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MENINGEAL VESSELS

VARIATIONS: IN MAN AND APES

RELATION TO SKULL AND VENOUS SINUSES.

by

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INTRODUCTORY.

During the summer of last year (1921), I commenced the special study of the meningeal vessels, their variations and connections, in order to determine whether, the variations of the main vascular channels are constant in various types of skulls (with special reference to Scottish types), and if so, by the application of this knowledge, to offer suggestions to operating surgeons as to the most likely points at which to expose one or other of the divisions of the middle meningeal arteries in cases of haemorrhage.

In the earlier stages of the work I used plaster of Paris casts of the interior of skulls, but soon discovered, by means of orthogonal projections, I could get more useful information and at the same time more exact localisation of the main branches. I found that, although the actual branching of the meningeal vessels is subject to great variation in the main, the chief divisions do not differ as markedly in position and character as a superficial glance had led me to believe.

During my perusal of the literature I came across an article by V. Giuffrida-Ruggeri (Zeitschrift für Morphologie und Anthropologie, 1918, page 401 - 412) in which he describes a method of classification of the branches of the middle meningeal artery. With this as a guide, I made an attempt to classify the arterial branching with the material at my disposal.
The description of his types, however, are somewhat confused, and so I determined to make an attempt at a classification of my own, which, although it resembles the one by Giuffrida – Ruggeri in the general conception and the names of some of the branches, is not exactly the same and, to my mind, somewhat simplified.

During my investigations, I was struck by the relative importance of the parietal bone in regard to the distribution of the middle meningeal vessels, and, after collecting about 160 parietals and a large number of skulls, I was able to evolve a classification, which, I flatter myself, could be applied to any human skull, whatever the race. I have as far as possible, inserted photographs in the text illustrating the various types. These consist chiefly of parietal bones, as a photograph of a sectioned skull does not always afford a complete enough view, owing to the irregularities, such as, the projection of the sphenoid, petrous portion of the temporal bone, etc. With these I have also compared the branching in certain lower animal types ('Orang-Otang, Gorilla, Chimpanzee, and Baboon) with illustrative photographs.

In current text – books of descriptive and surgical anatomy, the distribution of the meningeal vessels is dismissed very briefly and additional literature on the subject is very limited. Several references, however, are made to the grooves on the cranial aspect of the bones of the skull. These
references are concerned with a description of the character and possible significance of the grooves, rather than with their position in a possible classification of vascular distribution.

The parietal bone receives special attention, reference being made more particularly to certain grooves, of which two sets are distinguishable in some skulls, namely: (1) a large groove in the anterior parietal region immediately behind the coronal suture, and, occasionally overlying it in parts; (2) some small deep grooves in the region of the vertex of the skull. These grooves differ very considerably from the ordinary meningeal grooves.

Various views are held as to the causative agent in the production of these grooves, but in my classification I have assumed that the ordinary grooves, whether produced by arteries or accompanying venous channels, correspond to arterial branches, whether these are directly in contact with the bone or not.

I was so much impressed by the variation in the extent and depth of the grooves and the relative frequency of the large anterior groove, as well as the smaller deep grooves described by Oscar Schultze (Zeitschrift f. Morphologie und Anthropologie, 1899, p. 451), that I have estimated the proportion of cases in which they occur. To illustrate some of the marked variations I have included photographs as I am convinced that no
written description on my part could take their place. Some of the photographs, to which I may refer under this section, may have been inserted as illustrative of types of arterial branching, and if so, I shall quote the numbers of figures. To make reference to figures more convenient, I have duplicated the set of photographs and shall hand them in under separate cover.

By means of macro- and micro-scoptic sections, and injection of the vascular channels (of the head and neck) of subjects of various ages, I was able to study the connections of the external, cerebral and meningeal venous channels. In addition, I was able to determine the relative positions of the main meningeal arterial branches to their accompanying venous channels. During these investigations, I discovered certain venous channels in the middle cranial fossa. One of these was mentioned by Dr. F. W. Jones (Journal of Anatomy and Physiology, 1912, p. 235) but no reference to it seems to have found its way into text—books published after that date. As it occurs frequently enough to warrant mention in larger text—books I submit a brief description, together with illustrative photographs.

Another venous channel, anastomotic in character and often consisting of more than one branch, is to be found in the region of the lesser wing of the sphenoid. I have not seen it described
elsewhere and as it establishes important connections, I have deemed it worthy of mention. Unfortunately, in this instance I have no photographic record, but only illustrative drawings made from actual cases.

While comparing the general thickness of the skull with the vascular grooves at various parts, my attention was drawn to the frequent occurrence of a large diploic venous channel in the middle parietal region. Best seen in thin skulls by transillumination, it resembles a venous lacuna in a great many cases, and receives connections from most, if not all, the main diploic veins. As such a constant diploic venous channel, often fairly extensive, may cause inconvenience at an operation, if opened into, I have in a few cases illustrated the position and extent topographically.

I have been very fortunate, owing to the kindness of Professor Arthur Robinson, in obtaining sufficient material, which included the bodies in the dissecting room during the winter session 1921—1922, some foetuses and one child of 2 1/2 years, as well as access to the Anatomical Museum of the University of Edinburgh. Owing to the kindness of Professor E. Smith and his staff in the Pathological Department, Royal Infirmary, Edinburgh, I have had excellent opportunities of examining the cranial contents, soon after death, in a large number of cases.

The material, as regards the lower animal skulls, was rather limited, but, in the case of
the human subject, by examining such a large number of specimens, I have been able, to a great extent, to eliminate fallacies due to individual variations.

Although, no special reference may be made to a certain number of figures, in the text, these all help to illustrate the numerous variations encountered and as they are of special interest I was loathe to omit them.
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for the study of the grooves found on the inner aspect of the bones of the skull, various methods were used.

I began with plaster of Paris casts of the cranial cavity. These supplied me with useful information regarding the general distribution of the grooves, in relationship to the original contents of the skull, and that, although, theoretically they should be of inestimable value, in practice they are apt to be misleading. The reason that casts are often disappointing is probably not far to seek. In the first place, they are extremely difficult to produce and to perfect them is almost impossible; secondly, the configuration may be such that a valuable part of the cast may remain behind when the cast itself is being removed—e.g., where there is a groove with overhanging edges such as is described in the text. Certain details are strikingly brought out by the casts, and very often, grooves unsuspected when the actual skull was examined, very clearly demonstrated as minute ridges.

The arachnoidal depressions and ordinary grooves, with everted edges, are very well shown on the casts as prominences and ridges respectively, and as such, give a very good idea of the original state of affairs.

I find that the casts show either too much, or else not enough, and, although, very instructive
and interesting as regards the main grooves in relation to different parts of the brain, and the anastomotic nature of the original contents of the grooves, the small differences are not as clear as one might expect. In some cases, the detail is so great that the discrimination between the grooves, depressions and sutures, as represented by the casts, is very difficult.

I have, therefore, only used casts supplementary to other methods. The examination of actual specimens I have found more advantageous, and by means of photographs, I have preserved a record of the various types observable. I have had to produce a considerable number of photographs, as variations are extremely numerous.

To estimate the characters of the grooves in more detail I have used ordinary, well-known methods. The depth and breadth I determined by means of a pair of calipers, of convenient size and type. In attempting to discover the relationship of the deeper grooves to the ordinary diploic venous channels, as well as, to the outer table of the skull, I have used fine saws and, have several times been well served by a file. By means of transillumination, very convenient in the presence of deep grooves or thin skulls, I obtained exceeding useful information, which no other method could have given.

In order to produce a record of the topography of the grooves or, in other words, of the meningeal vessels, my method of procedure was as follows:— (1) A sagittal tracing of the skull was
companying photograph illustrates the more important essential apparatus.

Reading from left to right, the photograph illustrates the following:—

(1) A form of levelling apparatus, which possesses two horizontal rods which move on a thicker vertical one and are arranged in such a way, that they may be approximated or separated in order to accommodate the skull or other specimens under consideration.

(2) A modification of the original Wetzel Perigraph.

(3) A second form of levelling apparatus is seen between the Perigraph and the centre of the picture.

(4) An anthropometric instrument modified from Wetzel's original. It consists of two vertical cylindrical pieces of metal, which can be fixed by means of clamps to a table, or some other rigid structure. These uprights are graduated in centimetres, and stretching between them there is a horizontal cylindrical bar. This latter tube is capable of being moved up or down, and clamped to the uprights at any desired level. Further, there is a device which can be moved along the horizontal bar and clamped when fixation is required. Fitting into this latter device, there are several
forms of clamps for fixing the specimen. Only one specimen at a time can be so fixed — in the photograph a half-skull is seen in the centre, correctly fixed and adjusted for the taking of a drawing of the cranial surface of that half of the skull. For clamping the various parts of the instrument, keys, in the form of rods, are used. These are seen attached to chains, which hang from a hook fixed to the left-hand upright (in this particular instrument).

(5) A larger type of Perigraph, also a modification of Wetzel's original, is seen standing on the marble slab near the edge, and in front of the right half of the last-named instrument.

The Perigraph

This is a very ingenious instrument and indispensable for this kind of work, and the latest modifications are a great improvement on the original invented by Wetzel. The types, used by me, are very well illustrated in the photograph.

They consist of a weighted foot-piece with two limbs projecting from it, the one vertical and the other horizontal. The vertical limb carries a ratchet-like device, which is brought into play by means
of a milled-headed screw. To this latter device is attached an arm of standard pattern, so that pointers of various shapes may be readily fixed, as they are in turn required for different specimens, or different parts of the same specimen.

These pointers are of various shapes, some curved and others angled. They possess certain characteristics; their actual points move round a fixed point, and, if the instrument is true, there should be no divergence from the fixed point, whether the rest of the particular pointer is in the vertical, the horizontal or any intermediate oblique plane; secondly, at their point of fixation to the projecting arm, they are capable of revolving so that the whole pointer, except the point, can occupy any plane. This latter arrangement is very convenient when the instrument is in use, and, in order, to fix the pointer in any particular plane, and to keep it fixed, the milled-headed screw, which helps to fix it to the projecting arm, has merely to be tightened.

In some types of Perigraphs, the vertical limb is graduated in centimetres and millimetres.

The horizontal limb projects from near the base of the foot-piece,
on the same side as the arm carrying the pointer. Fixed to the end away from the foot-piece, there is a device containing a vertical rod, controlled by a delicate spring, and ending below in a screw-thread. By means of this screw-thread, small conical pens, hollow for holding ink, can be fixed to the instrument. The device attached to the horizontal limb is of a delicate nature, and a very important part of the instrument. By means of certain sets of small screws and a ratchet-like arrangement, the point of the pen can be so adjusted as to be in the same vertical plane as the point of the pointer, in such a way, that a perpendicular dropped through the point (of the pointer) will pass through the centre of the conical pen, and meet the horizontal plane at right angles.

Before using the Perigraph the adjustment is an essential preliminary, as the accuracy of the drawings and subsequent measurements depends upon it entirely.

**SOFT PARTS**

The connections of the vascular channels on the inside of the skull with those on the external surface, as well as the relative position of meningeal arteries and veins to each other, were investi-
gated in various ways.

In the case of the Dissecting Room subjects, I trephined over the lateral sinus on both sides and blocked them with plasticine; next, I tied the internal jugular vein near the angle of the mandible, and, after trephining over the posterior end of the superior sagittal sinus, the latter was injected with blue starch solution.

The results obtained in these cases were, on the whole, highly satisfactory, but, that results, equally good and as instructed, could be obtained, by tying the innominate veins, and injecting the same fluid into the internal jugular veins. This latter method was adopted for the last series of subjects, which were dissected during the course of the Spring Term (1922).

This last-named method was also adopted for the injection of the venous channels in a child of 2½ years, and several foetuses at various stages of development.

In these cases, in addition, I injected the common carotid arteries with starch and red-lead preparation, which is commonly used for the injection of the arteries of Dissecting Room subjects.

The injections on all these subjects were not always easy to carry out, and a great deal of force had to be used in most of them. This was no doubt, due, to a great extent to the fact that they had been dead for weeks or even months, and, that the vascular channels either contained clotted blood, or were
collapsed and hardened by the formalin and other fluids used for the preservation of the body.

In the Post-Mortem Department of the Edinburgh Royal Infirmary, I had excellent opportunities of examining the soft parts soon after death. This was very much more satisfactory, as the vessels contained unclotted blood, which could be made to pass in various directions by means of gentle pressure, and, when the blood had escaped to too great an extent, a syringe, containing water, and introduced into one or other of the larger vascular channels, was a highly efficient method of demonstrating the connections and distribution of the cranial blood vessels. Further, I was able to obtain fresh portions of the meninges for the study of the structure and relative positions to each other of the arteries and veins, macroscopically, as well as microscopically.

Addendum

In describing the Perigraph and instruments required, I omitted to mention that a perfectly level surface is required in order to get the Perigraph to move smoothly; besides being level, the surface must be perfectly horizontal. A marble slab or plate of glass on adjustable screws supplies all requirements.

To fix the drawing paper, clips or weights are required. The latter are shown in the photograph.
About 10 years ago, as evidenced by the literature, there was stirred up a renewed interest in the anatomical arrangement of the blood vessels of the dura mater, and of the various types of grooves to be found on the cranial aspect of the skull.

The published studies were primarily devoted to the significance of the grooves, and the relationship of the venous channels accompanying the branches of the middle meningeal artery.

The meningeal grooves have been known for several centuries, but Dr. Oscar Schultzze (I.) appears to have been the first writer to refer to the different types of grooves described by older writers. In a short article, he mentions these types and gives an account, with illustrative photographs, of a set of small, deep-cut grooves in the region of the vertex of the skull. He regards these grooves, apparently first described by him, as being of venous origin, but regards the ordinary well-known meningeal grooves as being of arterial origin.

It was not until 1912, that Dr. F. Woolf Jones (2) in a very excellent article, combined the writings and ideas of various anatomists since 1615. He discusses the views held three centuries ago, shows how these have changed since that time, and endorses the oldest views, namely, that the
grooves on the inner surface of the skull are venous in origin.

In his own words: "not only was the venous origin of these grooves recognised 300 years ago, but, it appears that such an opinion was held for long, and, that little more than chance determined, and plagiarism stereotyped, the changed views that are held as orthodox today".

In support of his contention, he quotes extracts from the writing of various observers. In 1615, Helkiah Crooke, in his work "Micro-Cosmographia, a description of the Body of Man" (p. 713), leaves no doubt, that the generally accepted opinion in his day, was, that the grooves were impressed by veins. He talks of the "small bosomes, as also inscriptions like the path of a snail or emmet, for the vessels which run from the internal jugular through the thick membrane of the brain". In his pictures he depicts these vessels, and marks them as veins.

Thomas Bartholin, in 1673, referred to the "venarum impressiones" to be found on the inner aspect of the parietal bone.

Thomas Gibson, in 1697, in his work "The anatomy of Humane Bodies Epitomized", is also very definite about the venous origin of the grooves.

It appears, that by 1700, or soon after, the views had changed and anatomists began to teach that the grooves were produced by arteries. Just
before this time, (1682-84), the work of Thomas Willis became generally known and accepted. In his collected works (Vol. 1, p. 64), he refers to the arteries producing the grooves by their pulsation, while the bone of the skull are soft.

Dr. Wood Jones ascribes this change in the views after 1700, to the great influence of the teachings of Thomas Willis on anatomists of his day, and, for nearly two centuries after he died, his views were handed on and accepted as gospel.

In 1703, James Keill, in his work, entitled "Anatomy of the Humane Body Abrig'd," appears to be the first writer to have endorsed the opinions of Willis.

Between that time and the latter end of the 19th. century, there appeared no writings which questioned the accuracy of the views held for so long. Trolard was apparently the first to disagree, and, although he received very little support in his views, was followed by Professor Charpy, who gives a good account of the meningeal veins in "Traite d'Anatomie Humaine" (Poirier and Charpy Vol. 11, part 3, p. 931). Poirier himself, also, calls attention to a large groove immediately behind the coronal suture, and which often tunnels the pterion and ends in the groove for the sphenoparietal sinus. Before this time, in 1891, Breschet had described this groove, and from his work "Topographie crano-encephalique" Poirier has copied his illustration.
In 1899, Professor Oscar Schultze published his article already referred to.

In 1905, Professor Elliot Smith recorded a case (3) of a Turk, whose skull showed certain abnormally developed grooves, which he regards as being of venous origin. In another paper on the crania of modern people from Syria, Asia Minor, and the Balkan peninsula, he mentions "the extraordinary frequency with which one finds an exceptionally large middle meningeal vein deeply grooving the parietal bone parallel to the coronary suture from the tip of the lesser wing of the sphenoid to a point just behind the bregma, where very large, deep fossae are often found in the bone lodging great cauliflower-like masses of pachionian bodies" (4). The ordinary meningeal grooves, are apparently regarded as arterial in origin by him, as he expresses no definite opinion to the contrary.

Dr. Wood Jones, from whose article I borrowed the above historical outline, then proceeds to justify his opinion still further, by giving a detailed account of his methods of investigation and reasons for the conclusions arrived at. His investigations were chiefly concerned with the relative positions of the meningeal arteries and their accompanying venous channels. Towards the end of this paper, he suggested, in a tentative way, that in some cases of middle meningeal haemorrhage the vascular lesion could quite possibly be venous, and not arterial, as
was, and by a great many surgeons still is, believed to be the case.

In a paper (5), published some months later, he recorded some cases of middle meningeal haemorrhage, in which no arterial lesion could be found; and, as a result, expressed the view that if examined carefully, most cases of so called arterial haemorrhage would turn out to be venous. This apparently unorthodox statement caused a great deal of controversy at the time; and, judging from the later surgical textbooks, his opinions have not found much favour.

Since that time, Bernard Coen published an article (6), in which, he describes certain grooves on the inner aspect of the parietal bone, and regards them as being of diploic venous origin.

The meningeal arteries also, have been known and described for a very long time. Guiffrida-Ruggeri, who believes that the grooves are produced by the arteries, was the first to name the branches of the anterior and posterior divisions of the middle meningeal artery and to classify them. He also compares the grooving of certain types of monkey skulls with the human.

In the classification which I have evolved, I borrowed some of the names of branches labelled by him. Further, I made mention of the general arrangement of the grooves found in the Gorilla, Chimpanzee, Baboon, etc.

The general topographical arrangement of the
two terminal divisions of the middle meningeal artery has been known for a very long time, and several methods of localisation are recommended in various text books of applied anatomy.

As the posterior division is by far the more difficult one to localise exactly, I have studied the variations and estimated the proportions of such variations, with a view to suggesting a point at which the removal of a trephine-circle of bone is most likely to expose the artery.
The vascular grooves of interest, other than those for the well-known venous sinuses of the dura mater, found on the inner aspect of the skull, and best seen on the parietal bone, are divisible into three types:

(1) The "ordinary" meningeal grooves.

(2) The large groove in the anterior parietal region behind the coronal suture, and, in a few cases, overlying the suture in parts.

(3) Smaller, scattered deep grooves well seen near the vertex of the skull.

The "ordinary" meningeal grooves may be the only ones present in a particular skull, or, in addition, one or both the others may be present.

The "ordinary" meningeal grooves

These grooves, although faint in young and occasional adult skulls, are usually distinct. They differ very considerably in arrangement and character.

On the whole, they are shallow, with smooth everted edges, except at certain parts, where the inner table of the skull has tried to convert them into tunnels. In most human adult skulls, this tunnelling is well seen in the pterion region, where
there may be an actual bony canal, varying from a small bridge of bone stretching across the groove, to a tunnel several centimetres in length. In other cases the canalisation is incomplete, and the grooves merely present overhanging edges.

A complete canal, in the pterion region, was found present in the following percentage of cases examined:

<table>
<thead>
<tr>
<th>On both sides</th>
<th>Right side only</th>
<th>Left side only</th>
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<tr>
<td>48.8%</td>
<td>14%</td>
<td>29%</td>
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absent on both sides

8.2%

The specimens examined numbered nearly 200, and comprised skulls of several races.

The process of canalisation may go on to involve other grooves. These cases are rare, and I have only seen one case, in which the groove for the posterior terminal division of the middle meningeal artery and its accompanying venous channel, showed a distinct bony canal. This canal was 4 m.m. in length, and situated on the suture between the squamous temporal and the parietal bone, at the junction of the posterior third with the anterior two-thirds of the lower border of the parietal bone.

Figure 47 shows one of the terminal branches of the anterior division of the middle meningeal artery, in a distinct bony canal, for a short distance.
On examining the grooves in the average skull, it will be apparent that some, at least, if not most, of them, do not become narrower as they are traced towards the vertex of the skull. They may even appear to become broader ("like the path of a snail or emmet") and end near the vertex in large pacchionian depressions; the lateral lacunae; the superior sagittal sinus.

In rare instances, do the grooves resemble the branching of a tree (see fig. 33), and almost as rarely, do they have a tortuous course, strikingly suggestive of arterial branching (see fig. 49). Even in these cases, some of the grooves are seen to remain of the same size, or even to broaden out, as they approach their destinations.

Dr. Wood Jones (2), calls attention to the comparison of the distal ends of the grooves and the bore of the foramen spinosum. Referring to the disproportion, he says, "one is instantly struck by the apparent impossibility of an arterial trunk, which could pass through so small a hole, dividing into terminal branches which could produce such wide grooves upon the bone"; and further, that "the bore of most of the distal ramifications is much greater in all skulls than is the bore of the foramen spinosum!"

This disproportion is evident in the majority of skulls, certainly, but judging from the specimens which I have examined, I regard his statements as
rather too sweeping in character. In a fair number of cases, the disproportion is not nearly as obvious as he might lead one to believe, and reference to figs. 4, 47, and 50, will help to bear out my contention.

The anterior meningeal grooves, and occasionally those in the posterior cranial fossa, resemble arterial branching far more closely, and with much greater frequency, than the ordinary grooves for the middle meningeal vessels.

The general arrangement of the "ordinary" meningeal grooves, depends entirely on the type of vascular branching to which the specimen belongs—("Types of Arterial Branching," later). Briefly, some of the grooves, which diverge from the groove, which lodges the anterior terminal division of the middle meningeal artery and accompanying venous channel, may be distinct in the floor of the middle cranial fossa, or only when the pterion region is reached. In the latter case, they will be seen to radiate out from the sphenoidal angle of the parietal bone, or, in those cases, in which the main groove runs diagonally across the parietal bone, the smaller grooves proceed from it at various points.

Much the same sort of arrangement holds for the groove ascribed to the posterior middle meningeal vessels. Smaller grooves may converge on, or diverge from it, as it lies in the floor of the middle cranial fossa, or, soon after it reaches the parietal bone.
In a certain number of cases, the posterior meningeal groove appears to be absent, due, in reality, to the fact that the so-called posterior middle meningeal vessels only become differentiated after the sphenoidal angle of the parietal bone is reached. If a groove is present in the floor of the middle cranial fossa, it can usually be traced as far as the asterion region only, or a variable distance on to the occipital bone beyond.

In the ordinary state of affairs, if the grooves on the parietal bone are traced towards the vertex, they end, as we have already seen, in the groove for the superior sagittal sinus, pacchionian depressions, lateral lacunae, and in addition, some of them can be traced to scattered foramina near the vertex of the skull for the transmission of emissary veins. A fairly constant groove is found radiating from the posterior meningeal groove, and running towards the parietal foramen. In some cases, where the posterior meningeal groove is small, or does not reach as far as the foramen, a groove can be traced from the latter foramen to the anterior middle meningeal groove, directly or indirectly, through one of its branches.

It may be of interest to note, that I found the parietal foramen present in 80% of cases classified; of these, the foramen was well marked, in some having a diameter of 2 m.m., in 43%, and in the other 57% of cases one could merely say that the foramen
was present.

On tracing the large grooves towards the floor of the middle fossa, it will be found, that, by no means in all cases, do they converge on the foramen spinosum. Some of them appear to run towards the impressions of the well-known venous sinuses. The anterior meningeal groove may seem to disappear beneath the lesser wing of the sphenoid, or become definitely continuous with the sphenoparietal sinus, sometimes joining a temporal diploic vein as it does so (7). According to Dr. Wood Jones (2), at times this anterior division bends backwards as it passes the pterion, and then it usually appears to run towards the fore part of the foramen ovale.

In the same article, when referring to casts of the interior of the skull, he mentions that at the bottom of some of the meningeal grooves, represented by ridges on the casts, a minute, and often zigzag beading marks the arterial branches, and that sometimes a small groove of obvious arterial origin is seen next the "ordinary grooves" already described. He states also that these are by no means constant, and I must admit, that, although I have looked very carefully for the presence of these, I have been successful in a few cases only.
The large groove in the anterior parietal region.

I use the term "large" in this type of groove, because, when it is distinctly present, it is very large, in comparison to the "ordinary" meningeal grooves.

This groove is found more or less parallel to the coronal suture, but occasionally overlies it in some part of its course, and according to Coen, it may be the only groove to be seen on that side.

It may be a separate groove, from the region of the bregma down to the pterion, and disappear into the sphenoparietal sinus at the lateral extremity of the lesser wing of the sphenoid; or, it may be separate from the bregma down to the pterion region, where it may be found to join a large groove (or tunnel, if present) common to it, and the groove for the anterior middle meningeal vessels.

In a large proportion of cases, there is only a suggestion of this groove, which appears to be merely the continuation towards the bregma of the groove for the anterior middle meningeal vessels, or one or other of their terminal branches. In some cases, the two seem to be fused, and the grooves for the terminal branches of the anterior middle meningeal vessels diverge from it at various levels; in others, a ridge in the floor of the common groove shows the line of fusion; and yet, in others, there is imperfect
fusion, so that the two may be quite distinct in certain parts of their courses. Reference to certain figures will illustrate these variations very clearly: Figs. 2, 3, 6, 7 to 15, 17, 18, 19 to 24, etc. Fig. 65, shows three distinct grooves for a distance equal to about half the length of the anterior border of the parietal bone. Compare with Fig. 24.

When the anterior groove is obviously present, and of large size, a fairly common arrangement is to have the anterior middle meningeal groove a short distance behind the larger groove, and quite distinct from it, except possibly in the pterion region, where they may be confluent.

In character, this groove varies very considerably in different skulls, individually, probably as well as racially.

The size is very variable, and may rank with the impressions produced by the ordinarily recognised venous sinuses (Dr. Wood Jones) down to the size of one or other of the middle meningeal grooves. They are usually gutter-like, and although they may show smooth everted edges, are most commonly seen with overhanging edges. The edges of the groove are in some places only about 2 m. m. apart, where as, the lateral walls are 5 to 6 mm. apart (Coen).

Figs. 2, 3, 19, 31 illustrate cases of this type in a striking manner.

The actual depth varies with the thickness of the skull, although the relative depth may be greater in thin skulls. Often the floor of the groove is
represented only by the outer table, which, is often extremely thin — a fraction of a millimetre — and readily transmits light.

Traced towards the vertex of the skull, the groove may seem to divide into two; but, whether single or double, it will be seen to end in the impression for the superior sagittal sinus, a lateral lacuna, or a cluster of pachionian bodies, thus resembling very closely the terminations of some of the "ordinary" meningeal grooves.

At, or near its termination, in the region of the vertex, or anywhere along its course, this groove may have foramina opening into it. These foramina only pierce the inner table, and suggest the paths by means of which some of the diploic veins have reached the inner surface of the cranium.

In a few cases, the large groove is comparatively small over the upper half of the parietal bone, and, as it runs downwards, it is joined by an apparently obvious diploic venous groove, after which the original groove may be considerably larger. Figs. 9, 10, and 13.

These foramina are by no means limited to the large anterior groove. They may appear anywhere, the most constant ones being found along the impression for the superior sagittal, or, in fact, any other sinus, along the impressions for the lateral lacunae and pachionian bodies, and the grooves
which lodge the middle meningeal vessels, or any of their branches. They are often very numerous, and there is no doubt, that through them run connecting branches between the diploic and meningeal vessels. Figs. 13, and 14., illustrate these foramina very well. Fig. 13 is very interesting in this particular connection.

As mentioned before, several observers have noted the presence of a large groove immediately behind the coronal suture, but they are not all agreed on the possible significance.

Professor Elliot Smith has described it in a Turk, and later stated that he found it "with extraordinary frequency" in the crania of modern people, from Syria, Asia Minor, and the Balkan Peninsula.

Poirier and Charpey have also described this groove.

Dr. Wood Jones, in 1912, also referred to the presence of this groove, and, in full agreement with the other writers above referred to, regards it as "merely an exaggeration of what is normal in the ordinary English subject".

Shortly after this, Bernard Coen published an article, in which he refers to a few very interesting cases of this description. He quotes the opinions of the other observers merely to disagree. He believes that the gutter-like groove, in some cases at any rate, is due to "diploic venous tissue which has come to
the surface by the erosion of the inner table of the skull, and that "it is possible that, when there is only one gutter-like groove present, the meningeal and diploic vessels may be contained in the same groove", and not to the ordinary meningeal vessels.

In most of the cases, which I have examined, the evidence has been rather opposed to Coen. Only in two fresh cases (Post Mortem Room) and six dried specimens, have I found characters which substantiate Coen's argument. In one case in particular, there was very little doubt about the matter.

The presence of a sinus connecting the superior sagittal and sphenoparietal sinuses, first described by Breschet in 1891, I have found to be far more common than is generally supposed. A very common arrangement appears to be, the presence of this connecting sinus, and the venous channel accompanying the anterior middle meningeal artery, or one of its branches, in the anterior parietal region, running side by side from the vertex, down to the pterion region. At this point, they may occupy a common groove, or else a tunnel, at the lower part of which, the sinus enters the sphenoparietal sinus, and the other one bending posteriorly and medially towards the foramen spinosum, or in some cases the foramen ovale. In other cases, the two appear to be fused, and it is only near the tip of the lesser wing of the sphenoid, that the apparent double nature of the channel is seen.
All the writers, whose writings I have consulted, regard the large anterior groove as of rare occurrence in ordinary British crania. With this I disagree, as I have found it present in 23 out of a series of 44 bodies examined. In 7 of these, the groove was almost identical with the one illustrated in Fig. 15. In 2 out of the remaining 16 cases, the groove showed a double character, and was on the whole, better developed. In the remaining 14, the groove appeared to be merely an exaggeration of the groove for the anterior middle meningeal vessels, except that the latter could be definitely seen as a distinct groove about 2mm. posterior, and only confluent in the pterion region.

Of nearly 200 dried specimens, 106 showed an "abnormally" well-developed groove in the anterior parietal region. Of these, 65 appeared to be merely an exaggeration of the existing anterior middle meningeal groove, as the dimensions in the lower anterior parietal region or the floor of the middle cranial fossa seem to remain unchanged. In 16, the groove showed a double nature, with a ridge between them — this ridge was not always easy to distinguish along the whole course. In 25 of the specimens, there was no doubt about the presence of a large groove in front of the anterior middle meningeal groove, and quite distinct from it — in fact, in five cases, the direction of the groove did not follow a course
parallel to the coronal suture, but diverged, and in parts could be seen overlying the suture. This is well illustrated in Figs. 7, 14, 48.

Small, scattered deep grooves near the vertex.

In 1889, Oscar Schultze (1) called attention to small deep grooves, which, he regards as being of diploic venous origin, comparatively rare, as usually only to be found near the vertex.

In appearance, the grooves are rather suggestive of the branching of a tree, with the stem pointing towards, and often reaching, the impressions of one or other of the ordinary well-known venous sinuses of the dura mater. They are deep, well-cut, and appear to be connected with the region of the diploë.

I have found them present in about a third of the specimens examined, and, always in adult skulls. They are certainly not limited to the region of the vertex of the skull, but, seem to occur almost anywhere on the cranial surface of the skull. They are quite distinct from the other types of meningeal grooves, and can be seen crossing these in various regions.

I have not had many opportunities of examining these grooves and their contents in fresh cases, but, their characters and position are very suggestive of diploic venous tissue having produced them, by the
erosion of the inner table. Whatever their significance, they are chiefly of academic interest.

Types of these grooves are very well shown in Figs. 34, 35, 36, 41, 43, 53, 56, etc.

Relation of the meningeal grooves to Fracture.

With this question, the "ordinary" meningeal grooves, and the large groove in the anterior parietal region, are the chief ones concerned.

The large anterior groove deserves chief mention, as it is often separated from the outer surface of the skull merely by a very thin plate of bone, although the rest of the skull in the region may be three or four times as thick as the thin plate of bone. In fact, a mere glance at some of these skulls is enough to make one marvel at the fact, that the person had never sustained a fractured skull during life.

There is no doubt, that the presence of this groove, if at all well-marked, produces a distinct weakness in the cranial vault. A few cases, of actual fracture through this groove, are quoted: one, by Professor Elliot Smith (3.), one by Dr. Wood Jones (2) and one by Coen (6.). So far, I have not seen such cases, except for two cases in the dissecting room, where I fractured one skull-cap in
trying to remove it from a very adherent dura mater, and the other one by dropping it on to the wooden floor. On examination of the fragments, I found the line of fracture to have passed through the large groove immediately behind the coronal suture, and on trying to break up the fragments further (by means of the hands) I was successful only in one case, after the application of considerable force. The amount of force necessary to break up the fragments was the same in both cases, and I concluded that the abnormal fragility of the bone of the skull concerned.

The lateral sinus

The lateral sinus varies topographically, to a certain extent, in different human skulls, and very considerably in certain animal types. The orthogonal projections show up these variations and add interest to them. (See Notes).

It may be of interest to note the usual direction taken by the superior sagittal sinus. In Scottish crania, it turned to the right to form the right lateral sinus in 60% of cases; to form the left in 16%; and were equal, that is, the two lateral sinuses seem to get an equal share from the superior sagittal, in 24% of cases classified.
Comparison of grooves in certain Animal Types.

The material for this part was rather limited, I can only mention the more striking peculiarities and differences, from the human, as suggested by the few specimens at my disposal.

GORILLA

The grooving of the skull is rather interesting. From the pterion region, grooves, corresponding very closely to certain human types, radiate out, and proceed more or less backwards and upwards for the supply of the parietal region. Some of these grooves have a sort of parallel arrangement, very like the grooving in Scaphocephalic human skulls.

The point at which these various grooves begin to diverge, in the pterion region, is easy to determine, but to trace the parent groove towards its origin, is not nearly as easy. It appears to bend forwards, and to disappear through a foramen, which connects it with the orbital fossa. Only a small groove seems to connect it with the region of the foramen spinosum. What the explanation of this arrangement is, I should very much like to find out, and I hope at some future date to satisfy myself regarding it. It may
be, that the small groove lodges the anterior middle meningeal vessels, which are smaller than the human, and that a vein of considerable size lies in the wide groove, and is connected with the sphenoparietal sinus medially, and the orbital veins anteriorly. The posterior middle meningeal groove is small, runs along the petrous temporal, and seems to end, by bending sharply backwards, in the lateral sinus.

A very striking feature, is the presence of a large groove, apparently venous in origin, which runs from the large groove, in the pterion region, backwards towards the lateral sinus, and in the posterior half of its course, apparently accompanies the groove for the posterior middle meningeal vessels, and ends in the lateral sinus.

See Fig. 25 and Plate X1.

On the whole, the grooving is not as well marked as the average human type, but one specimen of a young Orang skull showed the grooves remarkably well-developed.

Fig. 26, was prepared to show this, but unfortunately there was not enough contrast to show it very well — Museum No. Or. 64.3. The branching is rather like the human, except that there are fewer branches, and the
ANUBIS BABOON (Cynocephalus Anubis).

In this case also, the two middle meningeal grooves diverge early. The posterior groove runs along the petrous temporal, and, when it reaches the parietal bone in the region of the posterior inferior angle, it curves forwards and takes quite a considerable part in the supply of the parietal region. The anterior branching resembles some types of human branching, but that of the posterior is quite different, and in fact, differs from all the other animal types which I have described, except, as regards the early branching of the posterior division.

Another interesting feature, is the presence of a relatively large groove, which ascends from the posterior cranial fossa, gives off a branch to the obelic region, and several smaller branches, which communicate with grooves branching off from the anterior and posterior middle meningeal grooves, about the middle of the parietal bone.

See Plate XV.
posterior middle meningeal vessels and their branches are rather more important for the supply of the parietal region than the average human type; also, the grooves for the anterior and posterior middle meningeal vessels diverge very soon.

I examined three specimens, and all of them showed the above features to a greater or lesser extent; in addition, they all showed distinct grooving in the floor of the posterior cranial fossa. Two of them showed the presence of the large groove in the middle cranial fossa, namely, the one mentioned in connection with the orang, as running from the pterion region towards the bend of the lateral sinus.

See Figs. 26 and 29, and Plate X///.

CHIMPANZEE

Here again, the branching of the middle meningeal groove takes place early, and the posterior groove runs along the petrous temporal, and then winds upwards over the posterior part of the parietal bone. Judging from the grooving, the posterior middle meningeal vessels are less developed than the anterior. Guiffrida-Ruggeri (8) has noted something similar.

See Fig. 27. and Plate X///.
These three casts show the shape of the original contents of the cranial cavity, the grooves (shown as ridges) and pacchionian bodies (shown as projections near vertex). The anastomotic nature of the branching is well seen, especially in the first one. In the 2nd, the lateral sinus is also painted in and shows up as a lighter area.
The meningeal arteries are derived from a great variety of sources, and according to current text-book teaching may be generally classified as follows:

1. Anterior meningeal,
2. Middle meningeal,
3. Accessory meningeal, and
4. Additional meningeal arteries.

I shall deal with the less important ones in the first instance.

The anterior meningeal artery

accompanies the anterior ethmoidal nerve across the cribiform plate of the ethmoid, and supplies a limited amount of the dura mater and bone in the anterior cranial fossa.

In a very few cases have I found it of fair size, and supplying the greater part of the floor of the anterior fossa and the inner aspect of the frontal bone. More commonly, the frontal region receives its chief arterial supply from the middle meningeal artery (see later). An anastomosis can usually be made out between the anterior meningeal arteries of the two sides, and, in addition, with "frontal" branches of the anterior division of the middle meningeal artery.
Accessory meningeal arteries.

These are inconstant, and often of small size. They arise either directly from the internal maxillary artery, or from the middle meningeal artery. The accessory middle meningeal artery, if present, enters the middle cranial fossa through the foramen ovale, supplies the semilunar ganglion, and the dura mater in the region, and terminates by anastomosing with branches of the middle meningeal and internal carotid artery.

Dr. A. W. Meyer, in his article "Spolia Anatomica" (Journal of Anatomy and Phys. 1913-14, Vol. IX, p. 143), describes a unilateral accessory aberrant meningeal artery arising from the occipital. The above artery, according to him, arose from the left occipital in the retro-mastoid region, was approximately 3 m.m. in diameter, and pierced the occipital bone obliquely in the middle of the medial nuchal line, 1 cm. dorsal to the dorsal margin of the foramen magnum. It reached the dura mater at the dorsal, upper and inner margin of the latter, and could be traced upwards along the internal occipital protuberance as far as the lambdoid suture. There was only an incomplete sulcus internally to accommodate it, and nothing else noteworthy about the rest of the meningeal arteries.

Additional meningeal arteries.

Usually of the nature of terminal twigs, these arteries are derived from (a) ascending pharyngeal, (b) occipital, and (c) vertebral arteries.
(a) Terminal twigs of the ascending pharyngeal artery enter the cranial cavity through foramen lacerum, jugular foramen and through the hypoglossal canal, and supply a limited area. The branch entering through the jugular foramen is usually the largest.

(b) Occipital branches, chiefly anastomotic in character, enter through the jugular, mastoid and parietal foramina. Anomalies, such as the one described by Dr. Meyer, are apparently of rare occurrence as I have not seen any described in other literature having a bearing on this subject, nor have I been able to discover any in all the cases which I have investigated.

(c) Meningeal branches from the vertebral artery appear through the foramen magnum and, although, frequently of fair size, rarely do they groove the floor of the posterior cranial fossa to any great extent. An anastomosis can sometimes be made out between these and terminal twigs of the posterior division of the middle meningeal artery. In addition, small meningeal branches of the occipital artery may sometimes be seen entering the posterior cranial fossa through small foramina scattered over the occipital bone and especially near the base of the skull. These in favourable cases may be seen to take part in an anastomosis between twigs from the vertebral and posterior meningeal arteries.
Peculiar types of branching.
The middle meningeal artery

The largest branch of the internal maxillary artery, arises at the lower border of the external pterygoid muscle, runs up between it and the sphenomandibular ligament, lateral to the tensor tympani, between the roots of the auriculo-temporal nerve, and behind the mandibular nerve, entering the middle cranial fossa through the foramen spinosum, and, after a variable course, breaks up into anterior and posterior terminal divisions.

The length of the common trunk and the exact point of bifurcation are subject to great variation. These are variously stated in the larger text books of descriptive and surgical anatomy. Cunningham(9) gives the length as 1.5 inches and the point of division as the great wing of the sphenoid. Poirier(10) gives the length as 2–4 cms. In Gray's anatomy(11) the point of division is given as the great wing of the sphenoid.

I have found the length of the main trunk varying considerably, the extremes being 6 cms. and 0.1 cm. and the average, estimated after examining about 60 skulls, about 3.5 cms. The point of bifurcation, although apparently unorthodox, I have found in the vast majority of cases to be the squamous portion of the temporal bone.

It may be stated in general terms that the direction of the middle meningeal artery, after its emergence.
through the foramen spinosum, determines to a great extent, the point at which, the two terminal divisions become individualized. As a general rule, when the main trunk runs laterally, or postero-laterally, across the temporo-sphenoidal suture, the point of bifurcation is on the squamous temporal; where as, if the initial direction is forwards and laterally, or directly forwards, the artery breaks up on the great wing of the sphenoid, or, as is fairly commonly the case, on the temporo-sphenoidal suture in the vicinity of the pterion.

Branches of the middle meningeal artery.

The following are the named branches:

(i) Ganglionic — small branches which supply the semilunar ganglion and the roots of the trigeminal nerve.

(ii) Superficial petrosal — a small branch arising near the foramen spinosum, after passing through the hiatus facialis canalis, anastomosing with the stylo-mastoid branch of the post. auricular artery. On its way it gives off twigs to the facial nerve and tympanic cavity.

(iii) Superior tympanic — a tiny branch which runs in the semicanal for the tensor tympani, and supplies this muscle and the lining membrane of the canal.
(iv) Orbital.--- One or more branches, anastomotic in character, pass through the superior orbital fissure into the orbit and communicate with the lacrimal or other branches of the ophthalmic artery. Very frequently an additional branch is distinguishable, coming off the anterior terminal branch of the middle meningeal and passing through a small canal immediately below the anterior and upper margin of the great wing of the sphenoid.

(v) Temporal.--- Minute branches which pass through foramina in the great wing of the sphenoid, and anastomose with the deep temporal arteries in the temporal fossa.

(vi) Anterior terminal division (or branch).--- Usually, although not invariably, the larger of the two terminal branches, passes upwards along the great wing of the sphenoid to the sphenoidal angle of the parietal bone, where it is sometimes enclosed in a distinct bony canal. From there, it is continued upwards a short distance behind the anterior border of the parietal bone, or upwards and posteriorly, giving off branches to
supply the anterior cranial fossa, the whole or part of the parietal region and sometimes the posterior cranial fossa.

(vii) Posterior terminal division (or branch).—  
Passes along the squamous part of the temporal bone, usually ascending to the parietal bone, and giving off branches, if it has not already done so, for the supply of part of the parietal region and posterior cranial fossa.

This is the average textbook description of these important terminal branches. This is not nearly sufficient, if a more detailed description of the course and distribution is required. The importance and relative size, as also the exact point at which they become individualized, vary very considerably in various skulls; in fact, quite commonly, the two sides differ widely from each other.

From these terminal divisions, a large number of branches are sooner or later distinguishable, and so constantly are they present in well-marked cases, that they deserve mention in a treatise, if not a textbook, on the subject.

Guiffrida-Ruggeri (8), was the first to name some of these and from him I have borrowed certain of the names.

The following branches are distinguishable in most cases:—

1. frontal
prefregmatic, bregmatic, post-bregmatic, middle parietal, pre-obelic, obelic, lambda tic, occipital, asteric.

This is rather detailed, but as the anterior and posterior terminal divisions of the middle meningeal artery, not infrequently, give off some, if not most, of their branches before they reach the parietal bone, it would be rather difficult to distinguish the original terminal branches on the parietal bone.

Frontal.— These branches, usually numerous, may come off individually, or from a common trunk, which arises either from the anterior terminal division of the middle meningeal artery in the pterion region, or from the bregmatic branch. As a rule, they are of small size, and their direction anteriorly across the coronal suture on to the cranial surface of the frontal bone, supplying it and anastomosing with the anterior meningeal arteries.
Pre-bregmatic. — Usually a branch of the bregmatic and may not appear distinct until a point very near the bregma is reached. It supplies a very limited area, immediately anterior to the coronal suture near the bregma, and communicates with the frontal and bregmatic branches.

Bregmatic branch. — Is the name given by Guiffrida-Ruggeri to the anterior terminal division of the middle meningeal artery. I prefer to regard this branch as distinctive and not synonymous with the anterior division. It varies considerably in size and relative importance. Where it appears to be the direct continuation of the anterior terminal division, it may be, and usually is, of large size. In the latter case, it may give off practically all the branches named in this classification. In some cases, it is distinct in the pterion region, running upwards a short distance behind the coronal suture, towards the bregma, giving off frontal, pre-bregmatic and not frequently one or more post-bregmatic branches. In a few cases, a bregmatic branch (or branches) is only seen
near the vertex of the skull, and coming off the post-bregmatic branch.

Post-bregmatic. — Usually a branch of the former one, and may not be distinct until a point a short distance from the vertex is reached. In a few cases, it comes off the anterior division in the middle cranial fossa before the parietal bone is reached, and is then usually of some importance, giving off the bregmatic (rarely), the middle parietal, pre-obelic, and even the obelic and lambdatic branches.

Mid-parietal. — In those cases in which the anterior and posterior branches are distinctive, this branch may come off either, or, as is more commonly the case, may arise as a common trunk with the pre-bregmatic, the pre-obelic, or even from a common trunk embodying itself, the pre-obelic, the obelic and lambdatic branches.

Pre-obelic. — A branch, originally contained in either the anterior or posterior division, may arise from a trunk common to one or more of the following: post-bregmatic, middle parietal, obelic or obelic-lambdatic
branches. It ramifies in the pre-obelic region.

Obelic.— A branch, similar in origin to the last, but commonly only associated with the lambdatic or the pre-obelic branch, and often not distinct until near its destination. It supplies the obelic region, where it anastomoses with the branch of the occipital artery, which enters the cranial cavity through the parietal foramen.

Lambdatic.— Guiffrida-Ruggeri calls the posterior division of the middle meningeal artery the "obelic-lambdatic branch," but, as the posterior division does not invariably give off a branch for the supply of the obelic region, I prefer to take these branches separately. In the majority of cases, no doubt, the posterior division is responsible for this branch, and, as a general rule, this depends on the relative size and importance of the posterior division. In some cases, the anterior division is the all-important one with all the aforementioned branches proceeding from it, and the posterior division rudimentary, or at any rate, of very little importance for the supply of the parietal region.
Occipital.— These are usually numerous, and they proceed as terminal twigs from either the anterior or the posterior division or from both. More commonly, however, the posterior division or one of its branches (the lambdatic), ends in the occipital region supplying it, and anastomosing with the ordinary meningeal arteries of the posterior cranial fossa.

Asteric.— A branch only of interest, because the posterior division, in those cases in which it is small, may end as the asteric, without taking any further part in the supply of the parietal region. More commonly, it proceeds from one of the occipital branches, as the latter are on their way to the posterior fossa, or, from the lambdatic branch just before, or just after, the latter reaches the parietal bone.

These ("named") branches may not be easily distinguishable until near their respective destinations, and even then, they may consist of twigs for the supply of the particular region. In the majority of cases, however, most, if not all of them, can be distinguished as individual branches for a short distance. It is not uncommon for some of the branches to appear distinct near the lower border of the parietal, and to continue on as such to their respective destinations.
A very free anastomosis exists between the various branches of the middle meningeal artery and those of its terminal divisions. In well marked cases, even in dry skulls, the grooves suggest a free anastomosis, and, I think Guiffria—Ruggeri is rather too apologetic where he refers to the suggestive appearances of the grooves. In fresh specimens, I have found that the ordinary meningeal grooves, in nearly every case, lodge an artery in addition to a venous channel whether the former happens to be in contact with bone or not; and therefore, I consider myself justified in interpreting similar grooves, found in dried specimens, in the same light. In some skulls, the appearance of the grooves is very striking—see figs. 1, 3, 16, 30, 31, 33, 39, 43 etc. +Plates; in others, the anastomotic nature is not so obvious, and, it is in these cases, that plaster of Paris casts of the interior of the skull, often call attention to small communicating branches, which were unsuspected when the skull only was examined. In fresh cases, the free inter-communication can be easily demonstrated by the injection of fluid into one of the main arterial branches, such as, the external carotid artery. I have done this, in the Post-Mortem room, in a large number of cases and I am satisfied that the inosculatio is free and very definite. The various branches of the middle meningeal artery anastomose also with the corresponding ones on the
opposite side, with branches of the anterior meningeal arteries, and those in the posterior cranial fossa. In other words, branches of the middle meningeal artery anastomose with the occipital, ascending pharyngeal, lacrimal and ophthalmic arteries; further, with the stylo-mastoid branch of the posterior auricular, through the substance of the temporal bone, with the accessory meningeal artery, and branches of the deep temporal arteries.
CLASSIFICATION OF TYPES OF ARTERIAL BRANCHING.

I attempted to make use of the classification suggested by Guiffrida-Ruggeri (8), but as I found his types rather confused, I decided on the following:

GROUP A.— In this group, the anterior division, or branch, reaches the parietal bone in the region of the pterion, and breaks up into branches for the supply of the parietal region, and, to a greater or less extent, the frontal and occipital region. The posterior division, in these cases, being small and negligible, as regards the supply of the parietal region—usually just supplying the asterion region—or, if large, running towards the posterior cranial fossa in the form of occipital branches.

To this group also belong those types in which no posterior division appears to be present, the anterior division seeming to be the parent trunk for those branches classified as terminal branches of the two terminal divisions of the middle meningeal artery. In reality, this latter appearance is due to the fact that the posterior division, only becomes individualized after the
parietal bone is reached, thus suggesting the absence of the posterior division.

19.8% of the specimens classified belong to this group.

**TYPES of GROUP A.**

(1) The artery appears in the pterion region, runs upwards towards the posterior half, that is, behind the mid-parietal region, and giving off branches "en route".

Figs. 35 to 38. The main stem runs in the anterior half of the parietal region, usually towards the bregma, with branches proceeding from it in various directions.

(2) In this group, both divisions take part in the supply of the parietal region, their branches being given off, either before, or after the parent trunks reach the parietal bone. This is by far the commonest arrangement. This group could be further divided into sub-groups:

(a) Those in which the two divisions...
do not give off terminal branches until the parietal is reached.

(b) Those, in which they give off some, not all, their terminal branches before the parietal bone is reached.

(c) Those, in which the anterior division only, is intact by the time the parietal is reached.

(d) Those, in which the posterior division only, is intact by the time the parietal is reached.

This further sub-division of Group B, seems to me to be quite unnecessary, and only apt to lead to confusion in the classification of the types. I have therefore, not made use of this sub-division, but, when discussing the types belonging to this group, I have merely estimated the proportion of cases, in which the anterior and posterior divisions of the middle meningeal artery are intact, or otherwise, by the time the parietal bone is reached.

+ 80.1% of the specimens classified belong to Group B.

TYPES OF GROUP B.

(1) The anterior division of the middle meningeal artery is the larger one, and gives off the chief terminal branches for the supply of the parietal region. It may give off branches as far back as,
the ophthalmic region, and including the ophthalmic branch.

(2) Where the posterior division is the larger, and the chief artery of supply to the parietal region, it usually gives off branches as far forward as the mid-parietal region, and, including the mid-parietal branch. In rare cases, it may be responsible for the post-bregmatic terminal branch.

(3) In this type, the two terminal divisions of the middle meningeal artery are apparently of the same size, and importance, as regards the supply of the parietal region. This is the neutral type, and is comparatively rare.

**Percentage of types of Group B.**

Type (1) 41.2%
Type (2) 24.6%
Type (3) 14.3%

In 48% of the members of group B, neither of the two terminal divisions of the middle meningeal artery gave off their terminal branches until the parietal bone was reached. In 7%, both divided into terminal branches before reaching the parietal bone.
In 41%, the anterior terminal division of the middle meningeal artery was intact, by the time the parietal was reached — that is, as regards terminal branches.

In 3%, the posterior division only, was intact.

**Group C.**

According to Giaffrida-Ruggeri, and, as shown in accompanying diagram taken from his classification, there appears to be a type of branching, unlike the members of the other groups. According to him, the anterior and posterior terminal divisions of the middle meningeal artery are not easily differentiated, but a common trunk runs on the temporal bone towards the pterion, and before reaching it, turning backwards and runs in the direction of the posterior cranial fossa. As it lies on the squamous temporal, it gives off bregmatic, middle parietal, lambdatic, and other terminal branches. I have not seen a case so far, but to make the classification complete I have mentioned it.
The meningeal venous channels, with very few exceptions, correspond very closely to the general distribution of the arterial branching;— I am not here referring to the ordinary well-known venous sinuses of the dura mater.

As regards structure, these venous channels appear to be more of the nature of sinuses, mere slits in the dura mater, and lined with endothelium, than true veins.

In text—books, two sets are described: one, small venous channels pouring blood into the sinuses; and the other, accompanying the arteries, and carrying the blood to venous trunks on the exterior of the cranium.

This latter arrangement is not always very clear, as the ordinary venous channels, which are present in all average cases, connect with the superior sagittal sinus, or one of its lacunae, above, and converge towards the floor of the middle cranial fossa, to end in large channels, which conduct the blood to the outside of the cranial cavity. From the meningeal venous channels, along their course from the vertex to the middle fossa, connecting branches radiate out, to connect up the channels themselves, to communicate with the dural venous sinuses, diploic veins, and emissary veins.
These two figures show a section of the superior sagittal sinus with a large lateral lacuna on one side, and bulging into the lacuna some pacchionian bodies are clearly seen. The large channel opening into the lateral lacuna is the termination of the large venous channel frequently found in the anterior parietal region.
When the large anterior parietal venous channel (described by Breschet in 1891, and later Poirier and Charpey, as well as, Elliot Smith, ), which connects up the superior sagittal and sphenoparietal sinuses, is distinctly present, and unaccompanied by an arterial branch, this channel would appear to belong to the first set mentioned in text-books. It could, however, by no means be called "small".

In the floor of the middle cranial fossa, numerous venous channels may be seen. A large number of them, may be traced into the cavernous sinus medially, a few channels forwards towards, and ending in the sphenoparietal sinus, a few postero-medially ending in the superior petrosal sinus, and the remainder, forming a plexus in the floor of the middle cranial fossa, especially in the region of the semilunar ganglion, and sending connecting channels through various foramina to join veins, or plexuses, outside the cranium. In about five per cent (5%) of bodies examined, I was able to trace a direct communication, between the inferior ophthalmic vein and these channels in the middle fossa.

During my investigation, by injection of the venous channels, I was struck, by the remarkable frequency, with which, connecting veins were found to connect some of the cerebral veins with the sphenoparietal sinus, and, occasionally, with meningeal venous channels near the anterior extremity of the cavernous
sinus. On perusal of the literature, I found no mention made of these connecting channels, and as they seem to be of some importance, I have kept a careful record of the number of cases in which I have found them to occur. Out of a series of 44 bodies examined, 37 showed a connection between the middle cerebral vein, or its tributaries, and the sphenoparietal sinus. In only 2 out of the 44 cases, was I able to trace a direct communication between the middle cerebral vein and the inferior ophthalmic, the connecting vein in each case passing through the superior orbital fissure. See Figs. 63 a, 63 b.

Another venous channel, casually mentioned by Dr. Wood Jones some years ago (2), is to be seen in the middle cranial fossa in a fair number of cases. This venous channel runs in an antero-posterior direction, superficial to the semilunar ganglion, and more or less parallel to the cavernous sinus. It usually connects with the superior petrosal sinus, or, in addition, with the hiatus canalis facialis, posteriorly. On tracing it forwards, it gives off one or more communicating branches to the ordinary middle meningeal venous channels, and then, as it approaches the lesser wing of the sphenoid, it is seen to consist of two or more divisions, which usually join the middle cerebral vein or its tributaries. In rare instances, does it connect with one, or other, of the ophthalmic veins. This channel, in some cases, appears to be uni-lateral, and, if so, is always present on the left side. It is
proportionately bigger in foetuses and infants, but, I have not been able to find any clue regarding its morphological significance. Out of the record of 31 cases, I have found this channel present in 23 instances; 16 showed it on both sides, and 7 on the left side only. Of the 23 cases, in only three, was I able to trace a direct communication, through the superior orbital fissure, to the inferior ophthalmic vein; all the others showed it terminating in divisions, which joined the middle cerebral vein. Fig. 64 shows it in a foetus (full-time), and Fig. 64a, is a micro-photograph of a section of the whole thickness of the dura mater, in the middle cranial fossa, showing the thin-walled large venous channel on the cerebral side of the dura mater, and the middle meningeal artery and accompanying venous sinus in the actual thickness of the dura mater. Figs. 65 and 66, show the adult condition in the actual skull or a portion of it.

As far as I could determine, there are no valves to be found in the cerebral or meningeal venous channels. Judging from the injections carried out before and after the removal of the skull cap, a very free and intimate communication exists between the cerebral, the meningeal, and the extra-cranial venous channels. In some few cases, the ordinary connections of the dural sinuses with the orbital veins, and the veins of the internal ear, are further
Fig. 67.

Middle meningeal artery

Venous sinuses on either side

Fig. 68.

Arterial aspect of dural mater

Large venous sinuses adjacent to artery

Venous sinuses deep to artery
supplemented by connections between the ophthalmic, auditory, and cerebral veins.

RELATIONSHIP OF MENINGEAL ARTERIAL AND VENOUS CHANNELS.

According to Dr. Wood Jones (23), the general arrangement is for the venous channels to occupy a space intermediate between the meningeal arteries and the skull, but that sometimes the artery is accompanied by two venous channels, one on each side, resembling vena comites; and, that in some cases, the artery appears to lie inside the venous channel, in much the same way, as the internal carotid artery lies in the cavernous sinus. Further, "contrary to the general belief of surgeons, the vascular tunnel at the pterion, although it lodges arterial branches, is typically formed by, and typically lodges, a venous sinus".

As regards this general relationship, most of the cases examined agree, but, the "vena comites" arrangement seems to be far commoner, than admitted by him. Figs. 67, 88, show this arrangement very well.

As regards the tunnel in the pterion region, I have found it to lodge a large venous channel in most cases, but, in a few, I have not been able to discover a venous channel of any size accompanying the anterior terminal division of the middle meningeal artery, during its course through the tunnel, although, immediately above the opening of the tunnel, the
groove may present dimensions, considerably larger than the calibre of the tunnel. Sometimes this groove seems to be of a double nature. Fig. 19. shows this state of affairs very well, and on approaching the tunnel, two grooves are seen to diverge, the anterior one running forwards, and apparently going to join the sphenoparietal sinus, the other one, entering the tunnel, and appearing through the foramen, seen in the thickness of the skull. The former, presumably lodged a venous channel connecting the superior sagittal and sphenoparietal sinuses, and the latter, the anterior terminal division of the middle meningeal artery and accompanying venous channel.
THE VASCULAR LESION IN MENINGEAL HAEMORRHAGE.

Some 10 years ago, the ordinary orthodox teaching, regarding the vascular lesion, in cases of middle meningeal haemorrhage, was seriously questioned by Dr. Wood Jones (5). This raised a great deal of controversy at the time, and although he quoted three actual cases, with illustrations, bearing out his contention, that in some, if not most, cases of middle meningeal haemorrhage, the lesion is venous, and not arterial, his views have not received much support.

I have enquired about the experiences of several Edinburgh surgeons, regarding the lesion found in cases operated upon by them, and their own opinions concerning this question. Very few of them, gave any support to the idea of haemorrhage, sufficient to cause symptoms, occurring from the venous channels accompanying the meningeal arteries (middle), although, they all agreed that in a very small percentage of cases, the artery had to be ligatured.

Emeritus — Professor F. M. Caird, stated that in all his experience, he could only recall one case, in which, he had to enlarge the opening in the skull, in order to reach the bleeding artery. He is of opinion, that the symptoms of haemorrhage, and the clot, are due to a torn artery and not a vein, and that, although no lesion may be found, the explanation is, that there is a small tear in the artery, the haemorrhage from which is controlled by the increased pressure
after symptoms have developed, and, by the time, the operation is performed, the bleeding has been arrested.

Whatever the general consensus of opinion might be, there is no doubt, that the meningeal (middle) venous channels are sometimes of such size, that haemorrhage, sufficient to cause symptoms, might quite well occur from them; this is specially liable to happen, when the large sinus is present in the anterior parietal region. At any rate, it is very desirable that, wherever possible, all cases of so-called, middle-meningeal haemorrhage should be carefully investigated, so as to settle this question finally.

The semilunar ganglion, and the main division of the trigeminal nerve, are comparatively often the objects of surgical procedures, and it is surprising that more cases do not end fatally, in view of the fact, that so many venous channels are intimately associated with it. Large venous channels, often plexiform in character, lie below, others medial, and yet others, above. Besides these, the ordinary meningeal venous channels and their connections, lie to the lateral side; so that it would appear, that any attempt at reaching the ganglion, by stripping the dura mater, or by passing a needle through the foramen ovale, must be attended with considerable haemorrhage.
The orthogonal projection prepared with the aid of the Perigraph, and other instruments described, comprise different types of human skulls—Dolichocephalic, Mesatoccephalic and Brachycephalic—and also certain animal types.

In all of them, the outer surface of the skull, including sutures, etc., is represented in green; the inner margin, sphenoidal and frontal sinuses, petrous temporal, internal auditory meatus, groove for the lateral sinus and the sella turcica are represented in purple; and the meningeal grooves in scarlet. In 2 cases, I have also portrayed the position, in the mid-parietal region, of the lacunae-like diploic venous channels, as knowledge of the presence of such a large lacuna may help the operator to avoid it, and thus avoid unnecessary haemorrhage.

The tracings, of all these various skulls, explain themselves far better than any lengthy description could ever do. They show several features of interest, and, among these, may be mentioned the variations of the shapes of the skulls, the differences in size of the pituitary fossa, variations of meningeal grooves, and the variations in position and size of the groove of the lateral sinus, more especially when comparing the human and animal types.

From the surgical aspect, as shown in the tracings of the human types, the variations are not
constant in Dolicho-, Mesato-, and Brachy-cephalic skulls, as regards the topographical positions of the grooves. In all of them, the anterior middle meningeal vessels may be localised in the pterion region; but, the posterior middle meningeal vessels vary somewhat, but, on the whole, these may be localised, far more accurately, in the majority of skulls, if the point of the trephine is entered about an inch and a half (1.5), above the upper border of the external auditory meatus, and, not an inch behind and an inch above the external auditory meatus, as is generally advised in text-books of surgical anatomy and operative surgery.

This is by far the most likely place, in which, to expose the posterior middle meningeal vessels, and, in addition, the trunk, before it branches, will be found there. If the other rule is followed, only a small branch may be exposed, and a good portion of the skull would have to be nibbled away in order to reach the main trunk. If this newly recommended method does not expose the posterior trunk, then it is usually very low down and has to be looked for on a horizontal plane, just above the bend of the lateral sinus.

The Plates number 15 and comprising:

3 Dolichocephalic Types numbers 1 to 3.
3 Mesatocephalic Types nos. 4 to 6.
2 Brachycephalic Types nos. 7 and 8.
1 Idiot no. 9.
2 Human Skulls, showing diploic lacunae.
4 Lower Animal Types, nos. 12 to 15.
SUMMARY AND CONCLUSIONS.

(1) That the grooves on the cranial aspect of the skull vary very considerably in character, although, to a smaller extent, as regards position; and, that there appear to be certain racial differences, and that, although certain animal types resemble the human very closely, others differ very widely.

(2) That the large gutter-like groove found in the anterior parietal region may lodge several vascular channels, and, that it is desirable that the nature of its contents should be further investigated, so as to come to some definite conclusion as to its significance as seen in dried specimens, or casts.

(3) That casts of the interior of skulls are very useful, and may clear up doubtful points in some cases, but, that the configuration of the skull may be such, that a perfect representation cannot be obtained; and, that in a few cases, the detail is more confusing than elucidating.

(4) That the meningeal arteries vary considerably, as regards their ultimate distribution; that, the middle meningeal artery and its terminal branches give off certain constant branches, and that some of these are worthy of mention in
larger text-books of descriptive anatomy; and
that the classification of arterial branching,
which I have evolved, is less confusing than
that suggested by Guiffrida — Ruggeri.

(5) That the meningeal arteries anastomose freely
with each other on one side, that these anastoma-
sing with those on the other side, and that,
they all anastomose freely with arteries out-
side the cranium.

(6) That the venous channels, cerebral, meningeal,
orbital, auditory and extra-cranial, communicate
very freely, and that there appears to be an
entire absence of valves, so that the blood
flow does not appear to be limited in any
particular direction, although the usual flow
is backwards towards the lateral sinuses and
hence into the internal jugular veins.

(7) That the large anterior parietal venous channel
is more common in British types of crania than
is generally supposed, and that the venous
channel accompanying the anterior division of
the middle meningeal artery, may appear to be
fused with the former, as far down as the pterion
region, where they may be seen to diverge.

(8) That the vein in the floor of the middle fossa
parallel to the cavernous sinus, as well as the
Connections between it and the sphenoparietal sinus, or the middle cerebral vein, or, between the sphenoparietal sinus and the middle cerebral vein, are constant enough to warrant description in text-books of anatomy.

(9) That on the whole, the meningeal venous channels lie between the corresponding arteries and the skull; that the question of haemorrhage from these venous channels in cases of middle meningeal haemorrhage, is at least interesting, and worthy of further investigation; and that, when there is a large sinus in the anterior parietal region, it may play a not inconsiderable part in the production of symptoms of middle meningeal haemorrhage.

(10) That topographical considerations are very instructive and interesting, not merely academically, but that these can be applied as means of localising more correctly, the more important divisions, or branches of blood vessels, as well as the larger blood sinuses; and that, in cases of posterior middle meningeal haemorrhage, the pin of the trephine entered one and a half (1.5 ins) inches above the external auditory meatus, is more likely to localise the main trunk than the usual point, linch above and behind the external auditory meatus, usually advised in text-books of surgical anatomy.
(II) That, the meningeal vessels vary very considerably in individual skulls; and that the suggestion, by Guiffrida-Ruggeri (8), that the branching may be made use of in dividing up the brain for descriptive purposes, is absurd and only likely to create confusion.

In conclusion, I wish to express my great indebtedness to Professor Arthur Robinson. It was at his suggestion that this work was undertaken, and his helpful advice and stimulating interest throughout, have greatly diminished the tedium of the work.

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Plate XIV
Chimpanzee
"Museum No. Ch. 641"
Thesis for the Degree of M.D. 1922.

MENINGEAL VESSELS

VARIATIONS IN MAN AND APES

RELATION TO SKULL BONE AND VENOUS SINUSES.

DUPLICATE SET OF PHOTOGRAPHS.

by

L. v. R. BECKER,

M.B., Ch.B.
Peculiar Types of Branching.

Fig. 33

Fig. 34