, pass anteriorly downward and insert on the deep aspect of the primary lamina Pi and its aponeurosis Ai. The most lateral fibers insert on the secondary lamina Si. The proximal fibers insert more proximal than the distal fibers.

**Extensor hallucis longus**

**General Description** (figs. 149, 150)

The extensor hallucis longus is a long triangular shaped muscle, which arises from the middle third of the anterior surface of the fibula and the adjacent interosseous membrane. It is located between the tibialis anterior and the extensor digitorum longus. It inserts with long and narrow tendon on the dorsum of the big toe at the base of the distal phalanx.

**Internal Tendons of Origin**

Formula: none

There is no single tendon of origin, but a series of very tiny tendons are visible at the ends of muscle fibers(figs. 149, 150).

**Internal Tendons of Insertion** (fig. 151)

Formula: Ai, Pi₁, Pi₂, Si.
The external tendon is long and narrow. It becomes the narrow aponeurosis A1 on the anterior medial and distal surfaces of the muscle. This aponeurosis A1 terminates with a long and narrow primary lamina Pi₁. This primary lamina Pi₁ is narrow and extends close to the origin of the muscle. The other primary lamina Pi₂ is on the lateral side and lower half of the muscle, and its tip bent slightly to the deep surface of the proximal part of Pi₁, after which it continues as the secondary lamina Si (fig. 151).

The Arrangement of the Muscle Fibers (figs. 152, 153)

Generally, the arrangement of the muscle fibers is of semipennate type, in which, the proximal fibers are more vertical than the distal fibers. The fibers of the superficial part (fig. 152) which arise from the anterior surface of the fibula and the adjacent interosseous membrane, insert on the superficial aspect of the primary laminae (Pi₁, Pi₂). The fibers of the deep part (fig. 153) of the muscle insert on the deep aspect of the primary laminae (Pi₁, Pi₂), and secondary lamina Si.

**Extensor digitorum longus**

General Description (figs. 154, 155, 156)

The extensor digitorum longus (fig. 154) arises from the opposing proximal three-fourths of the surfaces of the tibia and fibula, and the interosseous membrane. Its tendon divides into four slips to the lateral four toes. Each tendon inserts on the dorsum of the base of the distal
phalanx. This muscle, when isolated(figs. 155, 156), has a general
countour resembling two muscles which are connected with each other.

**Internal Tendons of Origin**

*Formula: none*

There is no single tendon of origin. A series of very tiny
tendons are visible at the ends of the muscle fibers(fig. 155). No
internal tendon is present.

**Internal Tendons of Insertion (fig. 157)**

*Formula: $A_i, P_{i_1}, P_{i_2}, P_{i_3}$.*

The external tendon consists of four slips for the lateral four
toies. These, together with the external tendon of the peroneus tertius,
fuse into one broad tendon(I) on the dorsum of the foot. This tendon
extends superiorly along the anterior border of the muscle to the
middle of the leg. A very narrow aponeurosis $A_i$ extends from the
posterior superior border of this tendon. The margins of this aponeu-
rosis penetrate the muscle mass as three parallel primary laminae($P_{i_1},
P_{i_2}, P_{i_3}$) which are partially fused with each other(fig. 157). The
third primary lamina $P_{i_3}$ is of triangular shape with a posteriorly
directed fringe-like border. It is the continuation of the external
tendon of the peroneus tertius muscle. The second primary lamina $P_{i_2}$
is the continuation of the external tendons of the lateral two toes.
It has a proximal fringe-like border and extends further proximally
than the third one($P_{i_3}$). The first primary lamina $P_{i_1}$ is the continua-
tion of the external tendons of the second and third toes. It is the
terminal part of this lamina twists slightly, and it has a serrulated
border.

**The Arrangement of the Muscle Fibers** (figs. 158, 159)

The fibers on the superficial surface (fig. 159) of the muscle originate from the opposing surface of the proximal part of the tibia and the entire anterior surface of the fibula. They pass downward and anteriorly, and insert on the superficial aspect of the primary laminae (Pi₁, Pi₂, Pi₃). The fibers on the deep surface (fig. 158) arise from the interosseus membrane, course in the same manner as those on the superficial surface, and insert on the deep aspect of the primary laminae (Pi₁, Pi₂, Pi₃).

**Peroneus tertius**

The peroneus tertius is the most posterior and most inferior extension of the extensor digitorum longus muscle. This muscle is inseparable from the latter. Its muscle fibers course in the same manner as those of the extensor digitorum longus muscle. The insertion of the peroneus tertius is by means of a long and narrow tendon on the base of the dorsal surface of the fifth metatarsal bone. This tendon extends proximally and becomes a primary lamina Pi₃ which is inseparable from the internal tendons of the extensor digitorum longus muscle. It is described with this muscle.
Peroneus longus

General Description (figs. 160, 161)

The peroneus longus arises from the upper one-third of the lateral surface of the fibula, and from the posterior intermuscular septum. Its external tendon inserts on the sole of the foot on the base of the first metatarsal and on the medial cuneiform bones.

Internal Tendons of Origin

Formula: \( A_{01}, A_{02} \).

There is no visible tendon of origin. There is one aponeurosis on the superficial surface (fig. 160) and another one on the deep surface (fig. 161) of the muscle. The superficial aponeurosis \( A_{01} \) arises from the proximal part of the fibula, and covers the anterior proximal surface of the muscle. It fuses with the deep fascia of the leg. The deep aponeurosis \( A_{02} \) arises from the proximal part of the interosseous membrane, and covers the posterior proximal part of the muscle.

Internal Tendons of Insertion (figs. 162, 163)

Formula: \( A_1, P_1, S_{11}, S_{12} \).

The external tendon is long and thick. It first lies in the sole of the foot, and then it is on the lateral side of the calcaneum behind the lateral malleolus. This tendon extends upward and becomes the aponeurosis \( A_1 \) (figs. 162, 163). Its posterior and terminal margins penetrate into the muscle as the primary lamina \( P_1 \). This lamina divides into two terminal unequal parts. The posterior part is a little smaller than the anterior one. Two small secondary laminae (\( S_{11} \) and \( S_{12} \)) arise
from the anterior part of the primary lamina Pi. The superficial secondary lamina $S_{i1}$ arises from the superficial surface of Pi as a thin lamina (fig. 162). The deep secondary lamina $S_{i2}$ arises as a ridge-like protrusion from the deep surface of Pi (fig. 163).

The Arrangement of the Muscle Fibers (figs. 164, 165)

The general arrangement of the muscle fibers is of the asymmetric pennate type. The proximal muscle fibers on the superficial surface (fig. 165) arise from the margins and the deep aspect of the superficial aponeurosis $A_{o1}$. They pass downward and insert on the terminal part of the superficial aspect of the primary lamina Pi, and its secondary lamina $S_{i1}$. The distal fibers arise from the intermuscular septum, pass obliquely downward, anteriorly and insert on the superficial aspect and posterior border of the primary lamina Pi. This portion extends more distally.

The muscle fibers on the deep surface (fig. 164) are slightly arranged as those on the superficial surface. The proximal fibers arise from the deep aspect of the deep aponeurosis $A_{o2}$. They pass downward and converge towards the terminal part and anterior border of the deep aspect of the primary lamina Pi, and its secondary lamina $S_{i2}$. The distal fibers arise from the intermuscular septum. These fibers pass obliquely downward, anteriorly and insert on the deep aspect of the posterior border of the primary lamina Pi. Again, this portion extends more distally.
Peroneus brevis

General Description (figs. 166, 167)

The peroneus brevis is an asymmetric pennate muscle which lies deep to the peroneus longus. The peroneus brevis arises from the lower two-thirds of the lateral surface of the fibula, and from the adjacent intermuscular septum. The tendon of insertion curves posterior to the lateral malleolus, and inserts on the lateral surface of the base of the fifth metatarsal bone.

Internal Tendons of Origin

Formula: \( A_{01}, A_{02} \).

There is no tendon of origin. Two long, and small aponeuroses (fig. 167) arise from the anterior and posterior intermuscular septa. These aponeuroses (\( A_{01} \) and \( A_{02} \)) cover the deep proximal surfaces of the muscle, one on the anterior side (\( A_{01} \)) and one on the posterior side (\( A_{02} \)) of the muscle.

Internal Tendons of Insertion (fig. 168)

Formula: \( A_1, P_1 \).

The external tendon is short and thick. It turns posteriorly around the lateral malleolus. The external tendon is continuous with the long aponeurosis \( A_1 \) (fig. 168) which extends close to the proximal origin of the muscle. The margin of this aponeurosis \( A_1 \) terminates as the primary lamina \( P_1 \) which has a serrated border. The anterior proximal part of the primary lamina curves deeply into the muscle mass.

The Arrangement of the Muscle Fibers (figs. 169, 170)

The arrangement of the muscle fibers on the superficial surface
is different from that on the deep surface. The muscle fibers on the superficial surface (fig. 169) arise from the deep aponeuroses (Ao1 and Ao2) and converge to the margins of the superficial aspect of the primary lamina Pi. Those fibers which insert on the posterior margin extend further distally than those on the anterior margin, thus forming an asymmetric arrangement.

The muscle fibers on the deep surface (fig. 170) arise from the deep aponeuroses (Ao1 and Ao2) and the interosseous membrane, pass downward, laterally, and insert on the deep aspect of the aponeurosis Ai and its primary lamina Pi. The fibers course parallel in such manner that the upper fibers insert more proximal, and the lower fibers more distal.

**Gastrocnemius**

**General Description** (figs. 171, 172)

The gastrocnemius has two heads of origin, and forms together with the soleus, the triceps surae. Both origins of the gastrocnemius arise from the facets above the condyles of the femur and parts of the capsules of the knee joint. These two heads are well separated, and insert on a single tendon, which fuses with that of the soleus, and forms the strong tendon Achilles. This tendon inserts on the posterior surface of the calcaneus.

**Internal Tendons of Origin** (figs. 173, 174)

The formula of the lateral head: Ao1, Po1, Po2, Po3, Po4, Po5, Po6, Po7, Po8.
The external tendon of this head is strong and short. An aponeurosis Ao₁ arises from this tendon and covers the posterior lateral surface of this belly. It has an oblanceolate contour (fig. 173) and a smooth margin. On the proximal deep surface of this aponeurosis Ao₁ arises a thin curved primary lamina Po₁. Distally, arise seven small, long, parallel, and ridge-like primary laminae (Po₂, Po₃, Po₄, Po₅, Po₆, Po₇, Po₈).

The formula of the medial head: Ao, Po₉, Po₁₀, Po₁₁, Po₁₂, Po₁₃, Po₁₄, Po₁₅, Po₁₆.

The external tendon is strong and thick. A broad aponeurosis Ao₂ with a flipper-like contour (fig. 174) and fringe-like borders, arises from this tendon and covers the posterior surface of this belly. The proximal medial border of the aponeurosis Ao₂ reflects towards the deep surface of the muscle. A long, thin, falciform shaped primary lamina Po₉ arises from the proximal lateral border of the aponeurosis Ao₂. On the deep aspect of the aponeurosis Ao₂, are seven small, long and ridge-like protrusions which represent the primary laminae Po₁₀, Po₁₁, Po₁₂, Po₁₃, Po₁₄, Po₁₅, Po₁₆.

Internal Tendons of Insertion (fig. 175)

Formula: Ai₁, Pi₁, Pi₂.

The external tendon is strong and thick. It is narrow and has an ovoid cross-section. This tendon receives on its deep surface the external tendon of the soleus muscle. The tendon broadens proximally until it terminates at the lower border of the muscle-tendon junction. This tendon terminates as an aponeurosis Ai₁ (fig. 175), and it is
separated from that of the A12 of the soleus (fig. 172). This aponeurosis A11 of the gastrocnemius covers the deep surface of the muscle. It terminates as two very short primary laminae (Pi1 and Pi2). The lateral primary lamina Pi1 has a few short and one long medial extensions. The medial primary lamina Pi2 has two short and one long lateral extensions.

The Arrangement of the Muscle Fibers (fig. 176)

The general arrangement of the muscle fibers of the superficial surface (fig. 176) of the lateral head is different from that of the deep surface. The fibers on the superficial surface arise from the margins of the aponeurosis A01 and display an asymmetric pennate arrangement. These fibers insert on the muscle-tendon junction of the lateral part of the aponeurosis A11. The deeper fibers arise from the deep surface of the aponeurosis A01 and its primary laminae (P01, P02, P03, P04, P05, P06, P07, P08), and insert on the proximal and deep aspect of the aponeurosis A11.

The muscle fibers on the deep surface (fig. 181) form a multipennate arrangement. The internal tendon septa necessary for such an arrangement are formed by the primary lamina P01, and the long medial extension of the lateral primary lamina P01. The most medial fibers arise from the proximal-medial surface of the lateral aponeurosis A01, and insert on the medial side of the long medial extension of the primary lamina Pi1. The middle fibers arise from the proximal deep surface of the primary lamina P01, and insert on the lateral side of the long medial protrusion of the lateral primary lamina Pi1. The lateral fibers
arise from the proximal deep surface of the aponeurosis Ao₁, lateral to the primary lamina Po₁, and insert on the deep surface of the proximal and lateral part of the primary lamina Pi₁.

The arrangement of the muscle fibers on the superficial surface of the medial head is also different from that of the deep surface. The fibers on the superficial surface (fig. 176) arise from the margins of the aponeurosis Ao₂ and form an asymmetric pennate arrangement. These fibers insert on the muscle-tendon junction of the medial part of the aponeurosis Ai₁. The deeper fibers arise from the deep surface of the aponeurosis Ao₂, and its primary laminae (Po₉, Po₁₀, Po₁₁, Po₁₂, Po₁₃, Po₁₄, Po₁₅, Po₁₆), and insert on the proximal and deep aspects of the aponeurosis Ai₁.

The muscle fibers on the deep surface (fig. 181) are arranged in a multipennate form with two internal tendon septa formed by the primary laminae Po₉ and Pi₂. The lateral fibers arise from the deep surface of the primary lamina Po₉ and insert on the lateral side of the long lateral extension of the medial primary lamina Pi₂. The middle fibers arise from the proximal deep surface of the aponeurosis Ao₂, and insert on the medial side of the long lateral extension. The medial fibers arise from the proximal medial surface of the aponeurosis Ao₂, and insert on the deep surface of the medial part of the medial primary lamina Pi₂.

**Soleus**

**General Description** (fig. 177)

The soleus is a large flat muscle. It lies deep to the gastroc-
nemius. The muscle arises from the soleal line and from the upper part of the fibula. It inserts into the deep surface of the tendo Achillis, which in turn, inserts on the posterior surface of the calcaneus.

**Internal Tendons of Origin** (figs. 178, 179)

Formula: \( Ao_1, Ao_2, Po_1, Po_2, Po_3, Po_4, So. \)

There is no visible tendon of origin. There are two aponeuroses (figs. 178, 179) which cover the deep surface of the muscle. The medial aponeurosis \( Ao_1 \) is large and curved. It margins become the primary lamina \( Po_1 \). Its lower medial margin has a fringe-like border, and contrariwise, the lower lateral margin is smooth. From the deep aspect of the proximal lateral border of this aponeurosis \( Ao_1 \) arises the primary lamina \( Po_2 \) which has a fringe-like border (figs. 178, 179). From the proximal half of this primary lamina \( Po_2 \), arises a secondary lamina \( So \) (fig. 179). This secondary lamina \( So \) lies close to the medial aponeurosis \( Ao_1 \). The lateral aponeurosis \( Ao_2 \) is small and elongated. Its terminal part becomes the pointed primary lamina \( Po_2 \) (fig. 178) which has a fringe-like border. From the deep aspect of the aponeurosis \( Ao_2 \) arises the long, thin primary lamina \( Po_4 \) (fig. 179) which terminates with an asymmetric fish tail-like configuration. This primary lamina \( Po_4 \) is as long as its aponeurosis of origin \( Ao_2 \). The two aponeuroses (\( Ao_1 \) and \( Ao_2 \)) are proximally connected by a thick tendinous arch (2, in fig. 178), and at its middle portion by a thin tendinous membrane (1, in fig. 178).

**Internal Tendons of Insertion** (fig. 180)

Formula: \( Ai_2, Pi_1, Pi_2, Pi_3 \).

The external tendon of the soleus is fused with that of the
gastrocnemius. This tendon is short and is oval shapes in cross-section. It expands as a fan-shaped aponeurosis $A_2$ (fig. 180), and fuses with the broad fan-shaped external tendon of the gastrocnemius. The proximal part of this aponeurosis separates from the latter at about the middle of the calf of the leg. Its terminal part forms two lobes. The margin of this aponeurosis $A_2$ becomes a very short primary lamina $P_1$. There are two primary laminae ($P_2$ and $P_3$) on the deep surface of the aponeurosis $A_2$. The lateral primary lamina $P_2$ is broad, and thin. It is narrow distally, but broader proximally and has an asymmetric fish tail-like termination. The medial primary lamina $P_3$ is narrow and long, and is shorter than the lateral primary lamina $P_2$.

The Arrangement of the Muscle Fibers (fig. 181)

The general arrangement of the muscle fibers on the superficial part is different from that of the deep part. The fibers in the superficial part arise from the proximal and posterior aspect of the aponeuroses $A_1$ and $A_2$. These fibers pass in a nearly parallel fashion downward, posteriorly, and insert on the proximal and anterior aspect of the aponeurosis $A_2$, and its primary lamina $P_1$.

The superficial muscle fibers in the deep part (fig. 181) form a multipennate arrangement with three primary laminae, $P_1$, $P_2$, $P_3$, of origin and one primary lamina $P_2$ of insertion. The muscle fibers of the lateral side arise from the primary lamina $P_3$, diverge in a pennate fashion, and insert on the lateral surface of the primary lamina $P_2$, and on the anterior (deep) aspect of the aponeurosis $A_2$. The muscle fibers of the medial side arise from the primary laminae $P_1$ and
Po₂, again diverge in a pennate fashion, and insert on the medial border of the primary lamina Pi₂, and on the anterior aspect of the aponeurosis Ai₂. This medial pennate structure extends more inferiorly than that of the lateral side. The muscle fibers on the deep side arise from the posterior aspect of the aponeuroses Ao₁ and Ao₂, its primary lamina Po₄, and its secondary lamina So. They pass nearly in a parallel fashion downward and posteriorly, and insert on the anterior (or deep) aspect of the aponeurosis Ai₂, and its primary laminae Pi₂ and Pi₃.

Plantaris

General Description (figs. 182, 183)

The plantaris is a fusiform shaped muscle. Its origin which is partially fused with the lateral head of the gastrocnemius is from a small area above the lateral condyle of the femur. The very long and small tendon of insertion passes obliquely between the gastrocnemius and soleus from lateral to medial. This tendon then runs along the medial border of the tendo Achillis, and inserts on the posterior and medial border of the calcaneus.

Internal Tendons of Origin (fig. 184)

Formula: Ao, Po.

The tendon of origin is very short. A thick aponeurosis Ao(fig. 184) is fused with the posterior and lateral parts of the capsule of the knee joint. The inferior deep surface extends as the primary lamina Po, which has a fringe-like termination.
Internal Tendons of Insertion (fig. 185)

Formula: \( A_1, P_{11}, P_{12} \).

The external tendon is very long and narrow. Proximally, it becomes the small triangular shaped aponeurosis \( A_1 \) (fig. 185). This aponeurosis covers the inferior and superficial surfaces of the muscle. This aponeurosis then terminates as the primary lamina \( P_{11} \) (fig. 185) with has a feather-like border. Close to the external tendon, another primary lamina \( P_{12} \) arises from the lateral border of the aponeurosis \( A_1 \). This primary lamina \( P_{12} \) bifurcates into a fish tail-like termination.

The Arrangement of the Muscle Fibers (figs. 186, 187, 188)

Generally, the muscle fibers of the superficial part (fig. 186) course differently from those of the deep part. The muscle fibers of the superficial proximal part arise from the proximal and posterior aspects of the aponeurosis \( A_0 \) (fig. 188). These fibers converge, and insert on the primary lamina \( P_{11} \). The fibers of the superficial distal part have a spindle-like arrangement. They arise from the distal and superficial aspect of the aponeurosis \( A_0 \) and its primary lamina \( P_0 \). These fibers first diverge, then converge, and insert on the superficial aspect of the primary lamina \( P_{12} \).

The muscle fibers on the deep part (fig. 187) arise from the deep aspect of the terminal part of the primary lamina \( P_0 \), and pass downward in a semipennate arrangement. The fibers insert on the deep aspect of the primary lamina \( P_{12} \).
**Popliteus**

**General Description (figs. 189, 190)**

The popliteus is a cone shaped muscle. It arises from the popliteal part of the lateral condyle of the femur, and from the posterior surface of the capsule of the knee joint. It passes from proximal lateral to distal medial. The muscle fibers insert on the floor of the popliteal surface of the tibia, above the soleal line.

**Internal Tendons of Origin (fig. 191)**

Formula: Po, So₁, So₂, So₃, So₄, So₅.

The external tendon is strong, thick, and triangular in outline. There is no aponeurosis. The primary lamina Po, arises directly from the base of the external tendon. This primary lamina Po together with the external tendon resemble the pectoral fin of a fish. On the deep aspect, there are five secondary laminae So₁, So₂, So₃, So₄, So₅. Two of these arise near the inferior border of the Po and three others arise in the middle of the Po.

**Internal Tendons of Insertion (figs. 192, 193)**

Formula: Ai, Pi₁, Pi₂, Pi₃, Pi₄, Pi₅, Pi₆, Pi₇.

The external tendon is very short and narrow. The aponeurosis Ai(fig. 192) has a triangular shape and has an irregular border. There is a series of seven thin primary laminae, Pi₁, Pi₂, Pi₃, Pi₄, Pi₅, Pi₆, Pi₇ on the deep aspect of this aponeurosis Ai(fig. 193).

**The Arrangement of the Muscle Fibers (figs. 194, 195)**

The superficial muscle fibers(fig. 194) arise from the superfi-
cial and proximal part of the primary lamina Po, and pass in a parallel fashion obliquely downward and medially. These fibers insert on the proximal and deep aspects of the aponeurosis Ai. The deeper fibers arise from the superficial and distal surfaces of the primary lamina Po, and insert on the distal and deep surfaces of the aponeurosis Ai, and its primary laminae Pi₁, Pi₂, Pi₃, Pi₄, Pi₅, Pi₆, Pi₇.

In the deep part (fig. 195), the muscle fibers arise from the deep aspect of the primary lamina Po, and its secondary laminae So₁, So₂, So₃, So₄, So₅. They insert on the popliteal surface of the tibia above the soleal line. The muscle fibers are staggered in such a manner that the proximal fibers insert proximally, and the distal fibers insert distally.

**Tibialis posterior**

**General Description (figs. 196, 197)**

The tibialis posterior is an elongated muscle which arises from the upper half of the posterior surface of the tibia, fibula, and the interosseous membrane. The long tendon of insertion turns around the medial malleolus and passes forward below the strong plantar calcaneonavicular ligament. This tendon then inserts on the tuberosity of the navicular, the cuboid, and the bases of the second, third, and fourth metatarsal bones.

**Internal Tendons of Origin (fig. 198)**

Formula: Ao₁, Ao₂, Ao₃, Ao₄.

There is no visible tendon of origin. There are two proximal
Aponeuroses (Ao₁ and Ao₃). The Ao₁ is thin, and it is located on the proximal and superficial surface of the muscle. The Ao₃ is thin and small, and it is located on the proximal deep and posterior surfaces of the muscle. There are two long aponeuroses (Ao₂ and Ao₄) in the middle of the muscle. The Ao₂ is long and broad (fig. 198). It arises from the interosseous membrane, and covers the superficial surface of the muscle. The Ao₄ is long and narrow. It also arises from the interosseous membrane, and covers the deep surface of the muscle.

Internal Tendons of Insertion (figs. 199, 200)

Formula: Ai, Pi₁, Pi₂, Si.

The external tendon is long and strong. Its proximal part becomes the aponeurosis Ai (fig. 200) which is reflected for a short distance on itself at its anterior border, thus forming an anteriorly open trough composed of two unequal sides of the primary laminae (Pi₁ and Pi₂, in fig. 199). The deep side of the aponeurosis Ai is broad, and penetrates into the deep part of the muscle as the primary lamina Pi₁ which has a fringe-like border. The terminal part of this primary lamina Pi₁ is broad, and curved. On the superficial aspect of this primary lamina Pi₁, arises a very small pinna-like secondary lamina Si (fig. 199). The superficial side of the trough is narrow, and it is a continuation of the anterior border of the aponeurosis Ai. It penetrates into the superficial part of the muscle as a very short lamina Pi₂ which has a fringe-like border (fig. 199).

The Arrangement of the Muscle Fibers (figs. 201, 202, 203)

The muscle fibers on the superficial part course in two different
patterns (fig. 201). The proximal fibers which arise from the deep aspect of the aponeurosis $A_0_1$, converge, and insert on the superficial surfaces of the primary laminae $P_i_1$ and $P_i_2$. The distal fibers which arise from the deep aspect of the aponeurosis $A_0_2$, pass obliquely downward, anteriorly, and insert on the superficial and distal surfaces of the primary lamina $P_i_1$. The somewhat deeper fibers insert on the deep aspect of the primary lamina $P_i_1$, and the secondary lamina $S_i$.

The muscle fibers on the deep part (fig. 202) also course in two different patterns. The proximal fibers arise from the deep aspect of the aponeurosis $A_0_3$, and from the posterior surface of the tibia. They converge and insert on the superficial and proximal surfaces of the primary lamina $P_i_1$. The distal fibers which arise from the deep aspect of the aponeurosis $A_0_4$, pass obliquely, anteriorly, and insert on the superficial aspect of the primary lamina $P_i_1$.

**Flexor digitorum longus**

**General Description** (figs. 204, 205)

The flexor digitorum longus arises from the middle third of the posterior surface of the shaft of the tibia, and from the adjacent medial intermuscular septum. Its long tendon of insertion enters the plantar surface of the foot inferior to the tendon of insertion of the flexor hallucis longus. This tendon then separates into four slips. Each of these slips inserts on the bases of the distal phalanges of the lateral four toes.
Internal Tendons of Origin (fig. 206)

Formula: $A_0_1$, $A_0_2$, $P_0$.

There is no visible tendon of origin. There are two aponeuroses ($A_0_1$ and $A_0_2$). The large aponeurosis $A_0_1$ (fig. 206) has a triangular shape. This aponeurosis $A_0_1$ covers the superficial and proximal surfaces of the muscle. The terminal part of this aponeurosis has a long and narrow extension which becomes the primary lamina $P_0$ (fig. 206). The aponeurosis $A_0_2$ has an oval shape. It covers the deep and proximal surfaces of the muscle. The anterior borders of these two aponeuroses ($A_0_1$ and $A_0_2$) fuse with each other at an acute angle.

Internal Tendons of Insertion (fig. 207)

Formula: $A_i$, $P_i$.

The major tendon arises from the union of the four tendons of the lateral four toes at the middle of the plantar surface of the foot. This tendon turns upward on the medial side of the calcaneus. The proximal part of the external tendon becomes the aponeurosis $A_i$ (fig. 207). This aponeurosis $A_i$ curves on itself and forms an anteriorly open trough. Its margins and terminal parts become the primary lamina $P_i$.

The Arrangement of the Muscle Fibers (figs. 208, 209, 210)

The greater part of the superficial and deep surfaces of the muscle are covered by superficial and deep aponeuroses. These two aponeuroses fuse with each other anteriorly and then form a trough which is open posteriorly. The muscle fibers on these surfaces course in a pennate arrangement (fig. 210). The fibers which arise from the superficial and deep aspects of the aponeuroses $A_0_1$ and $A_0_2$ form a
feather-like arrangement. They insert on the superficial surface of the primary lamina Pi. The deeper fibers which arise from the deep aspects of the aponeuroses Ao₁ and Ao₂, insert on the deep aspect of the primary lamina Pi.

**Flexor hallucis longus**

**General Description** (figs. 211, 212)

The flexor digitorum longus is an oblong shaped muscle with a flat proximal part and a thick distal part. The proximal part arises from the posterior surface of the middle third of the fibula. The distal part arises from the medial surface of the lower third of the fibula and the distal part of the interosseous membrane. Its long and oval shaped tendon of insertion turns to the plantar surface of the foot and inserts into the base of the distal phalanx of the big toe.

**Internal Tendons of Origin** (fig. 213)

**Formula:** Ao₁, Ao₂.

The external tendon is very short. There are two aponeuroses (Ao₁ and Ao₂ in fig. 213), which arise from this tendon. The aponeurosis Ao₁ lies on the proximal and superficial surfaces of the muscle. It is elongated and narrow. The aponeurosis Ao₂ lies on the proximal and deep surfaces of the muscle, and it has a long extension arising from its posterior border.

**Internal Tendons of Insertion** (fig. 214)

**Formula:** A₁, Pi₁, Pi₂, Si.

The external tendon is long and has an oval cross-section. It
extends superiorly to the anterior border of the muscle as the narrow aponeurosis Ai(fig. 214). This aponeurosis curves on itself and thus forms an anteriorly open trough. Its two borders, one superficial and one deep, are wide and penetrate into the muscle as the two primary laminae Pi₁ and Pi₂. From the superficial aspect of the superficial primary lamina Pi₁, arises a secondary lamina Si. This lamina is long and narrow, and extends proximally.

The Arrangement of the Muscle Fibers (figs. 215, 216, 217)

The muscle fibers on the superficial part course in three different directions. The proximal fibers which arise from the deep aspect of the aponeurosis Ai₁(fig. 215), pass directly downward and insert on the superficial and deep aspects of the primary lamina Pi₁. The middle fibers course in a pennate-like arrangement and insert on the middle and superficial aspect of the primary lamina Pi₁. The distal fibers course in a semipennate arrangement. These fibers arise from the medial surface and distal third of the fibula. They pass obliquely downward and anteriorly, and insert on the distal part of the superficial aspect of the primary lamina Pi₁.

The muscle fibers on the deep part course in two different directions. The proximal fibers which arise from the deep aspect of the aponeurosis Ao₂(fig. 216), pass directly downward and insert on the superficial aspect of the secondary lamina Si. The distal fibers course in a semipennate arrangement. They arise from the long extension of the aponeurosis Ao₂, pass obliquely downward, anteriorly, and insert on the superficial aspect of the primary lamina Pi₂.
The Muscles of the Foot

The muscles of the foot are divided, according to their locations, into two groups:

1. The Dorsum of the Foot:
   (1) Extensor digitorum brevis
   (2) Extensor hallucis brevis

2. The Plantar Aspect of the Foot:
   (1) Flexor digitorum brevis
   (2) Quadratus plantae
   (3) Abductor hallucis
   (4) Lumbricals
   (5) Abductor digiti minimi
   (6) Flexor digiti minimi brevis
   (7) Flexor hallucis brevis
   (8) Adductor hallucis
   (9) Interossei

Extensor digitorum brevis and Extensor hallucis brevis

General Description (figs. 218, 219)

The extensor digitorum brevis and the extensor hallucis brevis are on the dorsum of the foot. These two muscles are closely associated with each other. They arise with a common origin from the anterolateral part of the superficial surface of the calcaneus, talo-lateral ligament, and from the deep surface of the inferior extensor retinacu-
lum. From the proximally fused muscle mass arise three bellies, one for the extensor hallucis brevis, and two for the extensor digitorum brevis. The largest medial belly is the extensor hallucis brevis. Its tendon (1, in figs. 218, 219) inserts on the base of the proximal phalanx of the big toe; the somewhat smaller two lateral bellies represent the extensor digitorum brevis. Two tendons (3 and 4, in figs. 218, 219) arise from the most lateral belly which insert on the bases of the terminal phalanges of the third and the fourth toes. One tendon (2, in figs. 218, 219) which inserts on the base of the terminal phalanx of the second toe arises from the more medial belly.

**Internal Tendons of Origin** (fig. 220)

Formula: Ao, Po₁, Po₂, Po₃, Po₄, Po₅, Po₆, So₁, So₂, So₃.

There is no visible tendon of origin. On the deep surface is the very short aponeurosis Ao(fig. 219). Its terminal parts penetrate into the muscle as primary laminae. There are six primary laminae Po₁, Po₂, Po₃, Po₄, Po₅, Po₆(fig. 220). The spatial arrangement of these primary laminae is randomlike. No indication can be observed of the ultimate separation of the common muscle mass into three separate bellies. The first primary lamina Po₁ is small and triangular in outline. It lies most medially. The second primary lamina Po₂ is broad and quadrilateral in outline. It terminates with very short extensions. The third primary lamina Po₃ is of medium size. It divides and terminates with four short extensions. The fourth primary lamina Po₄ is small and narrow. The fifth primary lamina Po₅ is broad and long. It divides and terminates with four long extensions. The sixth primary lamina Po₆ lies most laterally and it is small, and has a triangular
shape. Three secondary laminae So_1, So_2, So_3 (fig. 220) arise from the superficial aspects of the primary laminae Po_3, Po_4 and Po_5. The first secondary lamina So_1 is broad and of oblong shape. It arises at an angle from the superficial aspect near the lateral border of the third primary lamina Po_3. The second secondary lamina So_2 is broad proximally and it tapers distally. This lamina arises at an angle from the superficial aspect and medial border of the fifth primary lamina Po_5. The third secondary lamina So_3 is long and narrow. It also arises at an angle from the superficial aspect and lateral border of the fifth primary lamina Po_5.

**Internal Tendons of Insertion** (figs. 221, 222, 223)

Formula of the extensor hallucis brevis: Ai_1, Pi_1.

The external tendon is long and oval shaped in cross-section. The proximal part of this tendon expands slightly and becomes the aponeurosis Ai_1. This aponeurosis terminates as the primary lamina Pi_1 (fig. 221). It has an outline like a maple leaf.

Formula of the extensor digitorum brevis: Ai_2, Ai_3, Ai_4, Pi_2, Pi_3, Pi_4, Si

The external tendon of the second toe (fig. 222) is separated from that of the third and the fourth toes (fig. 223). The proximal part of this tendon becomes the very small aponeurosis Ai_2. This aponeurosis terminates in a long and narrow primary lamina Pi_2 which has a fringe-like border. The external tendons of the third and the fourth toes are distally separated. Their proximal and lateral parts become the aponeuroses Ai_3 and Ai_4. The aponeurosis Ai_3 becomes the primary lamina Pi_3.
which is long and narrow. The aponeurosis Ai₄ terminates as the fan-shaped primary lamina Pi₄ which has a fringe-like border. The lateral border reflects on itself towards the superficial surface. From the distal part of the deep surface of Pi₄, arises the small secondary lamina Si. It extends medially between the primary laminae Pi₃ and Pi₄. The two primary laminae Pi₃ and Pi₄ are connected to each other by a small tendinous extension.

The Arrangement of the Muscle Fibers (figs. 224, 225)

The muscle fibers of the superficial part of the extensor hallucis brevis course differently from those of the deep part. The muscle fibers on the superficial part(fig. 224) form a pennate arrangement. These fibers arise from the superficial aspects of the primary laminae Po₁ and Po₂, and insert on the superficial aspect of the first primary lamina Pi₁.

The muscle fibers on the deep part(fig. 225) are parallel. These fibers arise from the deep aspects of the Po₁ and Po₂, and insert on the deep aspect of the primary lamina Pi₁.

The superficial muscle fibers(fig. 224) of the extensor digitorum brevis of the second toe arise from the superficial aspects of the primary laminae Po₃, Po₄, Po₅, and from the first secondary lamina So₁. They form a pennate arrangement, and insert on the superficial aspect of the primary lamina Pi₂. The muscle fibers of the third toe arise from the superficial aspects of the primary lamina Po₅, and from the second secondary lamina So₂. They form proximally a semipennate arrangement, but distally a pennate arrangement. These fibers insert on the
superficial aspect of the primary lamina Pi$_3$. The muscle fibers of the fourth toe arise from the superficial aspects of the primary laminae Po$_5$ and Po$_6$, and the third secondary lamina So$_3$. They form a semipennate arrangement, and insert on the superficial aspect of the primary lamina Pi$_4$.

The deep muscle fibers (fig. 225) of the second toe arise from the deep aspects of the primary laminae Po$_3$, Po$_4$, Po$_5$, and course in a parallel fashion. They insert on the deep aspect of the primary lamina Pi$_2$. The muscle fibers of the third toe arise from the deep aspect of the primary lamina Po$_5$, and display a spindle-like arrangement. They insert on the deep aspect of the primary lamina Pi$_3$. The muscle fibers of the fourth toe arise from the deep aspect of the primary laminae Po$_5$ and Po$_6$, and form a semipennate arrangement. They insert on the deep aspect of the primary lamina Pi$_4$.

**Flexor digitorum brevis**

*General Description* (figs. 226, 227)

The flexor digitorum brevis has four small bellies which are proximally fused. It arises as a single muscle mass from the medial process of the calcaneal tubercle, and the deep aspect (dorsal surface) of the proximal part of the plantar aponeurosis (fig. 226). It separates and divides into four muscle bellies distal to the origin from the plantar aponeurosis. There are four tendons, one to each belly. These tendons are split distally like a needle hole, and then insert on the sides of the middle phalanges of the lateral four toes.
Internal Tendons of Origin (fig. 228)

Formula: $A_0_1$, $A_0_2$, $P_0$.

The external tendon is short and thick, and is continuous with the plantar aponeurosis (fig. 228). From the deep aspect of the external tendon arises a small triangular shaped aponeurosis $A_0_1$ (fig. 228). Another aponeurosis $A_0_2$ arises from the deep aspect and distal border of the plantar aponeurosis. This aponeurosis is visible on the superficial surface of the muscle distal to the cut edge of the plantar aponeurosis (fig. 231). This aponeurosis $A_0_2$ terminates with a fringe-like border. A long and thin primary lamina $P_0$ arises from the deep aspects of the plantar aponeurosis. It is nearly at a right angle to the plantar aponeurosis. The proximal part of this primary lamina $P_0$ is also attached to the aponeurosis $A_0_1$.

Internal Tendons of Insertion (Figs. 229, 230)

Formula: $A_1$, $A_2$, $A_3$, $A_4$, $P_1$, $P_2$, $P_3$, $P_4$, $S_1$, $S_2$, $S_3$, $S_4$.

There are four external tendons to the lateral four toes. The four external tendons continue proximally as the aponeuroses $A_1$, $A_2$, $A_3$, $A_4$. These aponeuroses terminate as primary laminae $P_1$, $P_2$, $P_3$, $P_4$ respectively. The first two medial primary laminae ($P_1$ and $P_2$) fuse with each other (fig. 229). From the deep aspects of these fused primary laminae arise three very small, long, and ridge-like protrusions which represent the secondary laminae $S_1$, $S_2$, $S_3$. The third primary lamina $P_3$ is long and narrow. From the deep aspect of this primary lamina, arises the fourth secondary lamina $S_4$ (fig. 230) which has two small triangular extensions. The fourth primary lamina $P_4$ is very thin.
and narrow. No secondary lamina arises from the primary lamina \( P_{14} \).

The Arrangement of the Muscle Fibers (figs. 231, 232)

Generally, the muscle fibers of the superficial part course differently from those of the deep part.

The muscle fibers on the superficial part (fig. 231) arise from the deep aspect of the aponeurosis \( A_{o2} \). These fibers separate and divide into four muscle bellies. The fibers of each of these bellies converge and insert on the superficial aspects of each of the primary laminae \( P_{11}, P_{12}, P_{13}, P_{14} \).

The muscle fibers on the deep part (fig. 232) display a different arrangement. The fibers of the first belly which arise from the deep aspect of the distal and medial parts of the plantar aponeurosis form a semipennate arrangement. They pass obliquely from the medial border of the plantar aponeurosis to the deep aspect of the first primary lamina \( P_{11} \). The fibers of the second belly which arise from the deep aspect of the proximal and medial parts of the plantar aponeurosis, and from the medial surface of the primary lamina \( P_{o} \), converge and form an asymmetric pennate arrangement. The fibers which arise from the medial side of the deep aspect of the plantar aponeurosis pass obliquely forward to the medial side and insert on the deep aspect of the second primary lamina \( P_{12} \). The fibers which arise from the lateral side of the plantar aponeurosis and from the medial surface of the primary lamina \( P_{o} \) pass obliquely forward to the lateral side and insert on the deep aspect of the primary lamina \( P_{12} \), and its secondary laminae \( S_{11}, S_{12}, S_{13} \). The fibers of the third belly which arise from the lateral surface of the primary lamina \( P_{o} \) and from the deep aspect of the
plantar aponeurosis, converge and form a nearly symmetric pennate arrangement. The fibers which arise medially from the lateral surface of the primary lamina Po pass obliquely to the medial side and insert on the deep aspect of the primary lamina Pi₃. The fibers which arise laterally from the deep aspect of the plantar aponeurosis pass obliquely from lateral to medial and insert on the lateral side of the deep aspect of the primary lamina Pi₃ and its secondary lamina Si₄. The fibers of the fourth belly which arise from the plantar aponeurosis, form a semipennate arrangement. They pass distally and insert on the deep aspect of the primary lamina Pi₄.

**Quadratus plantae**

**General Description (figs. 233, 234)**

The quadratus plantae is described as a dual muscle. The medial fleshy origin (1, in figs. 233, 234) arises from the medial side and plantar surface of the calcaneus. The lateral tendinous origin (2, in figs. 233, 234) arises from the long plantar ligament (3, in fig. 233). Both of these origins fuse into a single insertion on the lateral and deep aspects of the tendon (4, in figs. 233, 234) of the flexor digitorum longus.

**Internal Tendons of Origin (fig. 235)**

Formula of the lateral head: Ao, Po.

The external tendon is very short. It expands on the superficial and middle surfaces of the muscle as the broad and thin aponeurosis Ao which has a fringe-like border. This aponeurosis Ao reflects
upon itself towards the deep surface, and penetrates into the muscle as the primary lamina Po (fig. 235). This primary lamina is club shaped and has a fringe-like border.

Formula of the medial head: none

There are neither external nor internal tendons of origin of the medial head.

**Internal Tendons of Insertion** (fig. 236)

Formula: $A_i, P_{i1}, P_{i2}$.

There is no visible tendon of insertion. The aponeurosis $A_i$ (fig. 236) arises from the deep aspect of the tendon (fig. 236) of the flexor digitorum longus. This aponeurosis terminates into the short and the long primary laminae $P_{i1}$ and $P_{i2}$ respectively (fig. 236). The short primary lamina $P_{i1}$ is thin, triangular in outline and has a fringe-like border. The long primary lamina $P_{i2}$ is thick and long, and also has a fringe-like border.

**The Arrangement of the Muscle Fibers** (figs. 237, 238, 239)

Generally, the muscle fibers originate from two heads, the tendinous (or lateral) head and the muscular (or medial) head. The superficial fibers of the tendinous head (fig. 237) arise from the deep aspect of the aponeurosis $A_o$. They pass forward in a parallel fashion and insert on the superficial and distal surfaces of the long primary lamina $P_{i2}$, and the superficial surface of the short primary lamina $P_{i1}$. The deeper fibers which arise more proximally from the aponeurosis $A_o$, insert on the superficial and intermediate surfaces of the long primary lamina $P_{i2}$. 
The superficial fibers of the muscular head arise from the medial side and the plantar surface of the calcaneus, and converge to the superficial and proximal surfaces of the long primary lamina Pi₂. The muscle fibers of the deep part (fig. 238) arise from two origins. The fibers of the proximal part arise from the medial side and plantar surface of the calcaneus. They converge and insert on the deep aspect and proximal two-thirds of the long primary lamina Pi₂. The fibers of the distal part arise from the superficial aspect of the primary lamina Po. They first diverge, then converge and insert on the deep aspects of the aponeurosis Ai. The deeper fibers which arise from the deep aspect of the primary lamina Po, insert on the deep aspect and medial part of the long primary lamina Pi₂, and on the short primary lamina Pi₁.

**Abductor hallucis**

**General Description (figs. 240, 241).**

The adductor hallucis arises from the medial process of the tuberosity of the calcaneus, and the deep surface of the flexor retinaculum. The tendon inserts on the medial side of the base of the proximal phalanx of the big toe.

**Internal Tendons of Origin (figs. 242, 243, 244)**

Formula: Ao₁, Ao₂, Po₁, Po₂, Po₃, Po₄, Po₅, Po₆.

The external tendon is flattened and irregularly shaped. There is a superficial and a deep aponeurosis. The superficial aponeurosis Ao₁ (fig. 243) is a continuation of the lower part of the external tendon. This aponeurosis terminates as the primary lamina Po₁ which has a fringe-
like border. The deep aponeurosis $A_0_2$ (fig. 242) is proximally broader. Its distal part tapers and becomes the primary laminae $P_0_2$, $P_0_3$, $P_0_4$, $P_0_5$, $P_0_6$.

Internal Tendons of Insertion (fig. 244)

Formula: $A_1$, $P_1_1$, $P_1_2$.

The external tendon is long and flattened. Its lower border is thick and extends posteriorly to become the aponeurosis $A_1$ (fig. 240). The margins and terminal parts of this aponeurosis $A_1$ penetrates into the muscle as a long and broad primary lamina $P_1_1$. This lamina has long fringe-like borders. From the deep aspect of the aponeurosis $A_1$, arises the second primary lamina $P_1_2$ (fig. 244) which has three small extensions.

The Arrangement of the Muscle Fibers (figs. 245, 246)

Generally, the muscle fibers of the superficial part course differently from those of the deep part. The muscle fibers on the superficial part (fig. 245) form a pennate arrangement. These fibers arise from the superficial aspect of the primary lamina $P_0_1$. They converge and insert on the superficial aspect and the distal part of the primary lamina $P_1_1$. The deeper fibers arise from the deep aspect of the aponeurosis $A_0_1$ and the primary lamina $P_0_1$, and insert on the superficial aspect and proximal part of the primary lamina $P_1_1$.

The muscle fibers on the deep part (fig. 246) form a semipennate arrangement. The fibers arise from the superficial aspect of the primary laminae $P_0_2$, $P_0_3$, $P_0_4$, $P_0_5$, $P_0_6$. They pass forward and insert on the superficial aspect of the primary lamina $P_1_2$, and its extensions. The uppermost fibers arise from the upper border of the primary lamina $P_0_6$. 
pass forward, and insert on the upper border of the primary lamina \( \text{Pi}_2 \) and the deep aspect of the aponeurosis \( \text{Ai} \). The lower fibers arises from the deep aspect of the primary lamina \( \text{Po}_2 \), pass forward, and insert on the deep aspect and the lower border of the primary lamina \( \text{Pi}_2 \). The deeper fibers arise from the deep aspect of the aponeurosis \( \text{Ao}_2 \), pass forward and insert on the deep aspect of the primary lamina \( \text{Pi}_1 \).

**Lumbricals**

**General Description** (figs. 247, 248)

The lumbricals are four small worm-like muscles which originate from the tendons(5, in figs. 247, 248) of the flexor digitorum longus. The three lateral muscles arise from the bifurcations between two adjacent tendons. The most medial one arises from the medial side of the tendon to the second toe. Each of the four muscles terminates in a tendon which, in turn, passes to the medial side of each toe, and inserts on the medial side of the base of the proximal phalanx of the lateral four toes. These insertions are deep to the expansion tendons of the extensor digitorum longus.

**Internal Tendons of Origin** (fig. 253)

Formula: \( \text{Po}_1, \text{Po}_2, \text{Po}_3, \text{Po}_4, \text{Po}_5, \text{Po}_6 \).

There are neither external tendons nor aponeurosis. Only six primary laminae \( \text{Po}_1, \text{Po}_2, \text{Po}_3, \text{Po}_4, \text{Po}_5, \text{Po}_6 \), can be found. The first and the fourth lumbricals have each one primary lamina(\( \text{Po}_1 \) and \( \text{Po}_6 \)). The two middle lumbricals(the second and the third) have each two primary laminae(\( \text{Po}_2 \) and \( \text{Po}_3 \); and \( \text{Po}_4 \) and \( \text{Po}_5 \)). The first primary lamina
$p_0$ is small. It arises from the medial side of the tendon of the second toe. The second and third primary laminae $p_2$ and $p_3$, are also small and have spiny surfaces. They arise from the adjacent sides of the tendons of the second and third toes. The fourth and the fifth primary laminae $p_4$ and $p_5$, are small and spiny, the $p_5$ being much shorter than the $p_4$. They arise from the adjacent sides of the tendons of the third and the fourth toes. The last primary lamina $p_6$ is also small and spiny. It is as long as the fourth primary lamina $p_4$, and arises from the lateral side of the tendon of the fourth toe.

**Internal Tendons of Insertion** (figs. 249, 250, 251, 252)

Formula: $A_i_1$, $A_i_2$, $A_i_3$, $A_i_4$, $P_i_1$, $P_i_2$, $P_i_3$, $P_i_4$, $S_i_1$, $S_i_2$.

There are four external tendons, one for each muscle. The proximal part of each of these tendons becomes a very small aponeurosis on the deep surface of the muscle. The first aponeurosis $A_i_1$ terminates as a primary lamina $P_i_1$ (fig. 249). It is broader distally, but narrow and long proximally. The second aponeurosis $A_i_2$ terminates as the primary lamina $P_i_2$. This lamina terminates in one short and two long extensions (fig. 250). The third aponeurosis $A_i_3$ terminates in a spear-shaped primary lamina $P_i_3$ which has a fringe-like border (fig. 251). The fourth aponeurosis $A_i_4$ is broader than the other aponeuroses and terminates in the primary lamina $P_i_4$ (fig. 252). This lamina again terminates with a fringe-like border. Two very small secondary laminae $S_i_1$ and $S_i_2$ arise from the medial border of the primary lamina $P_i_4$.

**The Arrangement of the Muscle Fibers** (figs. 254, 255)

The general arrangement of the muscle fibers will be described
for each individual lumbral.

The muscle fibers of the first lumbral form a semipennate arrangement in both, the superficial and the deep parts. The fibers of the superficial part (fig. 254) arise from the superficial aspect of the first primary lamina Po₁, pass forward, medially, and insert on the superficial aspect of the primary lamina Pi₁. The fibers of the deep part (fig. 255) arise from the deep aspect of the first primary lamina Po₁, and course in the same manner as those of the superficial part. These fibers insert on the deep aspect of the primary lamina Pi₁.

The muscle fibers of the second lumbral form a pennate arrangement in both, the superficial and the deep parts. The fibers of the superficial part arise from the superficial aspect of the second and third primary laminae (Po₂ and Po₃). These fibers insert on the superficial aspect of the primary lamina Pi₂. The fibers of the deep part are arranged similarly as those of the superficial part. They arise from the deep aspects of the second and third primary laminae (Po₂ and Po₃), and insert on the deep aspect of the second primary lamina Pi₂.

The muscle fibers of the superficial part of the third lumbral course differently from those of the deep part. The muscle fibers of the superficial part form a pennate arrangement. These fibers arise from the superficial aspects of the fourth and fifth primary laminae, (Po₄ and Po₅), and insert on the superficial aspect of the third primary lamina Pi₃. The muscle fibers in the deep part arise from the deep aspects of the fourth and fifth primary laminae (Po₄ and Po₅).
They form a spindle-like arrangement and insert on the deep aspect of the third primary lamina Pi₃.

The muscle fibers of the fourth lumbrical form a semipennate arrangement in both, the superficial and the deep parts. The muscle fibers on the superficial part arise from the superficial aspect of the primary lamina Po₆, pass forward, laterally and insert on the superficial aspect of the fourth primary lamina Pi₄. The fibers on the deep part course similarly as those of the superficial part. They arise from the deep aspect of the primary lamina Po₆, and insert on the deep aspect of the fourth primary lamina Pi₄, and the secondary laminae Si₁ and Si₂.

**Abductor digiti minimi**

**General Description** (figs. 256, 257)

The abductor digiti minimi arises from the lateral and plantar surfaces of the posterior end of the calcaneus, and from the plantar aponeurosis. The posterior half of the muscle is covered by a thick deep fascia which consists of a dense fibrous band, the calcaneo-metatarsal ligament according to Woodburne. It extends between the lateral process of the calcaneus and the base of the fifth metatarsal bone. This ligament could be named an aponeurosis Ao(fig. 256) because it covers and extends on the surface of the muscle. The short external tendon has an oval cross-section and insert on the lateral side of the base of the proximal phalanx of the fifth toe.
Internal Tendons of Origin (fig. 258)

Formula: Ao, Po₁, Po₂.

The external tendon is short and in continuation with the aponeurosis Ao (or calcaneo-metatarsal ligament). An extension arises from the distal border of this aponeurosis (fig. 258). There are three long band-like extrusions (2, 3, 4, in fig. 258), two of which form a V-shape on the deep aspect of the aponeurosis Ao. One extrusion (3) passes obliquely from postero-medial to antero-lateral. The other extrusion (2) is parallel to the lateral border of the aponeurosis Ao. The third extrusion (4, in fig. 258) which is parallel to the medial border of the aponeurosis. There are two primary laminae Po₁ and Po₂, which arise from the deep aspect of the aponeurosis Ao. The first primary lamina Po₁ arises medial to the posterior part of the oblique extrusion. This primary lamina Po₁ has a triangular shape, a fringe-like terminal border, and it extends medially. The second primary lamina Po₂ arises medial to the posterior part of the lateral extrusion. This lamina Po₂ has a rhomboid shape and it extends laterally. It also has a fringe-like terminal border.

Internal Tendons of Insertion (fig. 259)

Formula: Ai, Pi₁, Pi₂, Si₁, Si₂, Ti.

The external tendon becomes the aponeurosis Ai which is on the deep and medial surfaces. The posterior part of this aponeurosis bifurcates and becomes two primary laminae Pi₁ and Pi₂ (fig. 259). The primary lamina Pi₁ is on the medial side. It folds upon itself towards its deep and becomes bilaminated. From the superficial lamina, arises the
secondary lamina \( \text{Si}_1 \). The other primary lamina \( \text{Pi}_2 \) is on the lateral side. Its anterior part is connected to the primary lamina \( \text{Pi}_1 \) by an oblique band. From the medial border of this primary lamina \( \text{Pi}_2 \), arises the secondary lamina \( \text{Si}_2 \). The tertiary lamina \( \text{Ti} \) arises from the deep aspect of this secondary lamina \( \text{Si}_2 \).

The Arrangement of the Muscle Fibers (figs. 260, 261)

The muscle fibers are divided for descriptive purposes into posterior and anterior portions. Only the deep aspect of the posterior portion is visible(fig. 261). There, the fibers form a multipennate arrangement. The muscle fibers of the most medial part arise from the deep aspect of the aponeurosis \( \text{Ao} \) and from the primary lamina \( \text{Po}_1 \). They course in a pennate arrangement, and insert on the superficial aspect of the superficial layer of the primary lamina \( \text{Pi}_1 \). The deeper fibers insert on the deep layer of the primary lamina \( \text{Pi}_1 \). The muscle fibers of the middle part arise from the primary laminae \( \text{Po}_1 \) and \( \text{Po}_2 \), and the deep aspect of the aponeurosis \( \text{Ao} \). They also course in a pennate arrangement, and insert on the superficial aspect of the secondary lamina \( \text{Si}_2 \). The deeper fibers insert on the deep aspect of the secondary lamina \( \text{Si}_2 \), and the tertiary lamina \( \text{Ti} \). The muscle fibers of the most lateral part arise from the primary lamina \( \text{Po}_2 \) and the deep aspect of the lateral part of the aponeurosis \( \text{Ao} \). Again, they course in a pennate arrangement and insert on the superficial aspect of the primary lamina \( \text{Pi}_2 \). The deeper fibers insert on the deep aspect of the primary lamina \( \text{Pi}_2 \).
The muscle fibers in the anterior portion of both, the superficial (fig. 260) and deep (fig. 261) parts course in a semipennate arrangement. The muscle fibers arise from the medial border of the aponeurosis Ao. They pass forward, medially and insert on the deep aspect and lateral border of the aponeurosis Ai.

**Flexor digiti minimi brevis**

**General Description** (figs. 262, 263)

The flexor digiti minimi brevis is a fusiform shaped muscle, which arises from the plantar surface of the base of the fifth metatarsal bone and from the sheath of the peroneus longus, and inserts on the plantar surface of the base of the proximal phalanx of the fifth toe.

**Internal Tendons of Origin** (figs. 264, 265, 266)

*Formula:* Ao₁, Ao₂, Po₁, Po₂, Po₃, So, To, Qao.

The external tendon is thick and short. The internal tendons are complicated and consist of four layers. They are numbered from inferior to superior. The first layer has two aponeuroses Ao₁ and Ao₂ (fig. 265). They are in continuation with the deep surface of the external tendon. Each aponeurosis terminates into a primary lamina (Po₁ and Po₂). In addition, there is the third primary lamina Po₃ (fig. 265) which arises from the external tendon, and from the lateral border of the aponeurosis Ao₂. The second layer has only one secondary lamina So (fig. 264). It arises from the superficial aspect of the primary lamina Po₃, and is nearly of equal size as the latter. The third
layer has only one tertiary lamina To. It arises from the superficial aspect of the secondary lamina So, and it is only half as long as the latter. This tertiary lamina To terminates with three extensions. The medial two extensions are flat and parallel to the secondary lamina So. The lateral extension turns nearly perpendicular to the former, and it attaches to the quartery lamina Qao, which arises from the superficial aspect of the tertiary lamina To.

Internal Tendons of Insertion (figs. 264, 265, 266)

Formula: $A_1, A_2, A_3, A_4, A_5, P_1, P_2, P_3, P_4, P_5, P_6$. 

The external tendon is short and slightly curved. The internal tendons are arranged in two layers. The inferior layer is visible on the plantar (or superficial) surface, and it has four aponeuroses $A_1, A_2, A_3, A_4$. Each of these aponeuroses terminates in a primary lamina $P_1, P_2, P_3, P_4$ respectively (fig. 266). The first, the third and the fourth primary laminae are short and narrow. The second primary lamina $P_2$ is long and broad. It extends proximally close to the distal part of the external tendon of origin. The superior layer has only one aponeurosis $A_5$ (fig. 265). Its proximal part bifurcates into unequal extensions. The smaller one penetrates into the muscle, and becomes the very small primary lamina $P_5$. In addition, there is another primary lamina $P_6$. This primary lamina $P_6$ is large and longer, and it arises directly from the superior surface of the external tendon.

The Arrangement of the Muscle Fibers (figs. 267, 268)

Generally, the muscle fibers of the superficial part have a different course from those of the deep part. The fibers on the super-
ficial part (fig. 267) course in a parallel fashion. The fibers of the lateral side arise from the plantar surface of the tertiary lamina To, pass forward, and insert on the plantar surface of the third and the fourth primary laminae Pi₂ and Pi₄. The fibers of the middle part arise from the plantar surface of the quartery lamina Qao, pass forward, and deep to the fibers of the medial part. They insert on the dorsal surface of the second primary lamina Pi₂. The fibers of the medial part arise from the most medial and plantar surfaces of the quartery lamina Qao, and insert on the plantar surface of the second primary lamina Pi₂. The fibers of the most medial part arise from the plantar surface of the aponeurosis Ao₁, and the primary lamina Po₁, pass forward, and insert on the superficial surface of the primary lamina Pi₁. The deeper fibers of the superficial part arise from the plantar surface of the secondary lamina So, and insert on the dorsal surface of the primary laminae Pi₂, Pi₄, and the aponeuroses Ai₂, Ai₄.

The muscle fibers of the deep part (fig. 268) course in an asymmetric pennate-like arrangement. The fibers of the medial side arise from the dorsal surface of the primary laminae Po₁ and Po₂. They pass forward, and insert on the dorsal surface of the proximal part of the primary lamina Pi₁. The muscle fibers of the lateral side arise from the third primary lamina Po₃. They pass obliquely forward and laterally and insert on both, the dorsal and plantar surfaces of the primary lamina Pi₅, and the plantar surface of the aponeurosis Ai₅.

The deeper fibers of the deep part arise from the plantar surface of the primary laminae Po₁, Po₂, Po₃. They insert on the dorsal surface
of the distal part of the primary lamina Pi₆, and the aponeurosis Ai₅.

**Flexor hallucis brevis**

**General Description** (figs. 269, 270)

The flexor hallucis brevis is fused with the oblique head of the adductor hallucis. The flexor hallucis brevis arises from the plantar surface of the cuboid and the lateral cuneiform. The muscle divides distally into medial and lateral bellies (fig. 270). The medial belly inserts together with that of the abductor hallucis on the medial side of the base of the proximal phalanx of the big toe. The lateral belly inserts on the lateral side of the base of the proximal phalanx of the big toe. This muscle belly is connected to the adductor hallucis at its insertion.

**Internal Tendons of Origin** (figs. 273, 274)

Formula: Ao, Po₁, Po₂, So₁, So₂, So₃, So₄, To.

The external tendon is short and flattened. The aponeurosis Ao is a continuation of the external tendon, and it covers the deep proximal surface of the muscle. Its distal part terminates with three narrow extensions. The terminal part of the lateral extension penetrates into the muscle as the primary lamina Po₁ (fig. 274). From the deep aspect of the aponeurosis Ao, arises the very large primary lamina Po₂. This primary lamina Po₂, terminates with two broad and long extensions, a medial (above) and a lateral (below) one (fig. 274). The medial extension has a tooth-like margin. The lateral extension curves dorsally upon itself. It has also a tooth-like margin. On the superficial aspect
of the primary lamina Po₂, arise four secondary laminae So₁, So₂, So₃, So₄ (fig. 273). The middle two laminae So₂ and So₃, are small and have a triangular shape. The first secondary lamina So₁ is long and has a serrated border. The fourth secondary lamina So₄ is the largest, and it arises at an angle from the midline of the primary lamina Po₂. From the superficial aspect of this secondary lamina So₄, arises the tertiary lamina To (fig. 273). It is long and has a serrated border.

**Internal Tendons of Insertion** (figs. 271, 272, 273, 274)

Formula: Ai₁, Ai₂, Pi₁, Pi₂, Pi₃, Pi₄.

There are two external tendons, one arising from the medial belly, and the other one arising from the lateral belly. There are two primary laminae Pi₁ and Pi₂, which arise directly from the medial external tendon. They have triangular shapes; the Pi₁ is larger and longer than Pi₂, and both have fringe-like borders.

The external tendon of the lateral part is small. The aponeurosis Ai₁ which expands distally is a continuation of this external tendon and lies on the plantar surface of the muscle. The margins of this aponeurosis Ai₁ penetrate into the muscle as the primary lamina Pi₃ (fig. 273). The middle of the lateral border of this primary lamina Pi₃ is connected to the secondary lamina Si₆ (fig. 271) of the adductor hallucis. In addition, there is another aponeurosis Ai₂ on the dorsal surface of the muscle. It also arises from the external tendon of the lateral part. The margins of this aponeurosis Ai₂ penetrate into the muscle as the primary lamina Pi₄ (fig. 274). It is fan-shaped and has a fringe-like border. The lateral border curves dorsally upon itself.
The Arrangement of the Muscle Fibers (figs. 275, 276)

The muscle fibers of the dorsal part (fig. 276) course in a multipennate arrangement. The muscle fibers of the lateral part arise from the lateral surface of the primary lamina Po₂. They pass forward, laterally and insert on the medial surface of the secondary lamina Si₄ of the adductor hallucis. The deeper fibers arise from the deep surface of the primary lamina Po₂ and insert on the dorsal surface of the secondary lamina Si₆ of the adductor hallucis. The fibers which arise from the lateral border of the distal part of the primary lamina Po₂, pass forward, medially, and insert on the lateral surface of the aponeurosis Ai₂. The fibers of the middle part which arise from the dorsal and medial surfaces of the primary lamina Po₂, converge and insert on the dorsal surface of the primary lamina Pi₄. The deeper fibers arise from the distal part of the primary lamina Po₂ and insert on the deep surface of the primary lamina Pi₄ and the aponeurosis Ai₂. The muscle fibers of the medial part arise from the medial border of the primary lamina Po₂, diverge, and insert on the dorsal surface of the primary laminae Pi₁ and Pi₂.

The muscle fibers of the plantar surface (fig. 275) also course in a multipennate arrangement. The fibers of the medial part which arise from the deep surface of the secondary lamina So₄, pass forward, and insert on the superficial surface of the primary lamina Pi₁ and Pi₂ of the medial part. The muscle fibers of the middle part arise from the superficial surface of the secondary lamina So₄ and the tertiary lamina To. They pass forward, laterally and insert on the superficial
surface and medial border of the primary lamina $\text{Pi}_3$. The muscle fibers of the lateral part arise from the lateral border of the primary lamina $\text{Po}_2$. They pass forward and insert on the lateral border of the primary lamina $\text{Pi}_3$ and the secondary lamina $\text{Si}_6$ of the adductor hallucis.

**Adductor hallucis**

**General Description (figs. 269, 270)**

The adductor hallucis has two heads, a small transverse head and a large oblique head. The transverse head arises from the plantar surface of the metatarso-phalangeal ligament of the third, the fourth, and the fifth toes. This portion of the muscle fuses with the lateral side of the external tendon of the oblique head. The oblique head is thick and broad. It arises from the sheath of the peroneus tendon, and the bases of the second, the third and the fourth metatarsal bones. This portion, together with the transverse head, inserts on the lateral side of the base of the proximal phalanx of the big toe.

**Internal Tendons of Origin (figs. 272, 277, 280, 281, 282, 283)**

Formula of the transverse head: $\text{Po}_1$, $\text{Po}_2$, $\text{Po}_3$, $\text{Po}_4$, $\text{Po}_5$, $\text{Po}_6$.

The external tendon is short, thick, quadrilateral, and there is no visible aponeurosis. The internal tendons are arranged in two layers, each of which has three primary laminae named respectively $\text{Po}_1$, $\text{Po}_2$, $\text{Po}_3$; and $\text{Po}_4$, $\text{Po}_5$, $\text{Po}_6$.

Formula of the oblique head: $\text{Ao}_1$, $\text{Po}_7$, $\text{Po}_8$, $\text{Po}_9$, $\text{So}$.

The oblique head has medial and lateral origins which are
separated from each other. There is no visible external tendon. Both origins then fuse after a short distance and form a single muscle mass. The medial origin has the aponeurosis Ao, which covers the proximal superficial surface of the muscle. Its margin penetrates into the muscle as the primary lamina Po (figs. 277, 282). This primary lamina Po terminates with three extensions. The middle one is the longest of all. The lateral origin has no aponeurosis. The primary lamina Po (fig. 283) arises directly from the bony origin. This primary lamina Po is narrow proximally, and broader distally, and also terminates with three extensions. From the deep surface of this primary lamina Po arises the secondary lamina So (fig. 283). In addition, there is another primary lamina Po (fig. 272) originating from the bone which is close to the deep surface of the muscle. It curves laterally upon itself and becomes bilaminated.

**Internal Tendons of Insertion (figs. 277, 278, 279)**

**Formula:** Ai, Ai2, Pi, Pi2, Pi3, Pi4, Si1, Si2, Si3, Si4, Si5, Si6, Ti1, Ti2, Ti3.

The external tendon is very narrow and short. The internal tendons are very complicated and are connected to those of the flexor hallucis. The aponeurosis Ai (fig. 277) is in continuation with the external tendon and it is visible on the superficial surface of the muscle. The margins of this aponeurosis Ai penetrates proximally into the muscle as the primary lamina Pi. It is long and spindle shaped, and it extends close to the margin of the lateral head. The aponeurosis Ai2 (fig. 278) and the primary lamina Pi3 arise from the deep aspect and
distal part of the aponeurosis $A_{1_1}$. They fuse distally forming with each other an obtuse angle. The aponeurosis $A_{1_2}$ curves laterally and becomes the primary lamina $P_{1_2}$, which penetrates into the transverse head. Its terminal portion has a fringe-like border. The primary lamina $P_{1_3}$ extends proximally halfway toward the lateral origin. The curved secondary lamina $S_{1_1}$ arises from the deep aspect of the primary lamina $P_{1_1}$, and proximal to the aponeurosis $A_{1_2}$. The terminal border of $S_{1_1}$ has three extensions. The long and narrow secondary lamina $S_{1_2}$ arises at the junction of the lateral border of the secondary lamina $S_{1_1}$ and of the primary lamina $P_{1_1}$. The long and narrow tertiary lamina $T_{1_1}$ arises from the middle of the deep aspect of the secondary lamina $S_{1_1}$.

The broad primary lamina $P_{1_4}$(fig. 277) arises from the medial border of the aponeurosis $A_{1_1}$. Its proximal part terminates with six extensions. Two secondary laminae $S_{1_3}$ and $S_{1_4}$(fig. 278) arise from the distal part of the deep aspect of $P_{1_4}$. They meet each other in an acute angle forming a roof-like structure(fig. 279). Each of these secondary laminae($S_{1_3}$ and $S_{1_4}$) terminates with three extensions. The large tertiary laminae $T_{1_2}$ and the small $T_{1_3}$, which are perpendicular to each other arise from the inner surfaces of these secondary laminae $S_{1_3}$ and $S_{1_4}$(fig. 279).
Fig. 279 Diagram of a cross section A-A' of fig. 278 through the internal tendons of insertion of the adductor hallucis muscle.

Two other secondary laminae Si₅ and Si₆ arise from the deep aspect of the primary lamina Pi₄. The secondary lamina Si₅ lies inside the aforementioned roof-like arrangement forming by secondary laminae Si₃ and Si₄. The other secondary lamina Si₆ lies outside this roof-like arrangement. This secondary lamina Si₆ is narrow distally and wider proximally. It is attached to the primary lamina Pi₃ of the flexor hallucis brevis (fig. 278).

The Arrangement of the Muscle Fibers (figs. 275, 276)

The course of the muscle fibers is similar in both the superficial and deep parts of the transverse head. The fibers of the superficial part (fig. 275) arise from the primary laminae Po₁, Po₂, and Po₃, and insert on the superficial aspect of the primary lamina Pi₂. The fibers of the deep part (fig. 276) arise from the primary laminae Po₄,
Po5, and Po6. They also converge and insert on the dorsal aspect of the primary lamina Pi2.

Generally, the muscle fibers course differently in the deep and superficial parts of the oblique head. The muscle fibers of the deep part (fig. 276) display one pennate and two fusiform arrangements. The muscle fibers of the lateral part arise from their bony attachment and course in a small spindle-like arrangement. They insert on the deep aspect of the secondary lamina Si1 and the primary lamina Pi3. The deeper fibers insert on the deep aspect of the primary lamina Pi1. The muscle fibers of the middle part arise from the primary lamina Po9, and insert on the deep aspect of the secondary laminae Si3 and Si4. The deeper fibers arise from the primary lamina Po9, and insert on the tertiary laminae Ti1 and Ti2. The fibers of the medial part form a pennate arrangement. They arise from the deep aspect of the primary lamina Po7, and insert on the deep aspect of the primary lamina Pi4.

The muscle fibers of the superficial surface (fig. 275) form pennate and fusiform arrangements. A pennate arrangement is observed on the medial part. The muscle fibers arise from the medial and lateral borders of the primary laminae Po7, diverge, forming an inverted pennate arrangement, and insert on the distal parts of the superficial aspect of the primary lamina Pi4. The deeper fibers which arise from the deep aspect of the primary lamina Po7, insert on the proximal part of the primary lamina Pi4. The muscle fibers of the lateral part arise from the primary lamina Po8. They course in a spindle-like arrangement, and insert on the superficial aspect of the primary lamina Pi1. The deeper fibers
arise only from the distal part of the primary lamina \( P_0 \) and the secondary lamina \( S_0 \). They insert on the deep aspect of the primary lamina \( P_1 \), and the aponeurosis \( A_1 \).

**Interossei**

**General Description**

There are seven interosseus muscles of the foot, three plantar and four dorsal interossei. They originate from the sides of the metatarsal bones. Each interosseus inserts on one side of the capsules of a metatarso-phalangeal joint, and on the base of the proximal phalanx of the lateral three or four toes. The continuation of the external tendons with the expansion of the dorsal aponeuroses as described in some textbooks of anatomy could not be found.

**Plantar interossei**

The plantar interossei arise with a single origin from the medial surfaces of the bases and bodies of the lateral three metatarsal bones. Each muscle inserts on the capsule of the metatarso-phalangeal joint, and the medial surface of the base of the proximal phalanx of the lateral three toes.

**First plantar interosseus**

**General Description** (figs. 284, 285)

The first interosseus muscle arises with a single head from the medial surface of the body of the third metatarsal bone, and inserts on the same side on the base of the proximal phalanx of the correspon-
toe and the adjacent joint capsule.

Internal Tendons of Origin (figs. 286, 287)

Formula: $Ao, P_{01}, P_{02}$.

There is no visible tendon of origin. The aponeurosis $Ao$ arises from the bony origin, and extends on the medial surface of the muscle (fig. 284). Its terminal part becomes the primary lamina $P_{01}$ (fig. 286). In addition, there is another primary lamina $P_{02}$ (fig. 287) which also arises from the bony attachment. This primary lamina has a triangular shape, and it terminates with a fringe-like border.

Internal Tendons of Insertion (fig. 288)

Formula: $Ai, Pi$.

The external tendon is short and thick. The aponeurosis $Ai$ is the continuation of the external tendon. This aponeurosis extends proximally on the medial surface of the muscle, and becomes the primary lamina $Pi$ (fig. 288). It terminates with one short and three long extensions.

The Arrangement of the Muscle Fibers (figs. 289, 290)

The muscle fibers of the medial part (fig. 289) display two types of arrangement. The fibers of the upper part course in a parallel fashion. They arise from the primary lamina $P_{01}$, pass forward, and insert on the medial surface of the primary lamina $Pi$. The deeper fibers arise from the deep aspect of the aponeurosis $Ao$, and insert on the proximal part of the primary lamina $Pi$. The fibers of the lower part course in a semipennate arrangement. These fibers pass forward, and upward to insert on the upper border of the primary lamina $Pi$. 
The fibers of the lateral part (fig. 290) course in a nearly parallel fashion. They arise from the medial surface of the third metatarsal bone, pass forward, and insert on the lateral surface of the primary lamina Pi.

On the distal part of the muscle, there are two small muscle bundles, a superior and an inferior one. They arise from the distal part of the third metatarsal bone, and insert on the superior and inferior borders of the primary lamina Pi.

Second plantar interosseus

General Description (figs. 291, 292)

The second plantar interosseus arises with a single head which originates from medial surface of the body of the fourth metatarsal bone. The tendon of insertion inserts on the medial side of the base of the proximal phalanx of the fourth toe and the adjacent joint capsule.

Internal Tendons of Origin (figs. 293, 294)

Formula: Ao₁, Ao₂, Po₁, Po₂, Po₃.

There is no visible tendon of origin. A medial aponeurosis Ao₁ (fig. 294) and a dorsal aponeurosis Ao₂ (fig. 293) arise together from the body of the medial surface of the fourth metatarsal bone. The medial aponeurosis Ao₁ is broad and tapers distally. Its terminal part becomes the primary lamina Po₁. From the deep aspect of the aponeurosis Ao₁, arises the primary lamina Po₂. The dorsal aponeurosis Ao₂ is irregularly shaped and becomes the primary lamina Po₃.
Internal Tendons of Insertion (fig. 295)

Formula: Ai, Pi, Si1, Si2.

The external tendon is short and thick. The aponeurosis Ai is a continuation of the external tendon and extends proximally on the medial surface of the muscle. The terminal part of the aponeurosis Ai terminates with a broad primary lamina Pi (fig. 295), which terminates with a fringe-like border. From the deep surface of the primary lamina Pi, arises the secondary lamina Si1 which also has a fringe-like border. In addition, another small secondary lamina Si2 arises more distally from the primary lamina Pi.

The Arrangement of the Muscle Fibers (figs. 296, 297)

The muscle fibers of the medial part (fig. 297) arise from the primary laminae Po1 and Po2, pass forward and insert on the medial surfaces of the primary lamina Pi. The deeper fibers arise from the deep aspect of the primary lamina Po1, and the aponeuroses Ao1 and Ao2. They insert on the medial and proximal surfaces of the primary lamina Pi.

The muscle fibers of the lateral part (fig. 296) arise from the medial surface of the body of the fourth metatarsal bone. They pass forward and insert on the lateral aspect of the primary lamina Pi and on the secondary lamina Si. The fibers which arise from the primary lamina Po3, pass forward, and insert on the plantar border of the primary lamina Pi and on the secondary lamina Si2.
General Description (figs. 298, 299)

The third plantar interosseus arises with a single origin from the medial surface of the fifth metatarsal bone and the plantar metatarsal ligament. It inserts on the same side on the base of the proximal phalanx of the corresponding toe and the adjacent joint capsule.

Internal Tendons of Origin (fig. 300)

Formula: \(Ao, Po_1, Po_2\).

The external tendon of origin is broad and thick. The aponeurosis \(Ao\) (fig. 300) arises from the lateral surface of the external tendon and terminates as the primary lamina \(Po_1\). This primary lamina \(Po_1\) is long and narrow. In addition, there is a broad primary lamina \(Po_2\) which also arises from the external tendon. This primary lamina \(Po_2\) has four pointed extensions.

Internal Tendons of Insertion (fig. 301)

Formula: \(Ai, Pi, Si\).

The external tendon of insertion is short and thick. It extends proximally and becomes the aponeurosis \(Ai\) (fig. 298). It terminates as the long and broad primary lamina \(Pi\) (fig. 301) which has a fringe-like border. From the lateral surface of the primary lamina \(Pi\), arises the long and obliquely oriented secondary lamina \(Si\) which also has a fringe-like border.

The Arrangement of the Muscle Fibers (figs. 302, 303)

The muscle fibers of the lateral part course differently from those of the medial part. The fibers of the lateral part (fig. 302)
arise from the lateral surface of the primary lamina Po₁, course forward, upward, and insert on the upper aspect of the secondary lamina Si. The fibers which arise from the plantar metatarsal ligament course forward, downward, and insert on the lateral surface of the secondary lamina Si. They display a pennate arrangement. The deeper fibers arise from the deep aspect of the primary lamina Po₁ and the aponeurosis Ao, and insert on the lateral surface of the primary lamina Pi.

The muscle fibers of the medial part (fig. 303) form a fusiform-like arrangement. The more superficial fibers arise from the medial surface of the primary lamina Po₂, and insert on the medial surface of the distal part of the primary lamina Pi. The deeper fibers arise from the deep aspect of the primary lamina Po₂, and insert on the proximal part of the primary lamina Pi.

Dorsal interossei

There are four dorsal interossei. Each has two heads of origin which arise from the adjacent sides of the neighbouring metatarsal bones. The two heads of origin fuse into a single belly which inserts on the base of the proximal phalanx and on the capsule of the metatarso-phalangeal joint of the lateral four toes.

First dorsal interosseus

General Description (figs. 304, 305)

The first dorsal interosseus originates with two heads. The small medial head arises from the proximal lateral surfaces of the first metatarsal bone. The large lateral head arises from the proximal
medial surfaces of the second metatarsal bone. These two heads fuse and form a single belly, which inserts on the medial side of the base of the proximal phalanx of the second toe, and the capsule of the corresponding metatarso-phalangeal joint.

**Internal Tendons of Origin (figs. 306, 307)**

**Formula:** $A_0_1, A_0_2, P_0_1, P_0_2, P_0_3$.

The small medial head has a fleshy origin. There is neither an external nor an internal tendon of origin. The external tendon of the larger head is very short. There are two aponeuroses which arise from the external tendon. The aponeurosis $A_0_1$ is visible on the dorsomedial surface of the muscle. Its margins continue as the primary lamina $P_0_1$ (fig. 306). The upper part of the primary lamina $P_0_1$ curves slightly laterally. The aponeurosis $A_0_2$ is visible on the ventromedial surface of the muscle. It continues as the primary lamina $P_0_2$ which has a fringe-like border. On the lateral part (fig. 307) of the muscle is the third primary lamina $P_0_3$. It is long and narrow, and lies between the two primary laminae $P_0_1$ and $P_0_2$.

**Internal Tendons of Insertion (figs. 308, 309)**

**Formula:** $P_i_1, P_i_2, S_i$.

The external tendon is short and thick. No aponeurosis is present. Two primary laminae $P_i_1$ and $P_i_2$ directly arise from the external tendon (figs. 308, 309). The primary lamina $P_i_1$ is long and narrow. It terminates with two unequal extensions. The primary lamina $P_i_2$ is long and broad. From the medial surface of the primary lamina $P_i_2$, arises the curved secondary lamina $S_i$ (fig. 308).
The Arrangement of the Muscle Fibers (figs. 310, 311)

The muscle fibers of the small medial head arise from the lateral surface of the first metatarsal bone. They course nearly parallel and insert on both surfaces of the primary lamina $P_1$.

The more superficial fibers of the medial part (fig. 310) of the large lateral head arise from the primary lamina $P_2$, diverge and insert on the medial surfaces of the primary laminae $P_1$ and $P_2$, and on the secondary lamina $S_i$. The somewhat deeper fibers arise from the deep aspect of the primary lamina $P_2$ and the aponeurosis $A_1$, and insert on the proximal part of the primary lamina $P_2$.

The muscle fibers of the deep part (fig. 311) of the large lateral head arise from the medial surface of the second metatarsal bone. They converge and insert on the lateral aspect of the primary lamina $P_2$.

Second dorsal interosseus

General Description (figs. 312, 313)

The second dorsal interosseus has two heads. The long lateral head arises from the adjacent proximal surfaces of the second and third metatarsal bones. The short medial head arises from the distal and lateral surfaces of the second metatarsal bone. The external tendon of insertion inserts on the lateral surface of the base of the proximal phalanx of the second toe, and the adjacent joint capsule.

Internal Tendons of Origin (fig. 314)

Formula: $A_0, P_0, P_2, S_0$. 

There is neither external nor internal tendon of the short medial head. The external tendon of the long lateral head is short and flat. The aponeurosis Ao is visible on the medial surface of the muscle (fig. 314). Two primary laminae, the small Po₁ and the large Po₂ arise from the deep aspect of the aponeurosis Ao. The secondary lamina So arises from the deep distal surface of the primary lamina Po₂.

**Internal Tendons of Insertion** (fig. 315)

Formula: Pi, Si₁, Si₂.

The external tendon is short and thick. There is no aponeurosis present. The primary lamina Pi is curved slightly and arises directly from the external tendon. This primary lamina Pi is broader proximally. It has fringe-like borders, and terminates with two short extensions. Two secondary laminae Si₁ and Si₂ arise from the superior and medial surfaces of the primary lamina Pi, and close to the external tendon.

**The Arrangement of the Muscle Fibers** (figs. 316, 317)

The muscle fibers of the short medial head arise from the lateral surface of the second metatarsal bone, turn around to the superior surface of the muscle, and insert on the primary lamina Pi close to the tendon of insertion.

The muscle fibers of the lateral part (fig. 317) of the long lateral head arise from the medial surface of the third metatarsal and from the primary lamina Po and the secondary lamina So. They insert on the lateral aspect of the primary lamina Pi.

The muscle fibers of the medial part (fig. 316) of the long lateral head arise from the lateral surface of the second metatarsal
bone. They course nearly parallel and insert on the distal part of the medial aspect of the primary lamina \( P_1 \), and on the secondary laminae \( S_i_1 \) and \( S_i_2 \). The fibers of the more proximal part arise from the primary lamina \( P_0 \), and insert on the proximal part of the primary lamina \( P_1 \).

**Third dorsal interosseus**

**General Description** (figs. 318, 319)

The third dorsal interosseus is short and broad. It has a lateral and a medial head. The lateral head arises from the medial surface of the fourth metatarsal bone. The medial head arises from the lateral surface of the proximal part of the third, and the medial surface of the fourth metatarsal bone. These two heads fuse and form a single belly which inserts on the base of the lateral surface of the proximal phalanx of the third toe and the adjacent joint capsule.

**Internal Tendons of Origin**

Formula: none

Neither the lateral nor the medial heads have external or internal tendons.

**Internal Tendons of Insertion** (fig. 320)

Formula: \( A_i, P_{i_1}, P_{i_2} \).

The external tendon is short and thick, and continues as the aponeurosis \( A_i \) (fig. 320). It lies in the middle of the medial surface of the muscle. Its margin penetrates into the muscle as the primary lamina \( P_{i_1} \) of the lateral head which has a fringe-like border. The
second primary lamina $\text{Pi}_2$ of the medial head which is narrow distally, arises from the external tendon, and terminates again with a fringe-like border. The lower part of this primary lamina $\text{Pi}_2$ curves slightly toward the lateral surface.

The Arrangement of the Muscle Fibers (figs. 321, 322)

The muscle fibers of the lateral part (fig. 322) of the lateral head arise from the medial surface of the fourth metatarsal bone. These fibers insert on the lateral aspect of the primary lamina $\text{Pi}_1$. The upper fibers of the medial part (fig. 321) arise from the medial surface of the fourth metatarsal bone. They pass forward, downward, and insert on the medial and upper surfaces of the primary lamina $\text{Pi}_1$. The lower fibers course nearly parallel, and insert on the medial and lower surfaces of the primary lamina $\text{Pi}_1$.

The muscle fibers of the medial head arise from the plantar surface of the adjacent metatarsal bones. They pass forward, and insert both surfaces of the primary lamina $\text{Pi}_2$.

Fourth dorsal interosseus

General Description (figs. 323, 324)

The fourth dorsal interosseus has a lateral and a medial head. The lateral head arises with a fleshy origin from the proximal medial surface of the fifth metatarsal bone. The medial head is larger and arises with a tendinous origin from the lateral surface of the fourth metatarsal bone. The two heads fuse and form a single belly which inserts on the lateral surface of the base of the proximal phalanx of
the fourth toe, and the adjacent joint capsule.

**Internal Tendons of Origin** (figs. 325, 326)

Formula: $Ao_1, Ao_2, Ao_3, Po_1, Po_2, Po_3$.

The lateral head has neither external nor internal tendon. The external tendon of the medial head is very short. Three aponeuroses, a medial $Ao_1$, a lateral $Ao_2$, and a plantar $Ao_3$, arise from the short tendon. The aponeurosis $Ao_1$ is on the medial surface of the medial head (fig. 324). This aponeurosis $Ao_1$ is long and terminates as the primary lamina $Po_1$ (fig. 325). The aponeurosis $Ao_2$ is on the lateral surface (fig. 323) of the medial head and it is narrow proximally, and broad distally. It terminates as the primary lamina $Po_2$ (fig. 326) which has a fringe-like border. The very small aponeurosis $Ao_3$ is on the plantar surface of the medial head. It terminates as the broad primary lamina $Po_3$ (fig. 325) which has a fringe-like borders.

**Internal Tendons of Insertion** (figs. 327, 328)

Formula: $Pi, Si, Ti_1, Ti_2, Ti_3$.

The external tendon is short and thick. There is no aponeurosis present. The large fan-shaped primary lamina $Pi$ (fig. 327) arises directly from the external tendon. This primary lamina $Pi$ has seven extensions. Three of these are in the center part and extend more proximally. Two of the latter are on either side of the distal part of the primary lamina $Pi$. The secondary lamina $Si$ (figs. 327, 328) which is half as wide as the primary lamina $Pi$, arises from the lateral aspect of this primary lamina $Pi$. Three tertiary laminae $Ti_1, Ti_2, Ti_3$ (fig. 328) arise from the lateral aspect of the secondary lamina $Si$. 
The Arrangement of the Muscle Fibers (figs. 329, 330)

The muscle fibers of the lateral part (fig. 329) course in three different directions. The lower fibers which arise from the primary lamina Po₂, pass forward, upward, and insert on the proximal part of the lateral aspect of the primary lamina Pi. The middle fibers arise from the primary lamina Po₁. They pass forward, being superficial to the lower fibers, and insert on the distal part of the lateral aspect of the primary lamina Pi, secondary lamina Si, and tertiary lamina Ti₁. The upper fibers which arise from the medial surface of the fifth metatarsal bone, pass obliquely forward, downward, and insert on the lateral aspects of the secondary lamina Si, and tertiary laminae Ti₁ and Ti₂.

The majority of the muscle fibers on the medial part (fig. 330) of the medial head arise from the primary lamina Po₁. The muscle fibers of the lateral head arise from the medial surface of the fifth metatarsal bone. The fibers pass nearly parallel, forward and insert on the medial aspect of the primary lamina Pi, and secondary lamina Si. The uppermost distal fibers pass obliquely and insert on the upper two extensions of the primary lamina Pi. The lowermost fibers insert on the lower two extensions of the primary lamina Pi.
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<td></td>
<td>( Ai )</td>
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<tr>
<td>First dorsal interosseus</td>
<td>( Ao_1, Ao_2 )</td>
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<td>( Ai )</td>
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<td>Second dorsal interosseus</td>
<td>( A_0 )</td>
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<td></td>
<td>( Ai )</td>
</tr>
<tr>
<td>Third dorsal interosseus</td>
<td>( A_0 )</td>
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<tr>
<td></td>
<td>( Pi_1, Pi_2 )</td>
</tr>
<tr>
<td>Fourth dorsal interosseus</td>
<td>( Ao_1, Ao_2, Ao_3 )</td>
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<tr>
<td></td>
<td>( Ai )</td>
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<tr>
<td>Simple Internal Structures (P)</td>
<td>Moderate Complex Internal Structures (P, S, T)</td>
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<tr>
<td>--------------------------------</td>
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</tr>
<tr>
<td>(13) Gluteus maximus</td>
<td>(4) Iliacus</td>
</tr>
<tr>
<td>(7) Tensor fascia lata</td>
<td>(39) Gluteus medius</td>
</tr>
<tr>
<td>(1) Gemellus superior</td>
<td>(17) Gluteus minimus</td>
</tr>
<tr>
<td>(1) Gemellus inferior</td>
<td>(21) Piriformis</td>
</tr>
<tr>
<td>(0) Quadratus femoris</td>
<td>(27) Obturator internus</td>
</tr>
<tr>
<td>(2) Rectus femoris</td>
<td>(6) Sartorius</td>
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<tr>
<td>(4) Vastus femoris</td>
<td>(3) Semitendinosus</td>
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<tr>
<td>(3) Biceps femoris</td>
<td>(7) Semimembranosus</td>
</tr>
<tr>
<td>(3) Gracilis</td>
<td>(18) Pectineus</td>
</tr>
<tr>
<td>(1) Adductor longus</td>
<td>(2) Tibialis anterior</td>
</tr>
<tr>
<td>(1) Adductor brevis</td>
<td>(3) Extensor hallucis longus</td>
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<tr>
<td>(6) Adductor magnus</td>
<td>(3) Peroneus longus</td>
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<tr>
<td>(3) Extensor digitorum longus</td>
<td>(8) Soleus</td>
</tr>
<tr>
<td>(1) Peroneus brevis</td>
<td>(13) Popliteus</td>
</tr>
<tr>
<td>(18) Gastrocnemius</td>
<td>(3) Tibialis posterior</td>
</tr>
<tr>
<td>(3) Plantaris</td>
<td>(3) Flexor hallucis longus</td>
</tr>
<tr>
<td>(2) Flexor digitorum longus</td>
<td>(14) Extensor digitorum brevis</td>
</tr>
<tr>
<td>(3) Quadratus plantae</td>
<td>Externor hallucis brevis</td>
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<td>(8) Abductor hallucis</td>
<td>(9) Flexor digitorum brevis</td>
</tr>
<tr>
<td>(2) First lumbrical</td>
<td>(4) Fourth lumbrical</td>
</tr>
<tr>
<td>(3) Second lumbrical</td>
<td>(7) Abductor digiti minimi</td>
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<tr>
<td>(3) Third lumbrical</td>
<td>(11) Flexor hallucis brevis</td>
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<tr>
<td>(3) First plantar interosseus</td>
<td>(23) Adductor hallucis</td>
</tr>
<tr>
<td>(2) Third plantar interosseus</td>
<td>(6) Second plantar interosseus</td>
</tr>
<tr>
<td></td>
<td>(4) Third plantar interosseus</td>
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<td></td>
<td>(6) First dorsal interosseus</td>
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<td></td>
<td>(6) Second dorsal interosseus</td>
</tr>
<tr>
<td></td>
<td>(8) Fourth dorsal interosseus</td>
</tr>
</tbody>
</table>

Notes: The number in the parenthesis is the total number of the internal tendons of origin and insertion.
DISCUSSION

I. Significance of a Uniform Terminology of Internal Tendons

The terminology used for the description of internal structures of muscle is neither uniform nor consistent. The following terms have been used: longitudinal tendinous septa (Cleland, 1867), sagittal aponeurotic plate (McMurrich, 1902-03), intermediate tendon (Lubosch, 1914), central tendon (Reid, 1918; Cummins and his associates, 1946), tendinous lamina (Jager and Moll, 1951), stem tendon (Poglayen-Neuwall, 1953), intramuscular tendon (Markee, 1955; Iordansky, 1964), internal tendon (Teinze, 1969), and septa (Herring and Scapino, 1973). Actually, each of these names describes a different structure. A survey of modern dictionaries shows that some of these terms have nowadays taken on different meanings. We find in Stedman’s Medical and Webster’s Seventh New Collegiate dictionaries, that the aponeurosis is an expanded tendon that not only covers or invests a muscle, but also forms the termination and attachments of the muscle; the lamina is a thin plate or flat layer; the septum is a thin membrane or wall dividing two masses; the intermediate tendon is a tendon which is being interposed between two muscles. Obviously, these terms do not necessarily refer to internal structures of muscles, i.e. internal tendons.

Schafer and Thane in Quain’s Elements of Anatomy (1892) mentioned that tendons can be found on, and within muscles. However, these authors
did not develop the concept of clearly separating external tendons versus internal tendons. Jager and Moll, (1951), defined the "tendinous lamina" forming the continuation of the tendon into the muscle belly. Iordansky (1964), defined the "stem tendon" as an intramuscular tendon, i.e., one which arose from within the muscle mass. Recently, Heinze (1969), introduced the term "internal tendon" for an internal structure formed by the distribution of the aponeurosis within the muscle. However, he did not clearly distinguish between an aponeurosis which is by present day definition a superficial structure, and the internal tendon which is entirely within the muscle.

It obviously became necessary to develop a terminology for the internal tendons of muscles which can be rigourously applied without any ambiguity.

Our general definition is: the internal tendons are extensions of the external tendons within the muscle mass. The consecutive branchings of these internal tendons have been named, primary, secondary, tertiary, quartery, and quintary laminae. The external tendon is at either end of the muscle or extends on the superficial surface as the aponeurosis. Our terminology could be applied without difficulty to simple, as well as to most complex, arrangements of internal tendons.

II. Comparison of Our Observations with those of Previous Investigators

The internal structures of only three muscles of the human lower extremity have been previously studied. Reid (1918), Druner (1926), Cummins and his associates (1946), and Loetzke and Trzenschik (1969),
studied the soleus muscle; Cummins and his associates (1946) studied the gastrocnemius and plantaris. Reid (1918) seems to be the first to investigate the internal tendons of the human soleus. He described it as having a "central tendon" which corresponds to the middle "Rippe" of Druner (1926), and to the thin, oblique "tendinous lamina" of Cummins and his associates (1946). This central tendon is an antero-posterior oriented septum which arises from the posterior aponeurosis and the tendo Achillis. This central tendon is also visible on the anterior surface of the muscle as a "fishbone-like part" (Reid, 1918). In addition, Reid observed two separated tendinous sheets on either side of the central tendon. The margins of these tendinous sheets (our aponeuroses) penetrate into the muscle mass and become the "tendinous laminae" of Reid, and the "Ursprungsschinen" of Druner, or primary laminae in our terminology. The muscle fibers which arise from these aponeuroses converge and insert on the anterior portion of the central tendon and on the posterior aponeurosis of the soleus. These muscle fibers form a symmetric bipenniform arrangement. It has been classified as the "normal" type by Loetzke and Trzenschik (1969). Druner (1926) using a cross-sectional analysis, observed three septa (Rippen). The central tendon is in most cases located in the midline, and the two other primary laminae are found on either side of this central tendon.

Loetzke and Trzenschik observed, in one hundred and sixty five muscles, only two muscles in which the two primary laminae were of equal size. They could not find three primary laminae which had been described by Druner. These authors also attempted to classify the soleus on the
basis of a tibial or fibular location of the primary lamina. Using these criteria, they described ten different variations of the inner structure of the soleus.

In our investigation, only two unequal sized primary laminae have been observed. The large primary lamina which seems to correspond to the central tendon had been found on the fibular side of the muscle. The other small primary lamina had been located on the tibial side. This arrangement has not been described by Loetzke and Trzenschik.

The internal structure of the gastrocnemius has been studied by Cummins and his associates (1946). Although the aponeuroses of origin of the two heads of the muscle have been described, no internal tendons of origin of these two heads have been observed. On the other hand, these authors described "lamina" of insertion, which is in our terminology the aponeurosis of insertion. It arises separately from the broad aponeurosis that covers the posterior surface of the soleus muscle. This aponeurosis of insertion then becomes what Cummins et al., called the "septum", which extends between the two heads of the muscle. This septum corresponds to our primary lamina.

In our investigation of the gastrocnemius muscle, we observed the internal tendons of origin which have not been described by the previous authors. There are eight primary laminae which arise from the aponeurosis of each of the two heads of origin. On the other hand, our observations on the internal tendons of insertion agree with the findings of the previous authors.
The general anatomical features of the plantaris muscle have been also described by Cummins and his associates (1946). Neither external nor internal tendons of origin have been observed in this muscle. Only the external tendon of insertion is named. No description of the internal tendon of this muscle has been given.

We observed in our investigation a small primary lamina which arose from the aponeurosis of origin. On the other hand, a large primary lamina arose as a continuation of the aponeurosis of insertion. This primary lamina has one large and one small extension.

The structure of the semitendinosus is unique in so far as it has an intervening tendinous inscription, which divides the muscle into two parts. Such an intervening inscription has been observed in the semitendinosus of many mammals by Foster (1918). It also has been described in the horse and bovine by Kadletz (1931), and recently in the rabbit by Heinze and Beetz (1972). This tendinous inscription has not been described in detail in man. Only short remarks about it are found in some textbooks of anatomy (Piersol, 1919; Goss, 1973; Schaeffer, 1953; Romanes, 1972; and Hollinshead, 1969).

Our study first describes in detail the internal structure of this intervening tendinous inscription. This inscription not only truly separates the muscle into two parts, but it is structurally more than a simple dividing septum. This tendinous inscription is formed by one aponeurosis, one primary and one secondary lamina.

Piersol (1919) speculates in his textbook of Human Anatomy: "This condition may be the result of the end-to-end union of the tendon
of attachment of two primary distinct muscles (i.e. digastric), or to the persistence of some of the dividing lines which separate the various embryonic segments of which a muscle may be composed (i.e. rectus abdominis), or it may be due to a secondary form of attachment by a muscle in its course (i.e. omohyoid)." No enlightenment about this condition could be derived from the development of this muscle because no pertinent study could be found.

Christensen (1960) observed on a stillborn infant that the innervation of the semitendinosus is by two separate branches of the tibial nerve. Woodburne (1969) observed the same mode of innervation, although he did not mention the two separate portions of the muscle. Our own observations confirmed the previously described innervation by two branches of the tibial nerve. No conclusion about the significance of the two portions of the semitendinosus can be drawn from the mode of innervation.

The composition of the tendinous inscription is similar to the arrangement of the internal tendons of origin or insertion found in many muscles. This fact would fit best to Piersol's speculation that the two portions of the semitendinosus are the result of the end-to-end union of two primary distinct muscles.

III. The Formulae of the Internal Tendons

Our study of the internal structures of the muscles of the lower extremity is a morphological investigation. It essentially deals with the architectural arrangements of the internal tendons, and a qualitative assessment of their sizes. In addition, the dissections of the muscle
fibers which are a function of the presence and the arrangements of the internal tendons have been observed.

Many of the arrangements of the internal tendons have been found to be quite complex. Formulae have been introduced in order to reduce these complexities to a manageable form. These formulae express the composition of the external, as well as of the internal tendons.

Table 3 displays the formulae of the external and internal tendons of origin above the horizontal line, and those of the external and internal tendons of insertion below the line. The formulae of the external tendons are on the left side of the vertical line, those of the internal tendons are on the right side of the line. The abbreviations are: A. for aponeurosis, P. primary lamina, S. secondary lamina, T. tertiary lamina, Qa. quartery lamina, and Qi. quintary lamina. The subscript o indicates of origin and i indicates of insertion. The numbers indicate the numbers of the individual external tendons or internal tendinous laminae.

These formulae also permit an analysis of the complexity of the internal structures of the muscles. Most generally of interest is the mode of distribution of the complexity of the internal tendons among the muscles of the lower extremity. Specifically, the question to be answered is the distribution of the complexities or the lack thereof of the internal tendons between the origins and the insertions of the individual muscles.

The concept of symmetry has been used for analysis. Symmetrical formulae could be found for the origins and insertions of certain
muscles. Following this concept, other muscles have been found with asymmetric formulae for the origins and insertions. This group has been further subdivided according to the number of internal tendons in the origins and insertions.

In addition, some understanding of the significance of these arrangements of the internal tendons has been attempted.

The concept applied to these groups has been the constancy of the number of muscle fibers in the origins and insertions. Muscle fibers are attached to areas on bone, neighboring membranous structures, tendons, aponeuroses, and internal tendons. Rarely are all these structures involved in the compound origins or insertions. As the number of muscle fibers remain constant, the total areas of origin and insertion should be identical. If some of the above contributing areas are small, another area will be enlarged. Of interest to us is, how the internal tendons contribute to the equalization of the area of origin and insertion. This technique obviously allows only the assessment of the gross contributions of the internal tendons to this equalization.

1. **Muscles with symmetric formulae for origin and insertion**

   There are in the case of muscles with symmetric formulae, also identical numbers of the internal tendons present. However, it must be understood that the presence of symmetric formulae does not imply that the actual sizes of the individual internal tendons are identical. Symmetry then can be found in muscles with identical formulae which have either identical numbers of internal tendons, or no internal tendons.
1.1 Muscles with symmetric formulae and identical numbers of internal tendons in the origin and the insertion.

The muscles in this group are: flexor digitorum longus, and first lumbrical muscles.

The arrangements of the internal tendons of the flexor digitorum longus are extremely simple. There is only one primary lamina in the origin and in the insertion. The primary lamina of origin is small and short. The primary lamina of insertion is long and forms a trough-like structure. Although the type of branching of the internal tendons are identical, their actual configurations are dissimilar.

The arrangements of the internal tendons of the first lumbrical is also simple. There is also only one primary lamina in the origin and in the insertion. Their configurations are not similar. The primary lamina of origin is very small and has an oblong shape. There is no aponeurosis of origin, but the additional area for attachment of the muscle fibers is on both surfaces of the medial side of the tendon of the second toe of the flexor digitorum longus. The primary lamina of insertion is long and tapers proximally. It is a continuation from a small aponeurosis of insertion.

Symmetry of branching is associated with a simple arrangement of the internal tendons, and it can be found only in a few muscles. The actual configurations of the internal tendons, as far as the sizes and the specific sites of origin are concerned, have been found to be different in these two muscles. It does not appear that complete mirror images of the internal tendons is a governing principle in the
formation of the internal structure of muscles.

1.2 Muscles with symmetric formulae and absence of internal tendons in the origins and insertions

The muscles in this group are: the quadratus femoris and the articularis genus. These two muscles seem to have equal areas of origin and of insertion. There would be no need for a compensatory enlargement of the areas of attachment for muscle fibers either in the origin nor in the insertion.

2. Muscles with asymmetric formulae for origin and insertion

The majority of the muscles of the lower extremity belong to this group. Asymmetric branching of the internal tendons in the origin and the insertion is usually associated with different numbers of internal tendons in the origin and the insertion. This group is divided for analysis in four subgroups which are based on different degrees of differences in the numbers of internal tendons. Another subgroup contains those muscles which have asymmetric branching and identical numbers of internal tendons in the origins and the insertions.

2.1 Muscles with asymmetric formulae and different numbers of internal tendons of origin and of insertion

2.1.1 Muscles with no internal tendons of insertion

The muscles in this group are: tensor fascia lata, rectus femoris, adductor longus, adductor brevis, and adductor magnus. The question arises whether these muscles have some common structural features which could give an understanding of the absence of the internal tendons of insertion.
Generally, internal tendons provide areas for attachment of muscle fibers. Also, these areas of attachment, whether on bone, tendons and their aponeuroses, or internal tendons should be equal for the origin and the insertion.

Applying this concept, one might suspect that the lack of the internal tendons in the insertion indicates very small areas of attachment of origin. An analysis of these five muscles shows that their bony areas of origins are indeed quite small. But these areas of origin are moderately enlarged by aponeuroses, and in most cases by few internal tendons.

The analysis of the areas of insertions shows that the adductor magnus attaches on fairly large areas on bone, and on the aponeuroses of neighboring muscles. In addition, an enlargement of the area of insertion is provided by an aponeurosis. The insertions of the other four muscles in this group is by tendons on small bony areas. The expected enlargements of the areas of insertions are by either one or two large aponeuroses, or by several small aponeuroses.

One major characteristic of this group is the increase of the relatively small bony areas of origin by internal tendons and aponeuroses. The equalization of the areas of the insertion to those of the origin is provided, with the exception of the adductor magnus, by either a few large, or several small aponeuroses. It seems that the expansions of the external tendons, the aponeuroses, are adequate for this equalization, and no contributions are needed from areas of internal tendons.
2.1.2 Muscles with no internal tendons of origin

The muscles in this group are: iliacus, gemellus superior and gemellus inferior, vasti femoris, gracilis, tibialis anterior, extensor hallucis longus, extensor digitorum longus and peroneus tertius, peroneus longus, peroneus brevis, tibialis posterior, flexor hallucis longus, and third dorsal interosseus.

The concept of equal areas of attachments for the muscle fibers in the origins and in the insertions will be applied to the analysis of the fourteen muscles in this group. Which structural utilization then provides the equalization of the area of origin in the muscles in this group?

All muscles of this group have one major tendon which inserts either directly, or after its division into several small tendons. Other structures are utilized for the insertion of the muscle fibers in all these muscles. All fourteen muscles have internal tendons of insertion. These are simple, consisting only of primary and secondary laminae. In addition, eight muscles (vasti femoris, tibialis anterior, extensor hallucis longus, extensor digitorum longus, peroneus longus, peroneus brevis, tibialis posterior, and third dorsal interosseus) have aponeuroses. Generally, the areas for the insertion of muscle fibers are fairly large relative to the size of the muscle.

As there are no internal tendons in the origins of these muscles, other structures must provide areas of attachment equal in size to those of insertion. An analysis reveals that these fourteen muscles have relatively large areas of bony origins. These are sufficiently
large to provide the necessary areas in four muscles (gemelli, extensor digitorum longus, and third dorsal interosseus). Five muscles (vasti femoris, tibialis anterior, extensor hallucis longus, tibialis posterior, and flexor hallucis longus) utilize neighboring membranous structure, such as the intermuscular septa and the interosseous membrane for additional areas of origin. Aponeuroses provide such areas in six muscles (iliacus, tibialis anterior, peroneus longus, peroneus brevis, tibialis posterior, and flexor hallucis longus).

The muscle in this group utilize, besides aponeuroses, other structures for the equalization of the areas of attachment. Basically, the primary areas of bony origins are relatively large. Another increase in these areas is achieved by the use of neighboring membranous structures as origins.

2.1.3 Muscles with a greater number of internal tendons of origin than insertion

The muscles in this group are: Gluteus minimus, piriformis, obturator internus, sartorius, biceps femoris, semimembranosus, gastrocnemius, soleus, extensor digitorum brevis and extensor hallucis brevis, abductor hallucis, second and third lumbricals, flexor hallucis brevis, and first plantar interosseus.

The number of internal tendons of origin per muscle in this group ranges from two to seventeen. No correlation could be found between the number of internal tendons and the composition of the origins of the muscles by bony areas, internal tendons, and aponeuroses.

\[
\text{The ratio} \quad \frac{\text{Number of internal tendons of origin}}{\text{Number of internal tendons of insertion}}
\]
gives values ranging from 1.4-8.0. These values fall into two distinct group. Three values of 4.0, 5.0, and one of 8.0 fall into an upper group, and eleven values are between 1.4 and 2.5. No values are found in the considerable gap between the upper and lower group. The three muscles in the upper group are the abductor hallucis, sartorius, and the gastrocnemius with ratios of 4.0, 5.0, and 8.0 respectively. An analysis of the composition of the origins of these muscles shows that all have relatively small bony areas of origin. The substantially greater number of the internal tendons in the origins of these muscles compensate for the relatively small bony areas of origin. An analysis of the origins of the eleven muscles of the lower group shows that all have relatively large bony areas of origin. Seemingly, no large numbers of internal tendons are necessary for the equalization of the areas of origin and insertion.

The greater numbers of internal tendons of origin are by themselves meaningless. There is no correlation between these numbers and any specifics of the compound origins. However, when the ratios between the internal tendons of origins and insertions are considered, some understanding of the function of the greater numbers in the origins becomes possible. Three muscles with high ratios have relatively small bony origins. In these cases, the internal tendons serve the equalization of areas of origins and insertions.

2.1.4 Muscles with a greater numbers of internal tendons of insertion than of origin

The muscles in this group are: gluteus maximus, gluteus medius,
obturator externus, plantaris, popliteus, flexor digitorum brevis, quadratus plantae, fourth lumbrical, abductor digiti minimi, adductor hallucis, and fourth dorsal interosseus.

The numbers of internal tendons of insertion in the muscles of this group range from 26-2, whereas those of the origin range from 13-1. A qualitative analysis of the composition of the origin and insertion, as far as the bony areas and aponeuroses are concerned, shows that the areas of origin are larger than those of insertion. The greater numbers of internal tendons of insertion compensate for deficits in the bony areas of insertion. No subgroup can be found which would distinctly deviate from this general mechanism. The ratio

\[
\frac{\text{Number of internal tendons of insertion}}{\text{Number of internal tendons of origin}}
\]

are shown in the following table:

<table>
<thead>
<tr>
<th>Muscles</th>
<th>ratio</th>
<th>Muscles</th>
<th>ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>flexor digitorum brevis</td>
<td>8.0</td>
<td>quadratus plantae</td>
<td>2.0</td>
</tr>
<tr>
<td>gluteus maximus</td>
<td>5.5</td>
<td>obturator externus</td>
<td>1.7</td>
</tr>
<tr>
<td>fourth lumbrical</td>
<td>3.0</td>
<td>fourth dorsal interosseus</td>
<td>1.6</td>
</tr>
<tr>
<td>abductor digiti minimi</td>
<td>2.5</td>
<td>adductor hallucis</td>
<td>1.3</td>
</tr>
<tr>
<td>gluteus medius</td>
<td>2.0</td>
<td>popliteus</td>
<td>1.1</td>
</tr>
<tr>
<td>plantaris</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

High values are found only for two muscles, and lower values are associated with the majority of these muscles. The flexor digitorum brevis and the gluteus maximus have both relative large areas of origin,
either from an aponeurosis, or from bone. Both muscles have relatively
small areas of bony insertions. Obviously, greater number of internal
tendons of insertion provide an enlargement of the area of insertion
for these muscles. The analysis of the remaining muscles of this group
which have lower ratios, leads also to the conclusion that the internal
tendons of insertion provide enlargements of the areas of insertion.

The internal tendons of the muscles of this group provide an
equalization of the areas of insertion to those of origins.

2.2 Muscles with asymmetric formulae and equal numbers of internal
tendons of origin and insertion

These muscles have, in spite of their equal numbers, different
types of branching in the origin and in the insertion. The muscles in
this group are: pectineus, flexor digiti minimi brevis, second and
third plantar interossei, and first and second dorsal interossei.

The internal tendons found in the muscles of this group, whether
primary, secondary, tertiary, or quaterary ones, are of varying sizes.
The different sizes of the bony areas of origin cannot be grouped and
correlated with the areas of the internal tendons. Therefore, without
supporting evidence, one might only speculate that the internal tendons
may serve again the equalization of the areas of origin and of insertion.

IV. Significance of the symmetric and asymmetric formulae of the
internal tendons

Only very few muscles of the lower extremity display symmetric
formulae for their origins and insertions. Generally, these formulae
are no mirror images of each other in the origins and insertions. There are variations in the sizes of the internal tendons and their precise sites of origins. One might speculate that there has been an active and underlying principle of symmetry which became slightly altered by other unknown determinants.

The majority of the muscles show asymmetric formulae for the internal tendons of origin and insertion.

The internal tendons are part of the functional entity of the origin and of the insertion. The structures utilized for the attachments of muscle fibers include areas on bone, neighboring membranous structures, tendons, aponeuroses, and internal tendons. The total areas of origin equate the total areas of insertion. There is then an interchangeability of the individual areas of the origin or of the insertion. A reduction of one component area is compensated for by a corresponding increase of another component area.

The muscles which have internal tendons in neither the origin nor in the insertion, compensate with similar arrangements for these deficits in area. Basically, the compensatory increase in other areas is limited to the aponeuroses and the neighboring membranous structures. No compensatory contributions by internal tendons could be found.

The muscles which have a greater number of internal tendons either in the origin or in the insertion utilize a different mechanism. Here, the compensatory increase in other areas of attachment is basically limited to the internal tendons.
v. Significance of the degree of complexity of the internal tendons, and of their numbers

The internal tendons show large variations in their arrangements. It had been thought that there may be some significance related to the degree of complexity of these arrangements.

The muscles were arranged for analysis in three groups: Group A contained muscles with a simple internal structures, i.e. with only primary laminae. Group B contained muscles with moderately complex internal structures, i.e. with primary, secondary, and tertiary laminae. Group C contained muscles with most complex internal structures, i.e. with primary, secondary, tertiary, quartery, and quintary laminae. Table 4 shows the muscles in these groups.

No correlations could be established between the muscles in these different groups and any features of their external morphology or their functions.

Further analysis of the muscles in table 4 reveals that each group contains some muscles which have a substantially larger number of internal tendons. A group of thirteen muscles whose numbers of internal tendons vary from eleven to thirty-nine can be extracted from table 4. The following seven muscles of this group are topographically and functionally related to the hip joint: gluteus medius(39), obturator internus(27), piriformis(21), pectineus(18), gluteus minimus(17), gluteus maximus(13), and obturator externus(11). These muscles are the chief muscles of the extension, lateral and medial rotation, and abduction of the hip joint. These are powerful muscles. Such muscles
contain many fibers, and they are often large and bulky. These seven muscles are clustered around the hip joint in order to be able to produce their functions. The bony areas available for the origins and insertions of these muscles are limited. Many internal tendons provide additional areas for the attachment of muscle fibers. Seemingly, such an arrangement allows powerful muscles at locations where bony areas of attachments are limited.

VI. The relationship between muscle fibers and internal tendons and the usages of the term penniform

Penniform and its derivatives have been used to describe the relationship between muscle fibers and internal tendons. Unfortunately, many of these terms have not been used logically. The search for an early and meaningful terminology leads to the year 1919. Piersol described in his Textbook of Anatomy (1919) the arrangements of the muscle fibers which converge from either one or both sides to their attachments on a tendon. Such arrangements resemble a feather which has barbs on one or both sides of the quill. Piersol named these arrangements: "semipennate" and "pennate" respectively. Another arrangement can be observed in a broad muscle which has several parallel internal tendons. There, the muscle fibers alternately arise from one internal tendon and insert into the next internal tendon. Such an arrangement has been named "compound- or multipennate". One may wonder why Piersol's logical terminology became changed thereafter in a confusing way. Schaeffer (1953) defined the term "pennate" - a muscle in which the fibers approach the tendon from only one side. Yet,
according to Stedman's Medical Dictionary (1972), the term "semipennate" and "unipennate" are identical; semipennate means "penniform on one side; denoting a muscle in which the fibers are obliquely attached to one side of a tendon"; unipennate also means "having a feather arrangement on one side resembling one half of a feather". Literally, these two terms are not synonyms. Piersol's term "semipennate" which is concise and descriptive has been replaced by the terms "pennate" and "unipennate". Nevertheless, these terms have been used as synonyms up to the present time by many authors (Romanes, 1964; Goss, 1966; Wells, 1971). We used the term "semipennate" which we preferred for the description of the arrangement of the muscle fibers only on one side.

In another arrangement, the muscle fibers insert on a large segment of the tendon's circumference (Schaeffer, 1953). Such a muscle, looks on the open surface like a feather in which the barbs approach the quill from two directions. Schaeffer named this arrangement "bipennate", although he remarks that this term is not quite accurate. Literally, it means two pennates of two feathers. It seems that Piersol's term "pennate" for such an arrangement is more concise. His view is substantiated by Webster's definitions: pennate or pinnate means "resembling a feather, especially in having similar parts arranged on opposite sides of an axis like the barbs on the rachis of a feather". Examples given of pennate muscles are rectus femoris, long head of biceps femoris, semimembranosus, peroneus brevis, flexor digitorum longus and abductor hallucis. There is still another term used to describe the arrangement of the muscle fibers in our new definitions of
"bipennate", which according to Webster's Dictionary means twice pennate, and according to Stedman's Medical Dictionary means a double feather arrangement. Examples of such an arrangement would be the soleus and abductor digiti minimi.

Multipennate is the only term which is applied and used consistently by other authors. Interestingly, the deltoid is the only example of a multipennate muscle seemingly known to anatomists. Following my studies, I can add the following muscles, which also have a multipennate arrangement of their fibers: flexor digitorum brevis, flexor hallucis brevis, and the adductor hallucis.

For the above reasons, the following new terminology for the description of the arrangements of the muscle fibers has been adopted: "semipennate" for the muscle fibers only attached on one side of the internal tendon; "pennate" for muscle fibers attached on both sides of the internal tendon; "bipennate" for muscle fibers of two pennate.

Again, it should be emphasized that these terms describe only the arrangement of the fibers as seen on the surface of the muscle. Differently expressed, these terms then do not describe the course of the fibers deep in the muscle mass. Or, these terms are true only for the superficial part of the muscle, but not for the whole muscle. Perhaps this problem can be understood by using a special hairbrush as a visual aid. The brush shall have its bristles radiating nearly 180 degrees from its base plate. Seen from one side, the arrangement of the bristles and the base plate resemble muscle fibers attaching to a tendon in the semipennate arrangement. Cutting this brush at a deeper plane, the orderly
"semipennate" arrangement disappears. Bristles are cut at many angles, and at different distances from the base plate. This description demonstrates what Gans and Bock (1965) called the "geometric pattern", in which the muscle fibers are arranged radially around the circumference of a central tendon.

VII. Significance of the course of the muscle fibers in some muscles

The dissection of the internal tendons necessitated the individual removal of every muscle fiber. The course of these fibers has been recorded, and they are presented in the models of the internal tendons of the muscles. The emphasis has been to show how the internal tendons determine the course of the muscle fibers. The muscle fibers can also be considered in a more general way, emphasizing the overall course of the fibers in a muscle. Some of the functional implications of the overall course of the fibers will be discussed in the following part.

MacConail and Basmajian (1969) pointed out that the fibers in some muscles are twisted, and they named such muscles "twisted muscle". The fibers in such a muscle do not course straight from origin to insertion. Such a twisted arrangement can be easily visualized with the aid of a piece of cable containing many individual strands. If one cut end of this cable is twisted against the other end, the strands then course obliquely. The muscle fibers are not only twisted, but the fibers arising from both sides of the first cut end cross obliquely to the other sides of the second cut end. Simultaneously, the fibers arising from both sides of the second cut end cross obliquely to the
opposite sides of the first cut end. Consequently, the fibers from the two cut ends which can be taken for the origin and insertion of a muscle, cross each other, forming what MacConaill and Basmajian called a "cruciate muscle".

According to MacConaill and Basmajian (1969), the action of a muscle is governed by two general laws, "the law of approximation", and "the law of detorsion".

The law of approximation applies to that part of the action which tends to bring the insertion and origin closer together.

The law of detorsion applies only to that action of a twisted muscle which tends to bring the line of insertion into the same plane as the line of origin.

The adductor magnus is the only example of a twisted and cruciate muscle of the lower extremity given by MacConaill and Basmajian (1969). They described the muscle as an adductor, and an internal rotator of the hip, because its insertion lies behind the long axis of the femur. These two actions bring the origin and insertion closer together (law of approximation). In addition, describing it also as a potential extensor of the hip, they said: "Its fibers pass laterally to the femur from antero-posterior line of origin along the lower margin (conjoined ramus) of the hip bone to the supero-inferior line of insertion on the femur---Its fibers are so arranged that the law of detorsion makes it a potential extensor of the hip should the muscle act as a whole". The application of the law of approximation to the actions of the adduction and of internal rotation of the hip is logical. However, the application of
the law of detorsion of the action of the extension is not quite clear. Therefore we reapplied these two general laws to the actions of the adductor magnus as follows:

The muscle fibers arise from an antero-posterior area of the inferior conjoined ramus, and pass downward and laterally to their insertion on a supero-inferior area of the femur. The fibers of the most anterior part of the origin insert on the upper part of the femur. Some posterior fibers twist around the medial border of the muscle to its anterior part and insert on the lower part of the femur. The remaining posterior fibers which go to the entire area of insertion on the femur cross the fibers of the anterior part of the muscle.

When all the muscle fibers contract, the muscle adducts the thigh from an abducted position until the most medial fibers are vertical (law of approximation). Further contraction of the upper fibers brings the femur across the midline as in crossing the leg. In doing so it is also an external rotator and flexor of the thigh, for its insertion is behind the long axis of the femur. Extension is only possible from a flexed position.

The adductor magnus is a twisted muscle, in so far as the fibers originating from the posterior area of the conjoined ramus twist around the medial portion of the muscle and approach the anterior and lower part of insertion on the femur. Contraction will tend to bring the supero-inferior line of insertion into the same plane as the antero-posterior line of origin (law of detorsion). Therefore this portion of the muscle acts as an internal rotator of the thigh.
Our explanation of the actions of the adductor magnus as an
adductor, flexor, external and internal rotator are confirmed by the
early experimental investigation of the actions by Duchene (1866). He
used electrophysiological stimulation for studies and observed adduction,
lateral rotation by the upper part of the muscle, and medial rotation
by the lower part. However, he observed no flexion.

Our explanation also agrees with that of Hollinshead (1969). He
described the muscle as an adductor flexor, internal and external rotator.

We found in our studies that the pectineus is also like the
adductor magnus, a twisted and cruciate muscle. These characteristics
have not been observed by MacConaill and Basmajian (1969). The muscle
fibers arise from a latero-medial area of the superior ramus of the
pubis. They pass downward and laterally, and twist in such a way that
the most lateral fibers course anteriorly, while the most medial fibers
course posteriorly. They insert on the superior-inferior narrow area
of the femur.

When the muscle contracts, it tends to bring its insertion close
to its origin during adduction of the thigh (law of approximation).
Because its insertion is behind the long axis of the femur, the pectineus
is a flexor of the thigh. In doing so, it rotates the thigh externally
(lateral rotation), because it simultaneously tends to bring the superior-
inferior line of insertion into the same plane as the lateral-medial
line of origin (law of detorsion). Therefore, the pectineus is an
adductor, flexor, and lateral rotator.

Again, our analysis of the actions of the pectineus is confirmed
by the early investigation of Duchene (1866) who observed flexion,
adduction, and lateral rotation. The pectineus muscle is rarely described as a rotator of the thigh in the textbooks of anatomy. Contrary to the results of our analysis, Goss (1966) described the pectineus as a medial rotator. Hollinshead (1969) who described the pectineus as a lateral rotator, is in agreement with our analysis but disagree with that of Goss (1966).

MacConaill and Basmajian (1969) did not observe any muscle which is only "cruciate" without also simultaneously being "twisted".

We observed in our studies the adductor longus and the adductor brevis are "cruciate" muscles without being twisted. The standard textbooks of anatomy give the actions of both muscles as abduction, flexion, and lateral rotation.

The morphology of the adductor longus is similar to that of the lower part of the adductor magnus. Generally the muscle fibers of the adductor longus course obliquely downward and laterally in front of the adductor magnus. They insert on the posterior part of the femur adjacent to the lower and anterior fibers of the adductor magnus. Specifically, the majority of the anterior fibers of the adductor longus and a small portion of the lowest posterior fibers are long and course almost vertical, whereas the majority of the posterior fibers and a small portion of the uppermost anterior fibers are short and course more obliquely. The anterior fibers cross the posterior fibers. Applying the law of approximation, the adductor longus is an adductor, flexor and lateral rotator. The contraction of the anterior fibers will adduct the thigh until these fibers are vertical. Contraction of
the posterior fibers will further adduct the thigh across the midline. The adductor longus is a flexor of the thigh because the insertion lies behind the long axis of the femur. It will also rotate the thigh laterally during flexion. Only in a flexed position of the hip joint, the lowermost fibers tend to extend and rotate the thigh medially.

The morphology of the adductor brevis is similar to that of the upper part of the adductor magnus. Generally, the muscle fibers of the adductor brevis course obliquely downward and laterally in front of the upper part of the adductor magnus. They insert on the posterior part of the femur adjacent to the upper and anterior fibers of the adductor magnus. Specifically, the majority of the anterior fibers of the adductor brevis and a small portion of the lower posterior fibers are long and course obliquely, whereas the majority of the posterior fibers and a small portion of the uppermost anterior fibers are short and course more horizontal. Applying the law of approximation, the adductor brevis is an adductor, flexor, and lateral rotator of the thigh. The majority of the anterior fibers function like those of the adductor longus. Their contraction will adduct the thigh until these fibers course vertically. Further contraction of the posterior fibers will adduct the thigh across the midline. Again, because the insertion lies behind the long axis of the femur, the adductor brevis is a flexor of the thigh. In doing so, it will rotate the thigh laterally.
VII. Attachments of muscles which differ from the classical descriptions

Generally, the muscle attachments are well, and more or less uniformly described in the classical textbooks. We had observed different attachments of the quadratus plantae, the lumbricals, and the interossei.

The quadratus plantae (flexor digitorum accessorius) muscle is described as arising with two heads. Accordingly, the medial head arises from the medial plantar surface of the calcaneum (tuberosity), and the lateral head from the lateral plantar surface of this bone (tuberosity), (Piersol, 1919; Grant and Basmajian, 1965; and Hollinshead, 1969). These two origins are separated by the long plantar ligament (Goss, 1973; and Woodburne, 1969). Both origins have additional attachment from the adjacent borders (Craft, 1966) or from the corresponding margins (Lockhart, et al., 1965) of the long plantar ligament. Therefore, the medial head has an additional origin from the medial border of the long plantar ligament, and the lateral head has an additional origin from the lateral border of this ligament (Romanes, 1972). According to Cunningham's Textbook of Anatomy (Romanes, 1972), the lateral head is sometimes described to be absent. In this study, a lateral head which arises from the lateral tuberosity of the calcaneum and from the lateral border of the long plantar ligament could not be observed. Instead, a small and short lateral head had been observed which arises from the medial border of the long plantar ligament. This short lateral head lies underneath the medial head. It becomes visible only after elevating the medial head.
The insertions of the lumbrical muscles are described in most
standard textbooks of anatomy (Piersol, 1919; Goss, 1966; Romanes, 1964;
Grant and Basmajian, 1965; Lockhart, Hamilton, and Fyfe, 1965; and
Becker, Wilson, and Gehweilar, 1971) as being on the dorsal expansions
of the tendons of the extensor digitorum longus. This dorsal expansion
is given by these authors as the only place of insertions of the
lumbricals. However, Cunningham's Textbook of Anatomy (Romanes, 1964)
described additional insertion of the lumbricals on the capsules of the
metatarso-phalangeal joints, and on the bases of the proximal phalanges.
We found in our study insertions of the lumbrical muscles only on the
capsules of the metatarso-phalangeal joints, and the bases of the
proximal phalanges, but not on the dorsal expansions. Recently, Fahrer
and Chapuis (1973) report that the main functional insertions of the
lumbricals are on the capsules of the metatarso-phalangeal joints, and
only a "reduced" insertion is on the extensor expansion which according
to those authors is of no functional significances.

There are some controversies in the descriptions of the insertions
of the interosseus muscles. Romanes (1964), describes in Cunningham's
Textbook of Anatomy the insertions of the interossei on the bases of
the first phalanges, the capsules of the metatarso-phalangeal joints,
and on the dorsal expansions of the tendons of the extensor digitorum
longus. However, Goss (1966), in Gray's Anatomy; Lockhart, Hamilton, and
Fyfe (1965), in Anatomy of the Human Body; Grant and Basmajian (1965), in
Grant's Method; and Crafts (1966), in Textbook of Human Anatomy, describe
insertion only on the bases of the proximal phalanges and on the dorsal
expansions. Piersol (1919), in Human Anatomy, describes only one insertion into the membranous expansion. Contrary to these authors, Becker, Wilson, and Geheweiler (1971), in Anatomical Basis of Medical Practice, and Hollinshead (1969) in Textbook of Anatomy, describe insertion only on the proximal phalanges. Hollinshead remarks in his textbook that "the interossei of the foot do not regularly send any part of their insertions into the extensor tendons of the toes". Fahrer and Chapuis (1973), recently reported that they could not find any insertion into the extensor apparatus. Our observations confirm the insertions into the bases of the proximal phalanges and into the capsules of the metatarso-phalangeal joints. In no case could we find an insertion into the dorsal expansion.

IX. The Morphology of the Internal Tendons and the Anatomical Nomenclatures

Piersol (1919) had already commented that an inconsistent rationale has often been used for the naming of some muscles. He referred to muscles with more than one head of origin, which arise from different bones or structures, and which unite and insert with a common tendon. Such types of muscles are not consistently named according to their morphological appearances. He quotes the biceps femoris which is regarded as a single muscle, although it has two separate heads of origin and one common tendon of insertion. On the other hand, the iliacus and the psoas, as well as the gastrocnemius and the soleus are all named as individual muscle. However, the iliacus and the psoas insert together with one common tendon as well as the gastrocnemius and the
soleus.

Piersol's suggestions have been based on features of the external morphology. However, features of the internal morphology can be used for the naming of muscles with equal justification. Our study had revealed in detail the morphology of the internal tendons. These results will be critically applied to some of the names of muscles, as used, and as given in the P.N.A. (Paris Nomina Anatomica).

The biceps femoris is considered to be one muscle. Its external morphology shows two separate heads of origin. These unite and insert into a broad and long aponeurosis which becomes the common tendon of insertion. A primary lamina extends obliquely from this aponeurosis into the muscle mass. This primary lamina divides the aponeurosis into proximal and distal parts. The proximal part of the aponeurosis and the proximal aspect of the primary lamina provide insertion for the muscle fibers of the long head. The distal part of the aponeurosis and the distal aspect of the primary lamina provide insertion for the muscle fibers of the short head. This common tendon of insertion cannot be separated without depriving either the long head, or the short head of their insertions. The tendon of insertion is truly a common one for both heads, and the naming of the muscle as a single muscle with two heads, i.e. biceps femoris, is justified by the internal morphology.

The iliacus and the psoas major muscles arise each with one head, which are quite separated from each other. These two heads then form a common tendon of insertion. The iliacus and the psoas major are frequently regarded as one single muscle, and are named accordingly
iliopsoas (Goss, 1966; Hollinshead, 1969). Romanes (1964) regards the iliopsoas a "compound muscle". By contrast, Piersol (1919) and Crafts (1966) consider these muscles as two separate muscles. The morphology of the internal tendons of the psoas and iliacus is as follows: The common tendon of insertion expands into an aponeurosis located on the deep side of the iliacus. There are, arising from this aponeurosis, two primary laminae which extend into the mass of the iliacus, and one primary lamina which extends into the mass of the psoas. In addition, there is a secondary lamina which connects the primary lamina in the psoas to one of the primary laminae in the iliacus. One cannot separate these internal tendons without depriving either one of these two muscles of their insertion. Therefore, these muscles should be regarded as one muscle named iliopsoas or ilio-lumbar.

The gastrocnemius and soleus arise from three separate heads which join each other and form a common tendon of insertion. It is named in the P.N.A. as a single muscle, the triceps surae. Only Hollinshead (1969) and Woodburne (1969) accepted this term. Other authors still refer to separate muscles, i.e. the gastrocnemius and the soleus which join into a common tendon, the tendo Achillis.

Cummins and his associates (1946) studied the component part of the tendo Achillis. They described how the tendinous fibers of the gastrocnemius component converge downward from the broad aponeurosis on the anterior surface of the gastrocnemius towards their insertion. As these tendinous fibers descend downward on the posterior surface of the broad aponeurosis of the soleus, they spiral toward the anterior surface.
of the tendo Achillis. On the other hand, the tendinous fibers of the soleus component converge downward from the broad posterior aponeurosis of this muscle. They spiral toward the posterior surface of the tendon. These authors note that the two tendinous components can be almost separated save for some smaller fibers near the termination of these two tendons.

The gastrocnemius is generally described as one muscle with two bellies. Although no different concepts about this muscle have been expressed, a test of this concept utilizing the morphology of the internal structures may be of interest. The question to be asked is whether the gastrocnemius is one muscle with two heads, or two separate muscles.

A lateral and a medial primary lamina arise from the anteriorly located aponeurosis of insertion of the gastrocnemius. The lateral primary lamina receives muscle fibers from the lateral posterior aponeurosis of origin, and the medial primary lamina receives fibers from the medial posterior aponeurosis of origin. Clearly, the separation into two heads is also indicated by the internal structures. However, the single aponeurosis of insertion from which these primary laminae originate cannot be separated into lateral and medial parts. Therefore, the gastrocnemius should be considered as one muscle with two heads. Biceps surae may be a more fitting name.

In addition to the above muscles singled out by Piersol (1919), we felt that other muscles which have also more than one head of origin and a common tendon of insertion should be analyzed using the morphology
of the internal tendons. These muscles are: quadratus plantae (flexor accessorius), quadriceps femoris, adductor hallucis, and flexor hallucis brevis. The descriptions of the individual muscles are similar in the usual textbooks of anatomy. Neither studies nor discussions concerning the divisions of these muscles or the correctness of their names could be found.

The quadratus plantae is usually described as a single muscle with two heads. There are two separate heads of origin which arise from two different structures. The medial head arises by fleshy fibers from the medial tubercle of the calcaneum. The lateral head arises by a tendinous origin from the long plantar ligament. The medial and lateral heads of origin unite and form a common tendon which inserts on the tendon of the flexor digitorum longus. The internal structures of the insertion are two primary laminae which arise from a very short ventral aponeurosis. The proximal parts of these primary laminae give insertion to muscle fibers which arise from the medial head of origin. The distal parts of the primary laminae give insertion to muscle fibers which arise from the lateral head of origin. The relationships of these two heads can be compared to that of the biceps femoris. In the quadratus plantae, the medial head corresponds to the long head of the biceps femoris, and the lateral head corresponds to the short head of the biceps femoris. The internal tendons of the quadratus plantae cannot be separated without depriving either the parts of the medial head, or the medial and the lateral heads of their insertion. These internal tendons are truly a common tendon for both heads. Therefore it is a
single muscle with two bellies which would be better named biceps plantae.

The quadriceps femoris is named in the P.N.A. as one muscle with four heads. This terminology is generally used in the textbooks of anatomy. These four heads of origin unite and form a common tendon of insertion. Externally, the four heads can be easily separated into two distinct muscle masses, the rectus femoris and the vasti femoris. The rectus femoris arises by two heads from the anterior inferior iliac spine and the upper rim of the acetabulum. The vasti femoris arise from the entire anterior, lateral, and medial surfaces of the femur, and the adjacent intermuscular septa. The common tendon of insertion which is named the tendon of the quadriceps femoris is formed by the external tendons of the rectus femoris (tendo musculi recti femoris) and the vasti femoris. This common tendon is clearly separated proximally. A layer of connective tissue is found between the tendons of the rectus femoris and that of the vasti femoris. Careful dissection allows a separation of these two tendons distally to their insertions on the tuberosity of the tibia. The tendon of the vasti femoris is strong. The tendon of the rectus femoris is thin, and is additionally fused with the deep fascia of the leg. Therefore the rectus femoris and the vasti femoris should be regarded as two separated muscles.

The rectus femoris has no internal tendon of insertion. Only the external tendon extends as an aponeurosis on the posterior surface of the muscle. Clearly, according to the internal morphology, this muscle is a single muscle.
Externally, the vasti femoris are considered as being composed of three vasti (lateral, medial, and intermedius). Hollinshead (1969) noted that the separation of these vasti can only be accomplished with difficulty. The vasti are rather, as the name vastus implies, a large muscle mass.

The vasti femoris have no internal tendons of origin from the femur, the adjacent intermuscular septa, and the lateral and medial aponeuroses of origin. There is no internal structure which would indicate a separation of the origin into three heads. On the other hand, the external tendon of insertion extends proximally and becomes a narrow aponeurosis which lies on the vastus intermedius. This aponeurosis is separated from the aponeurosis of insertion of the rectus femoris by a thin layer of connective tissue. The aponeurosis of the vastus intermedius penetrates into the muscle mass and then becomes two primary laminae, one on each side. However, these primary laminae are not simply distributed in the lateral or medial vasti. Rather, the lateral primary lamina is found in the lateral vastus and in the vastus intermedius; and the medial primary lamina is found in the vastus medialis and in the vastus intermedius. Thus, there is no internal architecture which clearly separates the three vasti. There is no possibility of separating the aponeurosis or the internal tendons without depriving all three vasti or two vasti respectively of their insertion. Therefore this muscle should be considered as one muscle with one head of origin and named accordingly the vastus femoris.
The adductor hallucis and the flexor hallucis brevis are named as two different muscles in the P.N.A.

The flexor hallucis brevis arises with a single head from the cuboid and the long plantar ligament. The muscle mass splits about two-thirds distally and divides into two parts. The medial part inserts on the medial side of the base of the first phalanx. The lateral part is fused with the muscle mass of the oblique head of the adductor hallucis. From this fused mass arises a tendon which inserts on the lateral side of the base of the first phalanx. There arises, in addition, from about halfway of the flexor hallucis brevis a substantial muscular band which joins the distal part of the oblique head of the adductor hallucis.

The oblique head of the adductor hallucis arises from the bases of the second to the fourth metatarsal bones. The transverse head arises from the deep transverse metatarsal ligaments. The oblique head receives in its distal part, as already mentioned, the muscular band from the flexor hallucis brevis. After this junction, both, the oblique and the transverse heads fuse and form one tendon. This tendon fuses again with the tendon of insertion of the lateral part of the flexor hallucis brevis.

The external morphology of the flexor hallucis brevis and the adductor hallucis appears as one complex muscle with three heads of origin, and two parts of insertion.

The internal tendons of the flexor hallucis brevis are fairly simple with the exception of one peculiarity. Summing up the detailed
description of the internal tendons of insertion as presented in the results, the following arrangements have been found. There are two primary laminae of insertion in each of the lateral and medial parts. The peculiarity is a secondary lamina which arises from one of the primary laminae in the lateral part, and joins a primary lamina in the oblique head of the adductor hallucis. There is then a connection between the internal tendons of one muscle to the internal tendons of another muscle. This connecting internal tendon truly crosses from one muscle to the other. Not surprisingly, it is located within the muscular band connecting the flexor hallucis brevis with the oblique head of the adductor hallucis.

The internal tendons of insertion of the adductor hallucis are very complicated. There are three primary laminae, six secondary laminae, and three tertiary laminae in the oblique head. One of the primary laminae of this head fuses with the one primary lamina of the transverse head, and forms a common tendon of insertion. As already described, the aforementioned peculiar secondary lamina of the oblique head connects to one of the primary laminae in the lateral part of the flexor hallucis brevis, thus forming a connecting internal tendon between two muscles. This pattern of the internal tendons of the flexor hallucis brevis and adductor hallucis does not allow any separation into two muscles without depriving any muscle of its internal tendons. The internal morphology substantiates the external morphology of one muscle with three heads of origin and two parts of insertion. Such a muscle could be named triceps hallucis plantae.
The question arises whether there are other findings which may corroborate this new concept of a muscle as deduced from the architecture of the internal tendons.

The nerve supplies of the flexor hallucis brevis and of the adductor hallucis should give some helpful information. The flexor hallucis brevis is grossly innervated by a branch of the medial plantar nerve; and the adductor hallucis by a deep branch of the lateral plantar nerve. An analysis of the segmental innervation (Kendall, Kendall and Wadsworth, 1971) shows that the flexor hallucis brevis receives fibers from L (4), 5, S1; and the adductor hallucis from S1,2. These data indicate that each of these muscles develops from its own myotome, and that they also share one myotome.

No observations about the detailed development of the human flexor hallucis brevis and the adductor hallucis could be found.

Our observations finally lead to other questions namely whether these muscles are on an evolutionary scale incompletely fused or incompletely separated.

Interesting as such questions are, obviously, there is no information available which could help us to make a decision.
SUMMARY AND CONCLUSION

1. This study has been concerned with the morphology of the internal structure of the muscles of the human lower extremity. Specifically, the shapes and sizes of these internal tendons have been elucidated and recorded, as well as the relationship of the muscle fibers to these internal tendons.

2. Two hundred and twenty seven muscles from right and left lower extremities have been dissected by a special teasing method. Models of the internal structures of fifty five muscles of the left lower extremity were constructed for a better three-dimensional visualization.

3. A concise terminology of internal tendons was developed. External tendons are the tendons which are located at either end of the muscle and the aponeurosis covering a surface of the muscle. Any expansion of the external tendons into the muscle mass is defined as an internal tendon. The consecutive branches of internal tendons are named primary, secondary, tertiary, quarterly, and quintary laminae. Formulae were introduced which expressed the relationships of the external tendons to internal tendons. These formulae reduce the often very complex arrangements of the internal tendons to a manageable form. Furthermore, these formulae allow the analysis and the comparison of the internal tendons of different muscles.

187
4. Simple and complex arrangements of the internal tendons have been observed. An analysis has been made of these arrangements. Parameters considered were the symmetry and asymmetry of branching, and the number of internal tendons in the origins and insertions.

5. (a) Two muscles have symmetric formulae and identical number of internal tendons in the origin and in the insertion, i.e. flexor digitorum longus, and first lumbrical.

(b) Two muscles have no internal tendons in the origin and in the insertion, i.e. quadratus femoris, and articularis genus.

(c) Five muscles have no internal tendons in the insertion, i.e. tensor fascia lata, rectus femoris, adductor longus, adductor brevis, and adductor magnus.

(d) Fourteen muscles have no internal tendons in the origin, i.e. iliacus, gemellus superior and gemellus inferior, vasti femoris, gracilis, tibialis anterior, extensor hallucis longus, extensor digitorum longus and peroneur tertius, peroneus longus, peroneus brevis, tibialis posterior, flexor hallucis longus, and third dorsal interosseus.

(e) Fifteen muscles have a greater number of internal tendons of origin than of insertion, i.e. gluteus minimus, piriformis, obturator internus, sartorius, biceps femoris, semimembranosus, gastrocnemius, soleus, extensor digitorum brevis and extensor hallucis brevis, adductor hallucis, second and third lumbricals, flexor hallucis brevis, and first plantar interosseus.

(f) Eleven muscles have a greater number of internal tendons of insertion than of origin, i.e. gluteus maximus, gluteus medius,
obturator externus, plantaris, popliteus, flexor digitorum brevis, quadratus plantae, fourth lumbrical, abductor digiti minimi, adductor hallucis, and fourth dorsal interosseus.

(g) Six muscles have asymmetric formulae, but equal numbers of internal tendons of origin and insertion, i.e. flexor digiti minimi brevis, pectineus, second and third plantar interossei, and first and second dorsal interossei.

(h) One muscle has an intervening tendinous inscription, i.e. semitendinosus.

6. Further analysis shows that a large number of internal tendons at one attachment is associated with a large bony area at the other attachment. This increase in the number of internal tendons and its concomitant increase of the area of attachment at one end of the muscle compensates for large bony areas of attachment at the other end of the muscle.

7. Seven muscles which are functionally and topographically related to the hip joint each contain a large number of internal tendons. These muscles which move the hip joint have to be powerful. The multitude of muscle fibers in strong muscles need large areas of attachment. The bony pelvis is too small to provide large enough areas for attachments of powerful muscles. The necessary large areas of attachment are provided by many internal tendons.

8. The spatial relationships between internal tendons of origin and of insertion determine the course of the muscle fibers. Unipennate, bipennate, and multipennate are the commonly used terms. An analysis
of these terms has been made, and it is proposed to use the more appropriate terms: semipennate, pennate, and bipennate. Finally, it must be emphasized that these terms described only the arrangement of the fibers as seen on the surface of the muscle.

9. The functional implications of a twisted and cruciate arrangement of the muscle fibers in the adductor magnus are described in the literature. We found such an arrangement of the muscle fibers also in the pectineus and in the adductor longus and brevis.

10. Different attachments of three muscles were found which have not been previously described.

(a) The origin of the lateral head of the quadratus plantae described as arising from the lateral tuberosity of the calcaneum and crossing below the long plantar ligament could not be observed.

(b) The insertions of the lumbricals and those of the interossei into the dorsal expansions could not be found.

11. The names of muscles are based on features of their external morphology. However, the internal morphology as expressed by the arrangements of the internal tendons can also be used for the naming of muscles. Analysing the internal morphology of the muscles of the lower extremity, the following suggestions are made for changes in the morphology: quadratus plantae = biceps plantae; quadriceps femoris = rectus femoris and vasti femoris; adductor hallucis and flexor hallucis brevis = triceps hallucis plantae.
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191


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Fig. 2 Anterior view of the iliacus muscle in situ. The psoas major muscle lies in the middle of the proximal left half of the iliacus. The very small anterior aponeurosis of origin (Ao₁) is located on the lateral part of the anterior surface of the muscle (above). The tendon of insertion (I) is attached to the lesser trochanter (right).

Fig. 3 Posterior view of the isolated iliacus muscle. The very small posterior aponeurosis of origin (Ao₂) is located on the lowest part of the lateral side of the posterior surface of the muscle (below). The aponeurosis of insertion (Ai) lies on the posterior surface of the muscle against the superior ramus of the pubis. I, tendon of insertion.
Fig. 4 Anterior-medial view of the external and internal tendons of insertion of the iliacus muscle, and the very large primary lamina(Pi) of the psoas major muscle is located proximally. The first and the second primary laminae(Pi₁ and Pi₂) arise from the aponeurosis Ai(see fig. 6 below). The third primary lamina(Pi₃) arises from the tendon of insertion(I). The secondary lamina(Si) arises from the deep aspect of Pi₁ and is connected to the Pi of the psoas major muscle.

Fig. 5 Lateral view of the external and internal tendons of insertion of the iliacus, and the very large primary lamina(Pi) of the psoas major muscle. I, tendon of insertion; Pi₁, Pi₂, Pi₃, First, second, and third primary laminae; Si, secondary lamina.

Fig. 6 Posterior view of the external and internal tendons of insertion of the iliacus, and the very large primary lamina(Pi) of the psoas major muscle. Ai, aponeurosis; I, tendon of insertion; Pi₁, Pi₂, Pi₃, first, second, and third primary laminae; Si, secondary lamina.
Fig. 7 Lateral view of the external and internal tendons of insertion of the iliacus. I, tendon of insertion; \( P_1 \), \( P_2 \), \( P_3 \), first, second, and third primary laminae.

Fig. 8 Anterior-medial view of the model of the ilio-psoas muscles. The directions of the muscle fibers are represented by wires. \( A_{01} \), superficial aponeurosis of origin; I, tendon of insertion; \( P_1 \), \( P_2 \), \( P_3 \), first, second, and third primary laminae of insertion; S1, secondary lamina of insertion.
Fig. 9 Anterior view of the model of the ilio-psoas muscles. Ao₁, superficial aponeurosis of origin of the iliacus; I, tendon of insertion; Pi, primary lamina of insertion of the psoas major muscle; Pi₁ and Pi₃, first and third primary laminae of insertion of the iliacus.

Fig. 10 Posterior view of the model of the ilio-psoas muscles. Ao₁, and Ao₂, superficial and deep aponeuroses of origin of the iliacus; Ai, aponeurosis of insertion of the iliacus; I, tendon of insertion; Pi, primary lamina of insertion of the psoas major; Pi₁, Pi₂, Pi₃, first, second, and third primary laminae of insertion of the iliacus.
Fig. 11  Superficial surface of the gluteus maximus muscle in situ. A very small superficial aponeurosis of origin($Ao_1$) is at the supero-medial margin of the muscle. The broad superficial aponeurosis of insertion($Ai_1$) is continuous with the ilio-tibial tract (white area at lower right).

Fig. 12  Deep surface of the gluteus maximus muscle. The origin of the muscle is reflected laterally (below). Large deep aponeurosis of origin($Ao_2$), and small deep aponeurosis of insertion($Ai_2$).
Fig. 13  Deep aspect of the anterior or deep aponeurosis Ao_2, and small posterior or superficial aponeurosis Ao_1 of origin of the gluteus maximus. First primary lamina (Po_1) originates from Ao_1; the fish tail-like primary laminae Po_2 and Po_3 arise from the deep aspect of Ao_2.

Fig. 14  Deep aspect of the external and internal tendons of insertion of the gluteus maximus. Ai_2, small deep aponeurosis which terminates into primary lamina (Pi_11); I_1 and I_2, tendons of insertion; Pi_1, Pi_2, Pi_3, Pi_5, Pi_6, Pi_7, Pi_8, Pi_9, Pi_10, primary laminae of different size which arise from the deep aspect of Ai (see fig. 15).
Fig. 15 Superficial aspect of the model of the external and internal tendons of the gluteus maximus. Fig. 11 of the specimen should be compared with this view of the model. White dotted area represents bone(sacrum); white striped lines represent the sacro-tuberous ligament; and the solid white area below represents the ilio-tibial tract. Wires indicate the direction of the muscle fibers. Ao₁ and Ao₂, superficial and deep aponeuroses of origin; Ai, superficial aponeurosis of insertion; Po₁, Po₂, Po₃, primary laminae of origin; numbers 3,4,5,6,9,10, represent the primary laminae of insertion Pi₃, Pi₄, Pi₅, Pi₆, Pi₉, Pi₁₀ respectively.

Fig. 16 Deep aspect of the model of the external and internal tendons of the gluteus maximus. Fig. 12 of the specimen should be compared with this view of the model. White dotted area represents bone(sacrum); white triangular area represents the sacro-tuberous ligament; and the solid white area above represents the ilio-tibial tract. The wires indicate the directions of the muscle fibers. Ao₂, deep aponeurosis of origin; Ai₂, deep aponeurosis of insertion; I₁ and I₂, tendons of insertion; numbers 3,6,9,10, represent primary laminae of insertion Pi₃, Pi₆, Pi₉, Pi₁₀, respectively.
Fig. 17 Superficial surface of the isolated gluteus medius muscle.
A very large gluteal fascia or aponeurosis $A_0_1$ covers the superior part of the superficial surface of the muscle. I, tendon of insertion.

Fig. 18 Deep surface of the isolated gluteus medius muscle. $A_0_2$ and $A_0_3$, aponeuroses of origin; $A_1_1$ and $A_1_2$, aponeuroses of insertion; I, tendon of insertion.
Fig. 19  External and internal tendons on the deep aspect of the gluteus medius. Most of the muscle fibers between tendons have been removed. Ao₂, aponeurosis of origin; Ai₁ and Ai₂, aponeuroses of insertion; I, tendon of insertion; Po₁₃, primary lamina of origin; Pi₁, Pi₂, Pi₃, primary laminae of insertion.

Fig. 20  Deep aspects of the aponeurosis of origin (Ao₁) of the gluteus medius. The deep aponeurosis of origin Ao₂ is reflected superiorly; twelve primary laminae of origin Po₁, Po₂, Po₃, Po₄, Po₅, Po₆, Po₇, Po₈, Po₉, Po₁₀, Po₁₁, Po₁₂, arise from the deep aspect of Ao₁.
Fig. 21 Deep surfaces of the external and internal tendons of insertion of the gluteus medius muscle. The triangular shaped aponeurosis Ai which is on the lateral side terminates into primary lamina Pi₁. The lunar shaped aponeurosis Ai₂ gives rise to the middle Pi₂ and the medial Pi₃ primary laminae. I, tendon of insertion. Note a series of eighteen secondary laminae (not labeled) of varying sizes radiates from the deep aspect of the primary lamina Pi₃.

Fig. 22 Superficial surfaces of the external and internal tendons of insertion of the gluteus medius. I, tendon of insertion; Pi₁, Pi₂, Pi₃, lateral, middle, and medial primary laminae of insertion; Si₁, Si₂, Si₃, Si₄, Si₅, secondary laminae of insertion which arise from the superficial surface of Pi₂.
Fig. 23 Superficial view of the model of the external and internal tendons of the gluteus medius. Fig. 17 of the specimen should be compared with this view of the model. The wires indicate the directions of the muscle fibers. Ao₁, aponeurosis of origin; Ai₁, aponeurosis of insertion; I, tendon of insertion; Pi₂ and Pi₃, middle and medial primary laminae of insertion; Si₁, Si₂, Si₃, Si₄, Si₅, secondary laminae of insertion.

Fig. 24 Deep aspect of the model of the external and internal tendons of the gluteus medius. Compare this view of the model with figs. 18 and 19 of the specimen. The wires indicate the directions of the muscle fibers. Ao₂ and Ao₃, aponeuroses of origin; Ai₁ and Ai₂, aponeuroses of insertion; I, tendon of insertion; Po₁₃, primary lamina of origin; Pi₂ and Pi₃, middle and medial primary laminae of insertion. Note the radiation of the secondary laminae (not labeled) on this surface of the primary lamina Pi₃.
Fig. 25  Superficial surface of the gluteus minimus(right) and deep surface of the gluteus medius(left). The very large superficial aponeurosis of insertion $A_i$ of the gluteus minimus is connected to the gluteus medius by three thin muscular slips. $I$, tendon of insertion of the gluteus minimus is partially fused with the lateral part of the tendon of the gluteus medius.

Fig. 26  Deep surface of the gluteus minimus. $A_o$, aponeurosis of origin; $A_{i_2}$, deep aponeurosis of insertion; $I$, tendon of insertion.
Fig. 27 Deep aspect of the internal tendons of origin of the gluteus minimus. Five primary lamina Po₁, Po₂, Po₃, Po₄, Po₅, arise from the aponeurosis Ao. Two secondary laminae So₁ and So₂, arise from the deep aspect of the primary laminae Po₂ and Po₃.

Fig. 28 Deep aspect of the external and internal tendons of insertion of the gluteus minimus. One large primary lamina Pi₁ divides the aponeurosis Ai₁ into a medial (below) and a lateral parts (above); six very small primary laminae Pi₂, Pi₃, Pi₄, Pi₅, Pi₆, Pi₇, arise from the deep aspect of the superficial aponeurosis Ai₁. The deep aponeurosis Ai₂ originates from the tendon of insertion(I).
Fig. 29  Superficial aspect of the model of the gluteus minimus. The wires indicate directions of the muscle fibers. White dots represent the bony origin (external surface of the ala of the ilium). Ai₁, superficial aponeurosis of insertion; I, tendon of insertion.

Fig. 30  Deep aspect of the model of the gluteus minimus. The wires indicate directions of the muscle fibers. White dots represent the bony origin (internal surface of the ala of the ilium). Ai₂, deep aponeurosis of insertion; Pi₁, Pi₂, Pi₃, Pi₆, Pi₇, primary laminae of insertion; I, tendon of insertion.
Fig. 31. Superficial surface of the tensor fascia lata. $A_{o_1}$ and $A_{o_2}$, superficial anterior and middle aponeuroses of origin; $A_{i_1}$, broad superficial aponeurosis of insertion. The white area at right is the ilio-tibial tract.

Fig. 32. Deep surface of the tensor fascia lata. $A_{o_4}$ and $A_{o_5}$, deep posterior and anterior aponeuroses of origin; $A_{i_2}$, broad deep aponeurosis of insertion. The white area at right is the ilio-tibial tract.
Fig. 33 Superficial surfaces of the external and internal tendons of origin of the tensor fascia lata. Each of the aponeuroses $A_o_1$, $A_o_2$, $A_o_3$, $A_o_4$, terminates respectively in a primary lamina($P_o_1$, $P_o_2$, $P_o_3$, $P_o_4$).

Fig. 34 Deep surfaces of the external and internal tendons of origin of the tensor fascia lata. The aponeurosis $A_o_4$ terminates in primary lamina $P_o_4$; the aponeurosis $A_o_5$, terminates in three primary laminae $P_o_5$, $P_o_6$, $P_o_7$. The primary lamina $P_o_1$, arises from the terminal part of the aponeurosis $A_o_1$, which is not visible in this view (see fig. 33).
Fig. 35 Superficial surface of the aponeurosis \( A_{1} \) and deep aspect of the aponeurosis \( A_{2} \) of insertion of the tensor fascia lata. Both aponeuroses continue into the ilio-tibial tract on the right.

Fig. 36 Superficial aspect of the model of the tensor fascia lata. Compare with fig. 31. Wires indicate directions of the muscle fibers. White area at right is the ilio-tibial tract. \( A_{01} \), \( A_{02} \), \( A_{04} \) aponeuroses of origin, each of these terminates into primary laminae \( P_{01} \), \( P_{02} \) (not labeled) and \( P_{04} \). \( A_{1} \) and \( A_{2} \) aponeuroses of insertion.

Fig. 37 Deep aspect of the model of the tensor fascia lata. Compare with fig. 32. Wires indicate directions of the muscle fibers. \( A_{04} \) and \( A_{05} \) aponeuroses of origin; \( A_{2} \), deep aponeurosis of insertion; \( P_{01} \), \( P_{04} \), \( P_{05} \), \( P_{06} \), \( P_{07} \), primary laminae of origin; white area at right is the ilio-tibial tract.
Fig. 38 Superficial or posterior surface of the piriformis muscle. Aponeurosis Ao of origin is narrow on this surface. I, tendon of insertion.

Fig. 39 Deep or anterior surface of the piriformis muscle. Aponeurosis Ao is forming a nearly complete ring around the muscle. I, tendon of insertion.
Fig. 40 Deep or internal aspect of the spread-out aponeurosis Au of origin of the piriformis. It terminates in nine dentate primary laminae Po₁, Po₂, Po₃ (cannot be seen), Po₄, Po₅, Po₆, Po₇, Po₈, Po₉. Additional five primary laminae Po₁₀, Po₁₁, Po₁₂, Po₁₃, Po₁₄, arise from the deep aspect of the aponeurosis Au.

Fig. 41 Superficial or posterior surfaces of the external and internal tendons of insertion of the piriformis. There is one long and one short primary laminae Pi₁ and Pi₂. Si₄ and Si₅, secondary laminae which arise from the superficial surface of Pi₁. I, tendon of insertion.
Fig. 42 Deep or anterior surfaces of the external and internal tendons of insertion of the piriformis. Three secondary laminae $S_1$, $S_2$, $S_3$; arise from the deep surface of the primary lamina $P_1$. I, tendon of insertion.

Fig. 43 Deep aspect of the model of the piriformis. Compare with fig. 39. Wires indicate directions of muscle fibers. Ao, aponeurosis of origin; I, tendon of insertion; $P_1$, primary lamina of insertion; $P_6$, $P_8$, $P_9$, primary laminae of origin; $S_1$, $S_2$, $S_3$, secondary laminae of insertion.

Fig. 44 Superficial aspect of the model of the piriformis. Compare with fig. 38. Wires indicate directions of muscle fibers. Ao, aponeurosis of origin; I, tendon of insertion; $P_1$, $P_2$, $P_4$, $P_5$, primary laminae of origin; $P_1$ and $P_2$, primary laminae of insertion; $S_4$ and $S_5$, secondary laminae of insertion.
Fig. 45 Superficial surface of the obturator internus together with the superior (left of the tendon of insertion I), and the inferior gemellus (right of the tendon of insertion I). Ao₁, superficial aponeurosis of origin; I, tendon of insertion of the obturator internus.

Fig. 46 Deep surface of the obturator internus, with the superior gemellus superiorly and the inferior gemellus inferiorly to the tendon of insertion I. Ao₂, deep aponeurosis of origin.
Fig. 47 Deep aspect of the superficial aponeurosis Ao₁ and of the internal tendons of origin of the obturator internus. The dentate-like primary laminae Po₁, Po₂, Po₃, Po₄, Po₅, Po₆, Po₇, Po₈, Po₉, Po₁₀, arise as terminal parts of the aponeurosis Ao₁. Additional three primary laminae Po₁₁, Po₁₂, Po₁₃, arise from the deep aspect of Ao₁.

Fig. 48 Deep aspect of the superficial aponeurosis Ao₁ and of the internal tendons of origin of the obturator internus. Both lateral and medial parts of the aponeurosis Ao₁ of fig. 47 are reflected laterally and medially respectively. Po₁₁, Po₁₂, Po₁₃, Po₁₄, primary laminae of origin. Note Po₁₄, which cannot be seen in fig. 47 is seen here.
Fig. 49  Superficial surface of the deep aponeurosis Ao₂ and of the internal tendons of origin of the obturator internus.
Aponeurosis Ao₂ and its three terminal primary laminae Po₁⁵, Po₁⁶ and Po₁⁷.

Fig. 50  Deep aspect of the deep aponeurosis Ao₂ and of the internal tendons of origin of the obturator internus. Ao₂, aponeurosis of origin; Po₁⁵, Po₁⁶, Po₁⁷, primary laminae of origin.

Fig. 51  Deep surface of the internal tendons of insertion of the obturator internus with eight aponeuroses of insertion Ai₁, Ai₂, Ai₃, Ai₄, Ai₅, Ai₆, Ai₇, Ai₈.
Fig. 53. Deep muscle fibers and fascicles of insertion of the adductor magnus muscle. See Fig. 52.

Fig. 54. Origin of insertion.
Fig. 52 Superficial surfaces of the external and internal tendons of insertion of the obturator internus. Primary laminae $P_i_1$, $P_i_2$, $P_i_3$, $P_i_4$, $P_i_7$, $P_i_8$, can be seen; two secondary laminae, $S_i_1$ and $S_i_2$, arise from the superficial aspect of the $P_i_3$ and $P_i_4$; I, tendon of insertion.

Fig. 53 Deep surfaces of the external and internal tendons of insertion of the obturator internus. Primary laminae $P_i_1$, $P_i_2$, $P_i_3$, $P_i_4$, $P_i_5$, $P_i_7$, $P_i_8$, can be seen; I, tendon of insertion.
Fig. 54  Superficial aspect of the model of the obturator internus. Compare with fig. 45. Wires indicate directions of muscle fibers. Ao₁, superficial aponeurosis of origin; I, tendon of insertion; Pi₁, Pi₂, Pi₃, Pi₄, Pi₅, Pi₇, Pi₈, primary laminae of insertion.

Fig. 55  Deep aspect of the model of the obturator internus. Compare with fig. 46. Ao₁ and Ao₂, superficial and deep aponeuroses of origin; I, tendon of insertion; numbers 1, 2, 3, 4, 5, 6, 7, 8, indicate the aponeuroses of insertion Ai₁, Ai₂, Ai₃, Ai₄, Ai₅, Ai₆, Ai₇, Ai₈.
Fig. 56 Deep aspect of the model of the obturator internus. The muscular part is vertical, and the tendinous part lies flat. Ao₁ and Ao₂, superficial and deep aponeuroses of origin; Ai, aponeurosis of insertion; I, tendon of insertion; Pi₁ and Pi₂, primary laminae of insertion of the gemellus superior and gemellus inferior respectively.

Fig. 57 Deep aspect of the superior gemellus(above) and the inferior gemellus(below). Muscle fibers of the obturator internus are removed. I, tendon of insertion of the obturator internus.
Fig. 58 Posterior or superficial surface of the quadratus femoris.
Ao₁, large aponeurosis of origin which in situ is hidden by
the ischial tuberosity; Ao₂, small aponeurosis of origin.

Fig. 59 Anterior or deep surface of the quadratus femoris. Ai₁,
large quadrilateral aponeurosis of insertion; Ai₂ and Ai₃,
two small triangular aponeuroses of insertion.
Fig. 60 Posterior or superficial aspect of the model of the quadratus femoris. Compare with fig. 58. The wires indicate directions of the muscle fibers. Ao₁ and Ao₂, aponeuroses of origin; Ai₁, Ai₂, Ai₃, aponeuroses of insertion.

Fig. 61 Anterior or deep aspect of the model of the quadratus femoris. Compare with fig. 59. The wires indicate directions of the muscle fibers. Ao₁ and Ao₂, aponeuroses of origin; Ai₁, Ai₂, Ai₃, aponeuroses of insertion.
Fig. 62 Superficial surface of the obturator externus. Ai₁, superficial aponeurosis of insertion; I, tendon of insertion.

Fig. 63 Deep surface of the obturator externus. Ai₂, deep aponeurosis of insertion; I, tendon of insertion.
Fig. 64 Deep aspects of the internal tendons of origin of the obturator externus. Four different sizes and shapes of isolated aponeuroses of origin, Ao₁, Ao₂, Ao₃, Ao₄; each of these terminates in a very short primary lamina, correspondingly named: Po₁, Po₂, Po₃, Po₄. I, tendon of insertion.

Fig. 65 Superficial surfaces of the external and internal tendons of insertion of the obturator externus. Ai₁, superficial aponeurosis of insertion; Pi, primary lamina; two large secondary laminae Si₁ and Si₂ arise from the deep aspect of the primary lamina Pi; I, tendon of insertion.
Fig. 66 Deep surfaces of the external and internal tendons of insertion of the obturator externus. $A_{i2}$, deep aponeurosis; I, tendon of insertion; $S_{i1}$, deep aspect of the first or anterior secondary lamina; $T_{i1}$ and $T_{i2}$, tertiary laminae.

Note: $T_{i1}$ is attached to the deep aspect of the aponeurosis $A_{i2}$, while $T_{i2}$ is attached to the quartery lamina ($Q_{ai}$). From the deep aspect of the quartery lamina $Q_{ai}$, arises the quintary lamina $Q_{ii}$.

Fig. 67 Deep aspect of the model of the obturator externus. Compare with figs. 63, 66. Wires indicate directions of muscle fibers. $A_{o1}$, $A_{o2}$, $A_{o3}$, $A_{o4}$, aponeuroses of origin; $A_{i2}$, deep aponeurosis of insertion; I, tendon of insertion; $S_{i1}$, first secondary lamina; $T_{i1}$, first tertiary lamina; $Q_{ai}$, quartery lamina; $Q_{ii}$, quintary lamina.
Fig. 68 Superficial aspect of the model of the obturator externus. Compare with figs. 62, 65. Wires indicate the directions of muscle fibers. Ao₁, Ao₂, Ao₃, Ao₄, aponeuroses of origin; Ai₁, superficial aponeurosis of insertion; I, tendon of insertion; Pi, primary lamina of insertion; Si₁ and Si₂, secondary lamina of insertion.

Fig. 69 Side view of the model of the obturator externus. Note the tertiary lamina Ti₂ in this view.
Fig. 70 Superficial or anterior surface of the proximal part of the sartorius muscle.

Fig. 71 Deep or posterior surface of the proximal part of the sartorius muscle.

Fig. 72 Superficial surface of the internal tendons of origin of the sartorius. Aponeuroses Ao₁ and Ao₂, each terminates into primary lamina Po₁ and Po₂. The secondary lamina So arises between the angle of the primary laminae Po₁ and Po₂.

Fig. 73 Deep surface of the internal tendons of origin of the sartorius. There are two aponeuroses Ao₂ and Ao₃, each terminates respectively in primary lamina Po₂ and Po₃. So, secondary lamina; To, tertiary lamina which arises at a nearly right angle from the deep surface of So.
Fig. 74  Superficial or medial surface of the distal part of the sartorius muscle with a broad and thin tendon (I) of insertion.

Fig. 75  Deep or lateral surface of the distal part of the sartorius muscle with a broad and thin tendon (I) of insertion.
Fig. 76 Superficial surfaces of the external and internal tendons of insertion of the sartorius. Only one primary lamina PI arises directly from the tendon of insertion (I).

Fig. 77 Superficial aspect of the model of the sartorius. Compare with figs. 70, 72, 74, 76. Wires indicate directions of muscle fibers. I, tendon of insertion; Pi, primary lamina of insertion.

Fig. 78. Deep aspect of the model of the sartorius. Compare with figs. 71, 73, 75. Wires indicate directions of muscle fibers. I, tendon of insertion; Pi, primary lamina of insertion.
Fig. 79 Anterior or superficial surface of the quadriceps femoris in situ. Ao₁, aponeurosis of origin of the rectus femoris; O, tendon of origin of the rectus femoris; I₁, tendon of insertion of the quadriceps femoris or tendo musculi recti femoris.

Fig. 80 Antero-lateral view of the vastus lateralis with partially reflected rectus femoris. Ao₂, aponeurosis of origin of the vastus lateralis; Ai₁, aponeurosis of insertion of the rectus femoris; I₁, tendo musculi recti femoris; O, tendon of origin of the rectus femoris.

Fig. 81 Deep aspect of the external and internal tendons of origin of the rectus femoris. The large aponeurosis Ao₁ terminates in the primary lamina Po₁. Another primary lamina Po₂ arises at an angle of 45 degree from the deep aspect of Ao₁. O, tendon of origin of the rectus femoris.
Fig. 82 Deep aspect of the aponeurosis Ao₂ of origin of the vastus lateralis after removal of the muscle fibers. The lateral border of Ao₂ (below) is fused with the lateral intermuscular septum(2).

Fig. 83 Deep aspect of the aponeurosis Ao₃ of origin of the vastus medialis after removal of the muscle fibers. The medial border indicated by an oblique line between white area (left) and dark area (right) of Ao₃ is continuous with the medial intermuscular septum(3).
Fig. 84 Anterior surface of the internal tendons of insertion of the three vasti; the rectus femoris is reflected inferiorly (right in the picture). Ao₂ and Ao₃, aponeuroses of origin of the vastus lateralis and vastus medialis; Ai₁, aponeurosis of insertion of the rectus femoris; Ai₂, aponeurosis of insertion of the vastus intermedius; Pi₁ and Pi₂, primary laminae of insertion of the vastus lateralis and vastus medialis.

Fig. 85 Posterior or deep surface of the quadriceps femoris with the elongated cone-shaped articularis genus(l).
Fig. 86  Superficial or anterior aspect of the model of the quadriceps femoris. Compare with fig. 79. The wires indicate directions of the muscle fibers. 0, tendon of origin of the rectus femoris; Ao₁, aponeurosis of origin of the rectus femoris; I₁, tendon of insertion of the rectus femoris; I₂, tendon of insertion of the vasti femoris; Po₁, primary lamina of origin of the rectus femoris; Pi₁, primary lamina of insertion of the vastus lateralis.

Fig. 87  Antero-lateral view of the model of the quadriceps femoris. Compare with fig. 80. The wires indicate directions of the muscle fibers. 0, tendon of origin of the rectus femoris; Ao₁, aponeurosis of origin of the rectus femoris; Ao₂, aponeurosis of origin of the vastus lateralis; Ai₁, aponeurosis of insertion of the rectus femoris; Ai₂, aponeurosis of insertion of the vastus intermedius; I₁, tendon of insertion of the rectus femoris; I₂, tendon of insertion of the vasti femoris; Po₁, primary lamina of origin of the rectus femoris; Pi₁, primary lamina of insertion of the vastus lateralis.

Fig. 88  Deep or posterior view of the model of the quadriceps femoris. Compare with fig. 85. The wires indicate directions of the muscle fibers. White striped lines indicate medial intermuscular septum(above) and lateral intermuscular septum(below). I₂, tendon of insertion of the vasti femoris; 0, tendon of origin of the rectus femoris.
Fig. 89 Superficial or posterior surface of the hamstring muscles in situ. Biceps femoris is lateral (above); semitendinosus lies superficial to the semimembranosus (below).

Fig. 90 Deep aspect of the internal tendons of origin of the long head of the biceps femoris. O, tendon of origin. The aponeurosis Ao terminates in the primary lamina Po₁. Another primary lamina Po₂ arises from the deep aspect of Ao.

Fig. 91 Superficial aspect of the aponeurosis Ao of origin of the long head of the biceps femoris. Its distal part terminates in the primary lamina Po₁; its proximal part is covered by the aponeuroses Ao₁ and Ao₂ of origin of the semitendinosus. O, tendon of origin of biceps femoris and semitendinosus.
Fig. 92 Deep aspects of the external and internal tendons of insertion of the biceps femoris. The primary lamina Pi arises from the deep aspect of the aponeurosis Ai. I, tendon of insertion.

Fig. 93 Superficial view of the model of the biceps femoris. Compare with fig. 89. The wires indicate directions of the muscle fibers. White area on the left is the external tendon of origin (O). I, tendon of insertion; P01, primary lamina of origin of the long head; Ai, aponeurosis of insertion.

Fig. 94 Deep aspect of the model of the biceps femoris. The wires indicate directions of the muscle fibers. Ao, aponeurosis of origin; P01, P02, primary laminae of origin of the long head; Ai, aponeurosis of insertion; Pi, primary lamina of insertion; I, tendon of insertion; O, tendon of origin of the long head.
Fig. 95 Superficial surface of the semitendinosus muscle. 0, tendon of origin; Ao, aponeurosis of origin of the biceps femoris is reflected downward; Po₁, primary lamina of origin of the biceps femoris. An aponeurosis Ao₂ of origin arises from the tendon(0) of origin. A, aponeurosis of the intervening tendinous inscription. I, tendon of insertion of the semitendinosus.

Fig. 96 Deep surface of the semitendinosus muscle. The primary laminae Po₁ and Po₂ of origin of the biceps femoris are reflected upward. 0, tendon of origin; Ao₁, aponeurosis of origin; Ai, aponeurosis of insertion; I, tendon of insertion of the semitendinosus. Note: an obliquely serrated line which is the margin of the secondary lamina S (see fig. 99) in the middle of the muscle separates the muscle into upper(left) and lower(right) parts.
Fig. 97 Deep surfaces of the external tendon 0 and the aponeurosis of origin of the semitendinosus muscle. The short aponeurosis Ao1 and the deep aspect of the long aponeurosis Ao2 form a V-shape which covers the deep and superficial surfaces of the muscle.

Fig. 98 Superficial aspect of the internal tendons of the intervening tendinous inscription of the semitendinosus. The aponeurosis A terminates in the primary lamina P superiorly(left).

Fig. 99 Deep aspect of the internal tendons of the intervening tendinous inscription of the semitendinosus. The aponeurosis A is located inferiorly(right), while the primary lamina P is located superiorly(left). The secondary lamina S arises from the deep aspect of the primary lamina P. Together, A, P, and S, completely separate the muscle into upper and lower parts.
Fig. 100  Deep aspects of the external and internal tendons of insertion of the semitendinosus. The aponeurosis Ai curves and terminates in the primary lamina Pi. I, tendon of insertion.

Fig. 101  Deep aspect of the model of the semitendinosus. Compare with fig. 96. Wires indicate directions of muscle fibers. White area at left is the external tendon of origin O. Ao_l, aponeurosis of origin; Ai, aponeurosis of insertion; I, tendon of insertion; Pi, primary lamina of insertion; P, primary lamina of inscription; S, secondary lamina of inscription.

Fig. 102  Superficial view of the model of the semitendinosus. Compare with fig. 95. Wires indicate directions of the muscle fibers. A, aponeurosis of the tendinous inscription; P, primary lamina of tendinous inscription; Ao_2, aponeurosis of origin; I, tendon of insertion.

Fig. 103  Side view of the model of the semitendinosus. O, tendon of origin; S, secondary lamina of tendinous inscription; P, primary lamina of tendinous inscription; I, tendon of insertion; Ai, aponeurosis of insertion; Pi, primary lamina of insertion.
Fig. 104 Superficial surface of the semimembranosus in situ. 1, the long head of the biceps femoris, and 2, the tendon of the semitendinosus are reflected laterally. The proximal tendinous part becomes a thin aponeurosis Ao of origin; the distal muscular part is thick. 0, tendon of origin; I, tendon of insertion.

Fig. 105 Deep surface of the isolated semimembranosus. Ai, aponeurosis of insertion; I, tendon of insertion; 0, tendon of origin.

Fig. 106 Deep aspect of the external and internal tendons of origin of the semimembranosus. The aponeurosis Ao terminates in the primary lamina Po₁. Three small additional primary laminae Po₂, Po₃, Po₄, arise from the deep aspect of Ao. The secondary lamina So arises from the deep aspect and lateral side of Po₁. 0, tendon of origin.
Fig. 107  Superficial aspect of the external and internal tendons of origin of the semimembranosus. The aponeurosis Ao terminates in the primary lamina Po. The secondary lamina So arises from the deep aspect of Po. O, tendon of origin.

Fig. 108  Deep aspect of the external and internal tendons of insertion of the semimembranosus. The aponeurosis Ai terminates in the primary lamina Pi. Another primary lamina Pi arises from the deep aspect of Ai. I, tendon of insertion.

Fig. 109  Deep aspect of the model of the semimembranosus. The wires indicate directions of the muscle fibers. Ai, aponeurosis of insertion; Pi, primary lamina of insertion; I, tendon of insertion; O, tendon of origin.
Fig. 110 Superficial aspect of the model of the semimembranosus.  
White area at left is the tendon of origin 0, which continues  
as the aponeurosis Ao. Po₁, primary lamina of origin; I,  
tendon of insertion. The wires indicate the directions of  
the muscle fibers.

Fig. 111 Lateral aspect of the model of the semimembranosus. The  
wires indicate the directions of the muscle fibers. 0,  
tendon of origin; Ao, aponeurosis of origin; I, tendon  
of insertion; Pi₁, primary lamina of insertion.

Fig. 112 Medial aspect of the model of the semimembranosus. The  
wires indicate the directions of the muscle fibers. 0,  
tendon of origin; Ao, aponeurosis of origin; I, tendon of  
insertion; Ai, aponeurosis of insertion; Pi₁, primary  
lamina of insertion.