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JOURNAL OF ANATOMY AND PHYSIOLOGY

ON THE INNERVATION OF THE NODAL TISSUE OF THE MAMMALIAN HEART.

By JEAN MEIKLEJOHN, M.B., Ch.B., *Carnegie Fellow.* (*From the Royal College of Physicians' Laboratory, Edinburgh.*)

SINCE their discovery, the sino-auricular (Keith-Flack, 1907) node and the auriculo-ventricular bundle (Kent and His, 1892) have been extensively described by many writers.

Histological research has, until recently, concerned itself chiefly with the nature and distribution of the primitive muscle, which is the most noticeable feature of those structures.

In 1906, Tawara (1), whose description of the muscular element of the auriculo-ventricular node and bundle is most exhaustive, stated that nerve fibres accompany the bundle in the sheep. In the bundle of the sheep and calf the nervous tissue is very abundant, and cells and large strands of nerve fibres form a striking feature in sections stained by Van Gieson's method, but Wilson (2) was the first (1909) to make a study of the nervous element of the bundle by special nerve stains. He used the intra-vitam methylene blue method, and worked chiefly with the calf, sheep, and pig. He states that he was less successful with human hearts and with those of carnivora. He describes in the calf's heart numerous nerve cells and ganglia, large nerve strands, and a very rich plexus of exceedingly fine fibrils, breaking up and closely surrounding the muscle fibres and groups of muscle fibres, but without any definite end organs in relation to the muscle cells.

Lydia de Witt (3) stated that in the calf and sheep nerve cells and fibres were numerous, and that the fibres could be followed to the finer ramifications of the bundle. She does not give a detailed description of the nerve element: her paper deals chiefly with the course and final distribution of the bundle.

Morison (4) has studied the nervous element of the sino-auricular node and the auriculo-ventricular bundle with the object of determining "whether the muscle cells of the sino-auricular and auriculo-ventricular muscle were innervated, and, if so, the character and manner of such innervation." He examined the sheep and pig, but adds a note to the effect that he has found what he takes to be "ultimate innervation of the bundle" in man. He employed the method of Sihler, and describes the innervation of the sino-auricular muscle by moniliform threads applying themselves to the muscle cells. The Purkinje fibres of the auriculo-ventricular bundle, he states, are supplied by shorter fibrils coming from the surrounding plexus, or by longer ones which he was able to trace to their origin from larger nerves.

B. S. and A. Oppenheimer (5) have stained nerve fibres and cells in the sino-auricular node of the sheep by the methylene blue intra-vitam method. They describe a few cells and fine nerve filaments forming a plexus round the muscle fibres. They, like Wilson, were unable to find any definite end organs. The plexus is a very fine one, and enters into very close relation with the muscle fibres. Their findings for the sino-auricular node are very similar to Wilson's for the auriculo-ventricular bundle as regards the finer nerve elements: they differ in that nerve cells are rarely found in the sino-auricular node.

It is noteworthy that, with the exception of Morison's, all the work done on the innervation of the primitive muscle has been done by means of methylene blue, and it appeared likely that, while the larger nerve strands found in the calf and sheep are absent in most other mammals, the failure to discover fine nerve elements in the hearts of man and of carnivora might be due to failure of the stain. Other classes of mammals have not been examined with regard to the innervation of the nodal tissue.

I have therefore attempted to determine the innervation of the primitive muscular tissue by means of different stains and in a number of different mammals.

The animals used for this research have been, chiefly, the monkey, guinea-pig, and rat. I at first investigated the innervation of the bundle in the hearts of calves and sheep by means of Cajal's silver method. As my results were mainly corroborative of those of Wilson (2), I shall not describe them here. I have also used human hearts and those of cats.

Methods.

The methods employed were Cajal's silver-reduction method (6) and the methylene blue intra-vitam method as described by Wilson (7). I have used the Van Gieson method as a control, although the Cajal method stains muscle quite sufficiently well to enable an exact location of the primitive muscle to be made, and the methylene blue sections were counterstained with safranine for this purpose.

I employed the method of Cajal with previous fixation in ammoniacal alcohol (6). The method is as follows:—

(1) Fixation in:

Alcohol, 96 per cent.	100 c.c.
Ammonia	10 drops.

24 hours.

(The specimens are best immersed first in weaker alcohol, with the same proportion of ammonia, a few hours.)

Wash in distilled water.

(2) Impregnation with silver nitrate:

1·5 per cent. at temp. 36° C.

6 to 8 days.

Wash in distilled water.

(3) Reduction in:

Ac. pyrogallic.	1 grm.
Formol	5 c.c.
Aq. dest.	100 c.c.

24 hours.

Wash in distilled water, pass through spirit, etc., imbed in paraffin in the usual way.

Sections were cut serially and in most cases about 8 μ thick. One section in five was usually mounted, although, in some cases, as in some of the monkey hearts, all the sections were mounted.

Some of the sections were toned in the following bath, freshly prepared,

Ammon. sulphocyanide	3 grms.
Sod. hyposulphite	3 grms.
Dist. water	100 c.c.
1 per cent. gold chloride	a few drops,

until the yellow colour had almost disappeared. They were then counterstained with safranine, which takes well after toning. It was found that only specimens in which the muscular and connective tissues had taken the impregnation very feebly, toned well. In others, toning resulted merely in a blackening of all structures. Where successful it gave much clearer and more beautiful results.

For the methylene blue method I followed closely Wilson's description (7), which is very complete. I used a very weak solution of the stain, and injected it through the aorta into the coronary arteries. Sections were cut in paraffin, serially, and about 10 μ thick. They were counterstained with safranine.

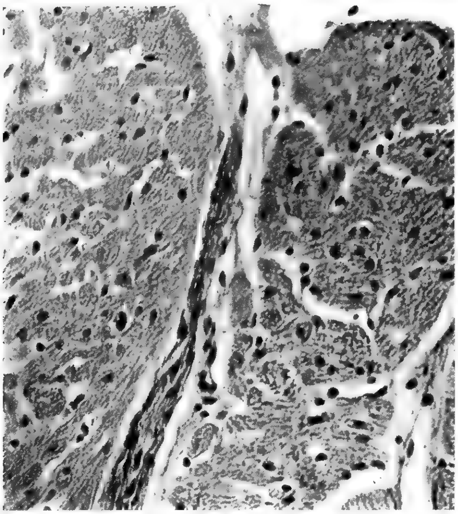

Fig. 1.—Sino-auricular node, monkey. Nerve passing through the node. (Silver, Leitz oc. 1, obj. 6.)

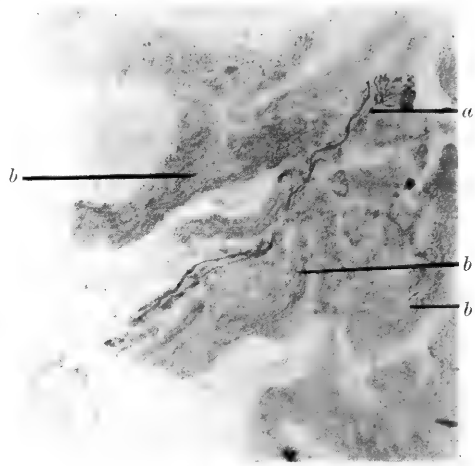

Fig. 2.—S.-A. node, monkey. Nerve fibres in the node. A small fibre is breaking up at (*a*) into numerous branches, (*b*) nodal muscle. (Silver, L. oc. 1, obj. 6.)

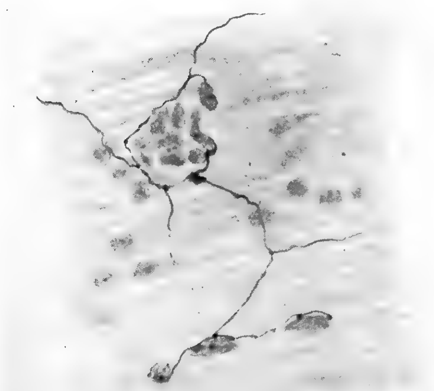

Fig. 3.—Part of fine plexus in S.-A. node, monkey. (Silver, L. oc. 4, obj. 6.)

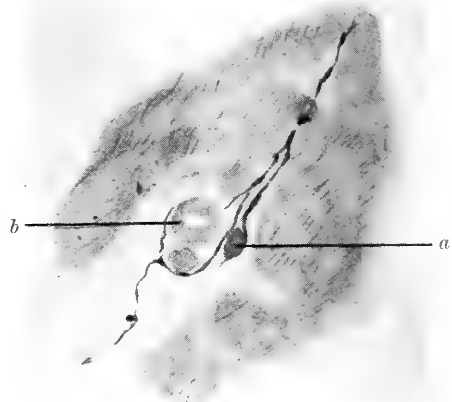

Fig. 4.—Small nerve fibril in S.-A. node (monkey) surrounding a nucleus at (*a*) and a muscle cell at (*b*). (Silver, L. oc. 4, obj. $\frac{1}{12}$.)

The Nerves of the Sino-Auricular Node.

I have examined the nerves of the sino-auricular node only in the monkey and in man.

In the monkey (Callitrix) I have been able to show by Cajal's method a very extensive innervation of the muscle. Two or three relatively large nerves enter the node from the large ganglia immediately above it. Of these nerves, one (fig. 1) appears to pass through the node without branching and to be distributed in the auricular muscle. The others, which are of about the same size, break up early and give off probably all the small fibrils to supply the primitive (or nodal) muscle. These small fibrils sometimes form a very delicate plexus around groups of muscle fibres (fig. 3), and at other times a fibre breaks up into a brush of fibrils which ramify among the muscle cells (fig. 2). A great variety of endings was found: occasionally a single filament passes off from a larger fibre and applies itself to a muscle cell (fig. 4): frequently a single fibre or several fibres break up around one or several nuclei and form a fine network. These endings vary from intricate "corpuscles" (the largest of which run through 4–5 sections 7 μ thick) surrounding a number of nuclei, to a single fibril branching to enclose a single nucleus. There are frequently small varicosities on the course of these fibrils and at their terminations. A number of endings are shown at figs. 5 to 12 (pp. 6, 7).

The nuclei forming the centre round which these fibrils break up present several points of interest. In many cases they are obviously muscle nuclei contained in the delicately reticular muscle characteristic of the primitive tissue, showing the ordinary appearances of a muscle cell nucleus in this situation (figs. 7, 8, 12, pp. 6, 7) Sometimes there is a single nucleus with a relatively small amount of muscle substance surrounding it, and with a small tail of muscle. The cells at (*a*) and (*b*) in fig. 5, and at (*b*) in fig. 8 appear to be of this character. Some of the more complex endings surround a cluster of nuclei which appear to be muscle nuclei, but which are much more closely grouped than the nuclei of the surrounding muscle. This is the case with the ending shown at fig. 11, p. 7. One occasionally finds, associated with a terminal network, a group of nuclei of a character difficult to determine. Such a group is shown at fig. 9, p. 7. A terminal branching filament is here wound spirally round a number of nuclei lying between two strands of muscle. These nuclei are rather smaller than the average of the muscle nuclei, and do not appear to be surrounded by muscle substance.

Very closely resembling some of the more complex endings described above, are the networks occurring in the course of some of the fibres. A

FIG. 5.—S.-A. node, monkey. Nerve fibrils surrounding nuclei. The nuclei at (*a*) and (*b*) have a small "tail" of muscle. (Silver, L. oc. 4, obj. $\frac{1}{12}$.)

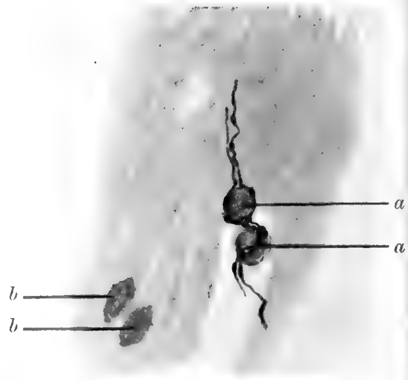

FIG. 6.—S.-A. node, monkey. Two nerve fibrils surrounding nuclei (*a*) in their course. The nuclei (*b*) are muscle nuclei. (Silver, L. oc. 4, obj. $\frac{1}{12}$.)

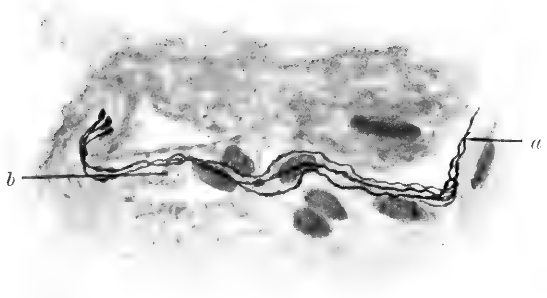

FIG. 7.—S.-A. node, monkey. Nerve fibril breaking up at (*a*) upon a muscle fibre; (*b*) the nuclei are muscle nuclei. (Silver, counter-stained with safranine, L. oc. 4, obj. $\frac{1}{12}$.)

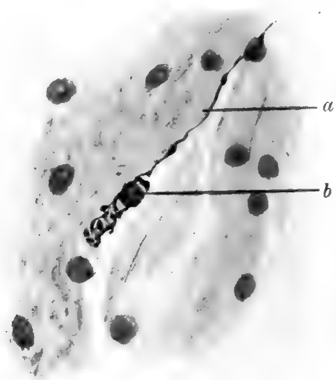

FIG. 8.—S.-A. node, monkey. Nerve fibril breaking up at (*a*) to surround a nucleus at (*b*). (Silver, counter-stained safranine, L. oc. 4, obj. $\frac{1}{12}$.)

FIG. 9.—S.-A. node, monkey. Nerve fibre forming a spiral round a group of nuclei. (Silver, L. oc. 4, obj. $\frac{1}{12}$.)

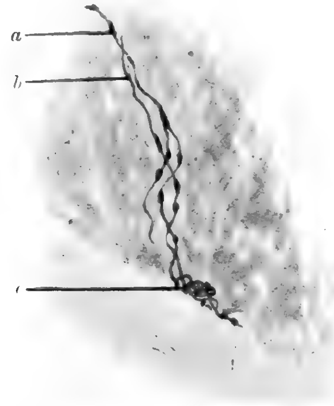

FIG. 10.—S.-A. node, monkey. Nerve fibrils (*a*) and (*b*) ending round a muscle nucleus at (*c*). (Silver, L. oc. 4, obj. $\frac{1}{12}$.)

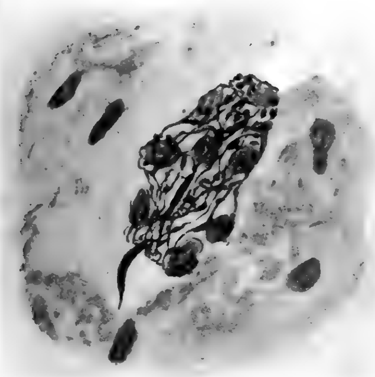

FIG. 11.—S.-A. node, monkey. Nerve fibril forming a network round a large group of nuclei. (Silver, counterstained safranine, L. oc. 4, obj. $\frac{1}{12}$.)

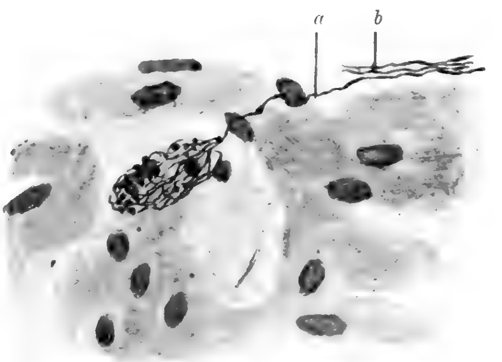

FIG. 12.—S.-A. node, monkey. Nerve fibril (*a*) coming from small nerve (*b*) to break up around a group of nuclei, probably muscle nuclei. (Silver, counterstained safranine, L. oc. 4, obj. $\frac{1}{12}$.)

small fibre sometimes breaks up in its course into a complex network, showing varicosities at the terminations and in the course of the fibrils. Sometimes several fibres combine in forming such a network, from which fibrils are sent out into the surrounding muscle (fig. 13, p. 9). Such a network appears to be a "station" on the course of the fibre: the one shown at fig. 13 could be traced through five sections 7μ thick.

No ganglion cells were found within the node.

In the human heart no nerve endings were found in the node. A number of nerves enter the node from the ganglia lying near it (fig. 14). These branch frequently, but, while quite small branches could be found among the muscle fibres, they could not be followed to ultimate terminations.

The Nerves of the Auriculo-Ventricular Bundle.

In the monkey the Cajal method alone was used. The results here were less definite than in the sino-auricular node, although in some respects very similar.

A number of nerves enter the nodal part of the auriculo-ventricular bundle from ganglia lying at the back of the heart and in the inter-auricular septum. These nerves pass forward in the inter-auricular septum, receiving branches from small ganglia lying near their course, and enter the nodal part of the bundle. One of these nerves and a ganglion cell associated with it are shown at fig. 15, p. 9. In the node the nerves quickly break up into small branches and single fibrils which ramify among the muscle fibres (fig. 16, p. 9). The fibrils give off very fine branches, some of which surround nuclei in a manner similar to the simpler endings described above for the sino-auricular node. Some of these branches are shown at fig. 17, p. 10. The nucleus at (a) appears to have a small "tail" of muscle, and the nerve fibril forms a very close connexion with this cell.

Fine nerve fibres can be followed into the right and left branches of the bundle, where they form a very fine plexus. The fibrils are less numerous and finer than in the nodal part of the bundle, but their distribution is similar. Here again they break up to surround nuclei. Fig. 17 (p. 10) shows a strand of the plexus forming a spiral round a chain of nuclei. A single fibre from the plexus is shown in the same figure applying itself to a muscle cell.

A branch from the plexus is shown at fig. 19, p. 12 (at a higher magnification), breaking up into numerous fine terminal filaments round a group of relatively small muscle fibres. These terminal filaments are very minute, and can only be followed with the oil-immersion lens.

In the guinea-pig the nervous element is very much more conspicuous.

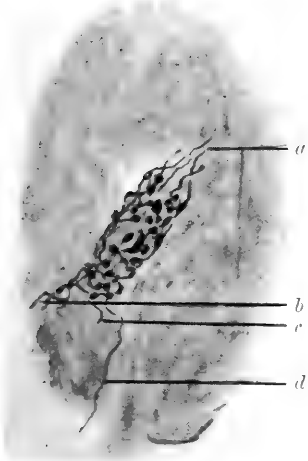

Fig. 13.—S.-A. node, monkey. A "station" in the course of a leash of fibrils. The fibrils enter at (*a*); fibrils (*b*), (*c*), and (*d*) pass off into the surrounding muscle. (Silver, L. oc. 4, obj. $\frac{1}{12}$.)

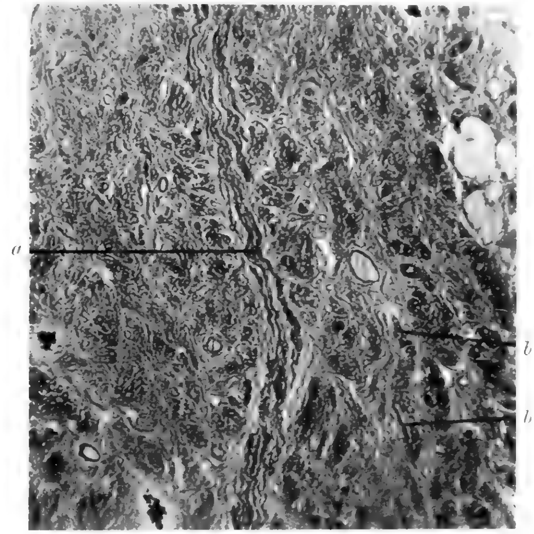

Fig. 14.—S.-A. node, human. Nerve (*a*) passing through the node Two small branches are shown at (*b*). (Silver. × 300.)

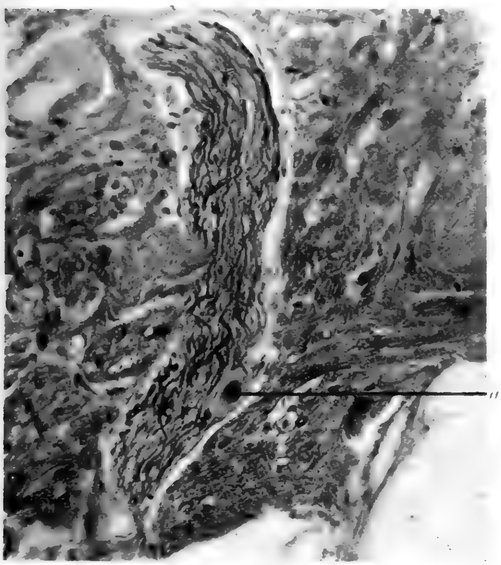

Fig. 15.—Auriculo-ventricular bundle, monkey. Nerve entering the nodal part of the bundle. (*a*) Nerve cell. (Silver. × 300.)

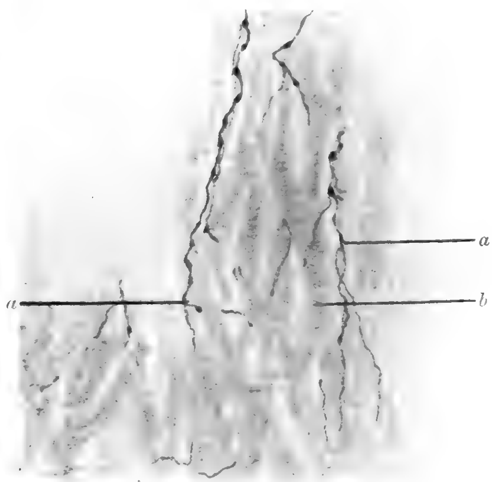

Fig. 16.—Auriculo-ventricular bundle. Nerves in the nodal part breaking up at (*a*) into five branches among the nodal muscle (*b*). (Silver. × 300.)

Large nerve strands enter the bundle through the inter-auricular septum. These nerves come from ganglia lying at the posterior part of the inter-auricular septum, as in the monkey's heart. Similar large strands of nerve fibres were found in all the hearts examined arising from these ganglia and running forward in the inter-auricular septum to enter the bundle in its auricular part. On entering the bundle the nerves break up quickly into larger and smaller strands. Many spread out upon the sheath of the bundle

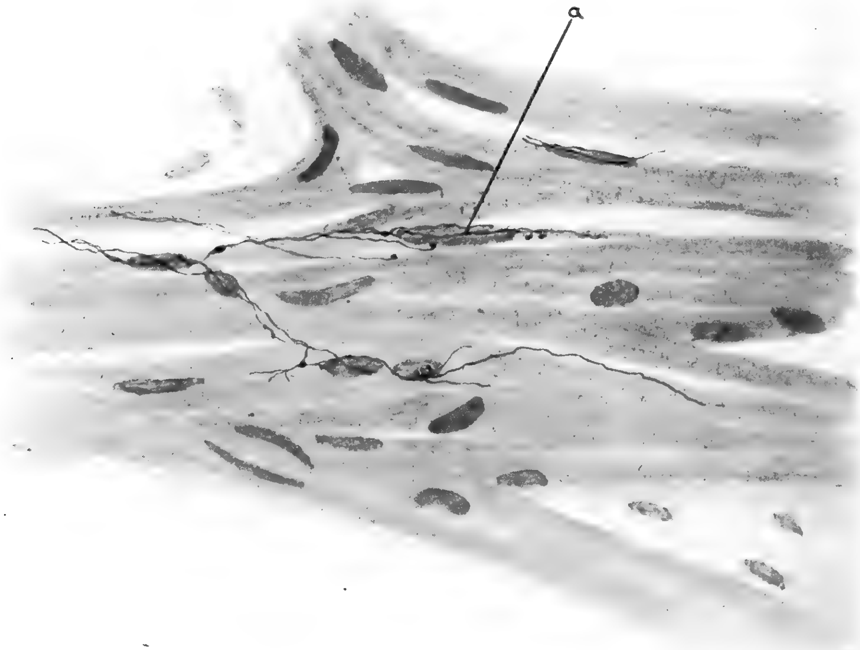

Fig. 17.—Auriculo-ventricular bundle, monkey. Terminal nerve filaments in the nodal part of the bundle. The nucleus at (*a*) has a small "tail" of muscle. (Silver. ×674)

(fig. 20, p. 13): these are for the most part single varicose fibres or small strands of varicose fibres. Nerve fibres also accompany the muscle fibres or groups of muscle fibres and give off branches which course among them and form a plexus. Fig. 21 shows a plexus round a large cluster of nuclei lying in the meshes of the muscular network. Sometimes a single fibre gives off a brush of fibrils which apply themselves to a muscle fibre (fig. 22, p. 13). Occasionally a fibre was found surrounding a muscle cell in a spiral manner (fig. 22). A few small ganglia are present in the bundle: those found were in the left branch just below the bifurcation (figs. 23, p. 13, and 24 and

25, p. 14). The bundle in the guinea-pig breaks up early into small branches, and wherever a branch could be followed a nerve fibre or two were found accompanying it.

The above is a description of specimens stained by Cajal's silver method. Methylene blue showed the finer ramifications of the nerve plexus. Fig. 26, p. 14, is from a specimen stained by this method. Several strands of

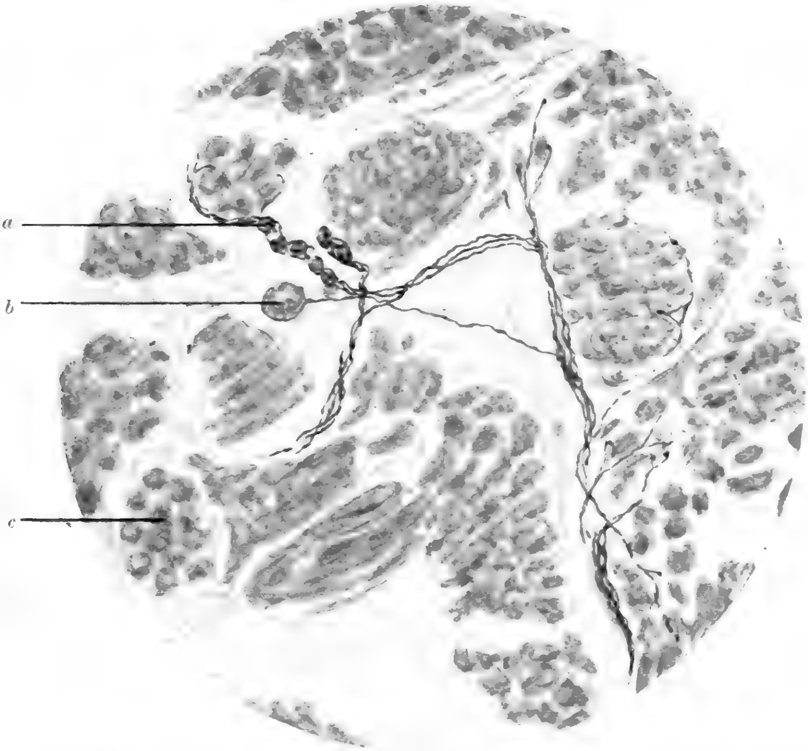

Fig. 18.—Auriculo-ventricular bundle, monkey. Nerve plexus in left branch of the bundle. The nerve filaments break up round a chain of nuclei at (*a*); at (*b*) a single filament is surrounding a muscle cell; (*c*) bundle muscle. (Silver. ×400.)

muscle fibres are shown surrounded by a very delicate plexus of varicose fibrils. The fibrils seem to form a very close connexion with the nuclei of the muscle-cells. There are no very definite "endings": the plexus appears to be continuous and merely to halt in its course to form an elaborate relation with these nuclei.

In the rat, as in the other animals examined, large nerves were traced entering the bundle from the ganglia at the back of the heart, by way of the inter-auricular septum. In the case of the rat nerves were also seen entering the bundle after its bifurcation. Fig. 27 (p. 15) shows some large strands entering the right branch.

The bundle muscle of the rat is much more compact than that of the guinea-pig, and, consequently, it is much more difficult with silver staining to determine the distribution and termination of the numerous nerve fibres which surround the bundle and penetrate its substance. Specimens stained

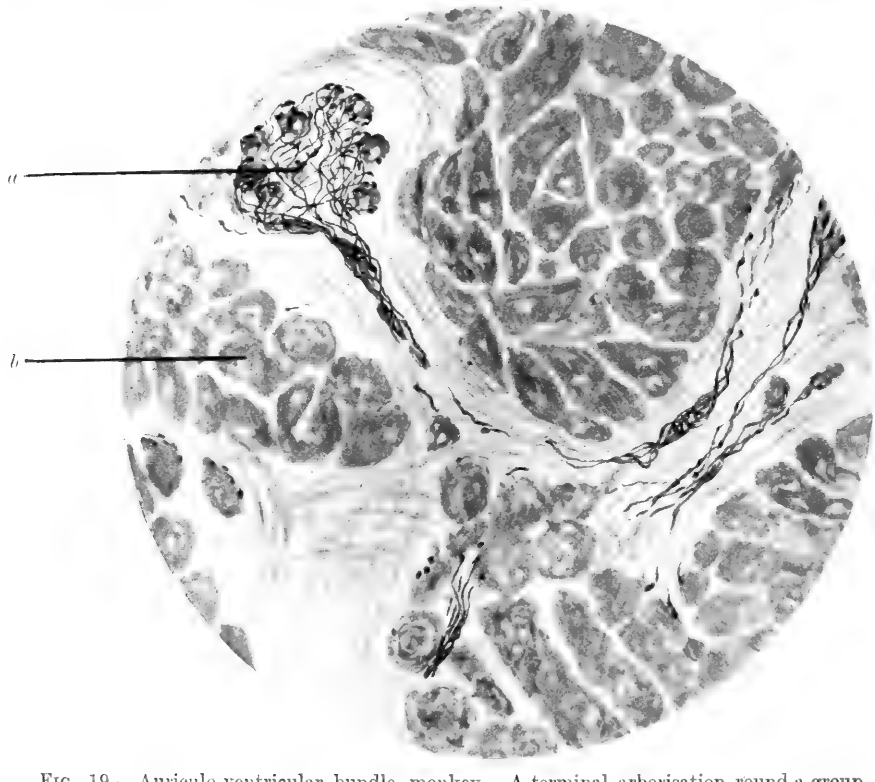

FIG. 19.—Auriculo-ventricular bundle, monkey. A terminal arborisation round a group of relatively small muscle fibres (*a*); (*b*) ordinary bundle muscle. (Silver. ×750.)

with methylene blue show the finer ramifications of the fibres which surround the strands of muscle. Fig. 28 (p. 16) shows the termination of a single nerve fibril.

It would appear that the nerve fibres in the rat are rather less numerous than in the guinea-pig, and their arrangement is less plexiform (fig. 29, p. 17). Fibres break up among the muscle fibres and form fine filaments which branch repeatedly and end in close relation with muscle cells (figs. 28 and 30, pp. 16, 17).

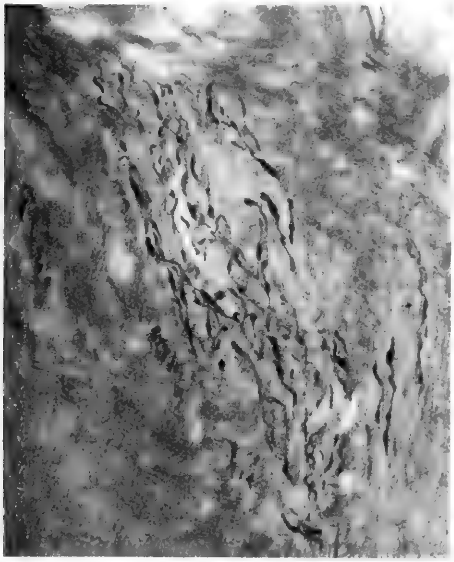

FIG. 20.—Auriculo - ventricular bundle, guinea-pig. Nerve fibres spreading out upon the sheath of the bundle. (Silver, L. oc. 1, obj. 6.)

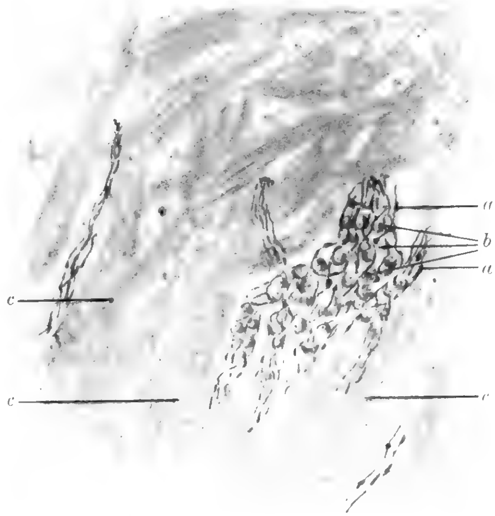

FIG. 21.—Auriculo - ventricular bundle, guinea-pig. Plexus of nerve fibres (*a*) round nuclei (*b*), and passing on to bundle muscle (*c*). (Silver, L. oc. 1, obj. 6.)

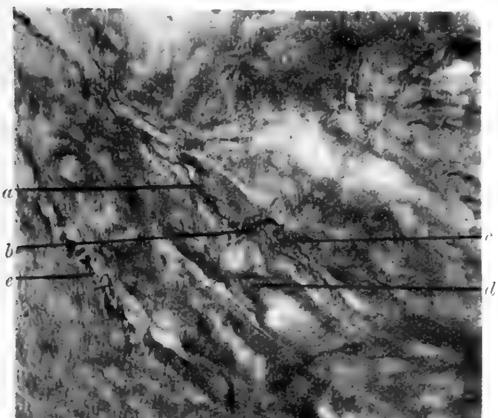

FIG. 22.—Auriculo - ventricular bundle, guinea-pig. Nerve fibre (*a*) breaking up into a brush of fibrils (*b*) in a muscle cell ; (*c*), (*d*) another muscle cell of the bundle ; (*e*) fibril coiled spirally round a small muscle cell. (Silver. ×300.)

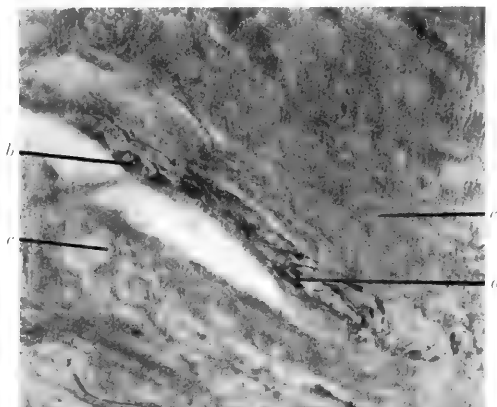

FIG. 23.—Auriculo-ventricular bundle, guinea-pig. A strand of varicose fibres (*a*) in the bundle ; (*b*) ganglion cell ; (*c*) bundle muscle. (Silver. ×300.)

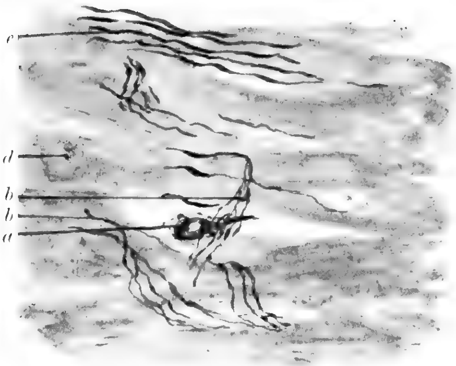

Fig. 24.—Auriculo-ventricular bundle, guinea-pig. A single ganglion cell (*a*) with pericellular network from fibrils (*b*); (*d*) bundle muscle; (*c*) strand of large fibres. (Silver. ×400.)

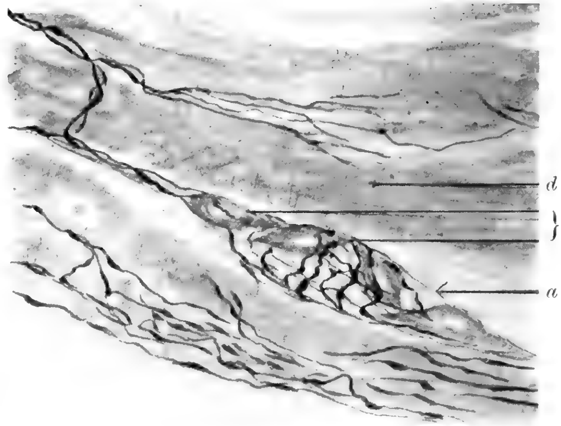

Fig. 25.—Auriculo-ventricular bundle, guinea-pig. Small ganglion (*a*) with uni- and bi-polar cells (*b*); (*d*), bundle muscle. From the left branch just below the bifurcation. (Silver. ×400.)

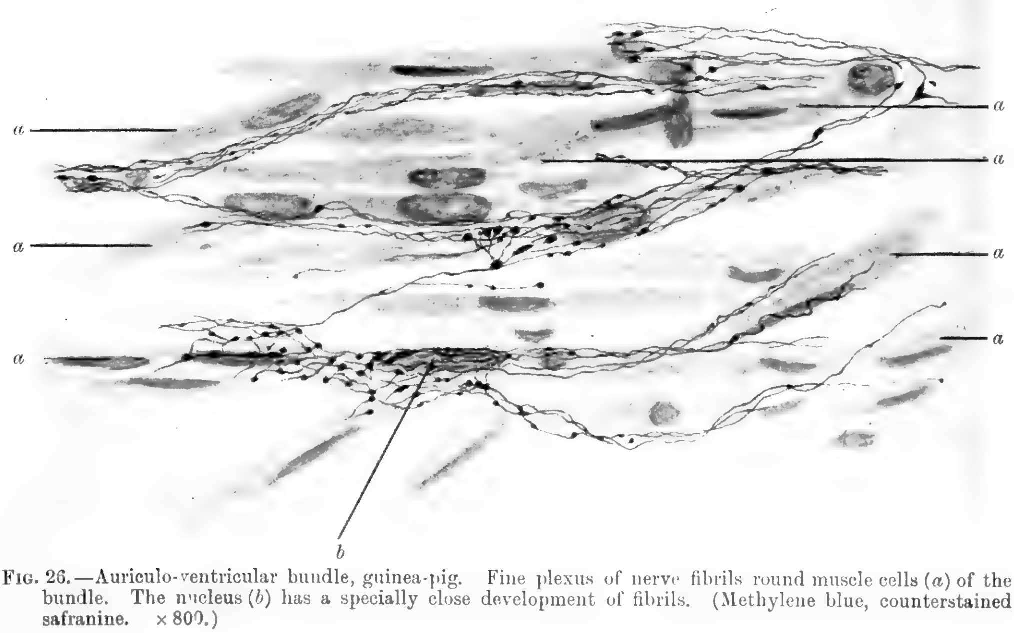

Fig. 26.—Auriculo-ventricular bundle, guinea-pig. Fine plexus of nerve fibrils round muscle cells (*a*) of the bundle. The nucleus (*b*) has a specially close development of fibrils. (Methylene blue, counterstained safranine. ×800.)

Specimens of the auriculo-ventricular bundle in the cat's heart show only scanty nerve fibres. A few strands were found entering the node and coursing for some distance in the bundle. Some of these break up and send filaments among the adjacent muscle fibres, but no extensive innervation was found.

The results for the human heart were similarly disappointing. Only a few small fibres were found in the bundle, nothing of the nature of a nerve plexus or nerve endings.

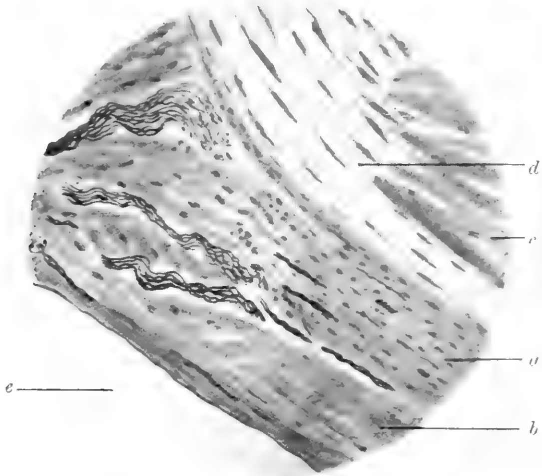

Fig. 27—Auriculo-ventricular bundle, rat. Nerves entering the right branch from the inter-auricular septum. (*a*) right branch of bundle; (*b*) auricular muscle; (*c*) ventricular muscle; (*d*) central fibrous septum; (*e*) cavity of right auricle. (Silver. × 200.)

The failure to demonstrate more than a few nerve fibres in human hearts and in those of carnivora may have been due to non-success of the staining, but, as the adjacent ganglia and the nerve fibrils around their cells were well stained in most of the specimens, such an explanation may not hold Further investigations on the subject are being carried out.

Summary.

(1) The nervous constituent of the nodal tissue of the heart is a very variable one in different mammals.

(2) In all the animals examined there are ganglia in close relation with both the sino-auricular node and the auriculo-ventricular bundle. Ganglia lie in the immediate vicinity of the sino-auricular node and

send numerous fibres into it, while the auriculo-ventricular bundle is connected with the ganglia in the posterior part of the inter-auricular septum

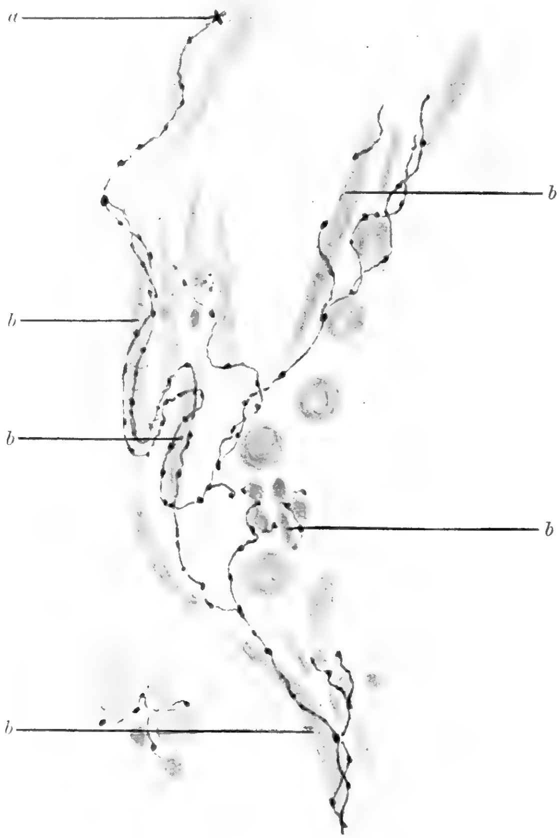

FIG. 28.—Auriculo-ventricular bundle, rat A single nerve fibril (*a*) branching to surround a number of muscle cells (*b*). (Methylene blue. ×800.)

through nerves passing forward in that septum to enter the bundle in its auricular portion.

(3) In the monkey the sino-auricular node has a rich nerve-supply.

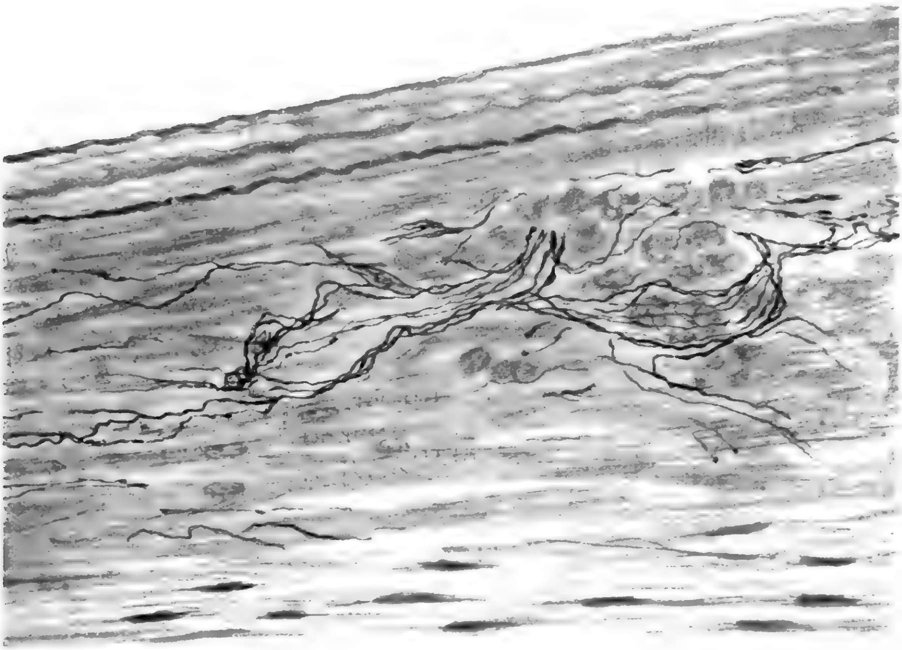

FIG. 29.—Auriculo-ventricular bundle, rat. Nerves breaking up among the muscle fibres of the bundle, left branch. (Silver. ×300.)

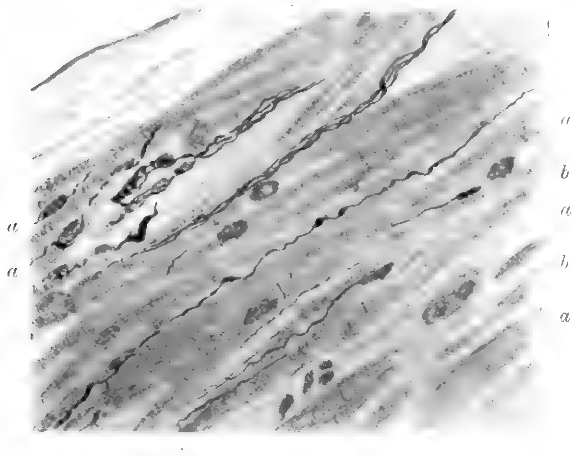

FIG. 30.—Auriculo-ventricular bundle, rat. Nerve fibrils (*a*) applied to the muscle fibres; (*b*) muscle nuclei. (Silver. ×400.)

The node contains highly specialised nerve endings quite distinct from those of ordinary cardiac muscle.

(4) The auriculo-ventricular bundle in all the hearts examined, except those of man and carnivora, has an abundant nerve-supply. This nerve-supply is a striking feature of the bundle in ungulates and in the guinea-pig and rat. In the monkey it is very much finer, but appears to be of a special character. In carnivora the nerve-supply appears to be scanty. The same is true of the human heart, although how far this appearance is due to the uncertainty of the special stains used for peripheral nerves is doubtful.

In conclusion, I wish to express my indebtedness to Dr James Ritchie, superintendent of this laboratory, at whose suggestion and under whose guidance this research was undertaken and carried out. Also to Dr W. T. Ritchie and Dr J. W. Dawson for much kind help in the course of the work. My thanks are also due to the Carnegie Trust for a grant towards the expenses of publication.

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RECONSTRUCTION IN MODELLING CLAY: A RAPID METHOD OF PLASTIC RECONSTRUCTION FROM SERIAL SECTIONS.

By David Waterston, M.A., M.D.

The method of plastic reconstruction described below was worked out in my laboratory during last winter. Its usefulness was tested by preparing models of a variety of objects, such as the external form of two embryos, the central nervous system, and the pharynx and its pouches in the embryo, and the results obtained were quite satisfactory.

The method appears to be a modified form of the "free modelling" which was employed by W. His in the preparation of the series of models, now universally known, illustrating the development of the human embryo and of the chick—a method which His strongly recommended for embryological work up to the last, when many other workers were using the wax-plate method of Born.

Peter's criticism of His' method (1) is that it demanded an unusually high "technical" equipment in the worker, and that it afforded possible sources of error, since only individual points were given of the outline of sections.

I am inclined to think that His' method was not followed by the workers who succeeded him largely because the additional modifications and improvements introduced into the wax-plate method, and especially the addition of "ritzer" lines for guidance, gave that method an accuracy which could not be attained by His' original method, which was used without such aids.

The method which I have worked out meets the requirements essential in any satisfactory reconstruction method, inasmuch as it depends upon exact technique and upon measurements, and is therefore independent of the personal factor in the reconstructor. It has the great advantage that a satisfactory model can be produced in a fraction of the time required by the wax-plate method. It is applicable to practically any degree of enlargement, though it is more suitable for the production of a large-sized model than of a small one.

A high degree of technical or artistic capacity in the modeller is not essential, and I believe that the amount of error in the model prepared by this method can be reduced to as small an amount as is involved in trimming the edges of wax-plates, a procedure which is necessary in Born's method, in order to remove the "terraced" appearance of the surface which is a result of that method, and which gives an erroneous idea of the surface.

In all its preliminary steps up to and including the drawing of the sections at a suitable magnification, the method follows exactly the same lines as the wax-plate method, and hence it is not necessary to describe these steps in detail.

Of the succeeding steps, perhaps the simplest description will be afforded by describing the procedure followed in preparing a model of the external surface of an embryo. Briefly stated, they consist in making a linear profile reconstruction of the median sagittal section of the embryo, and

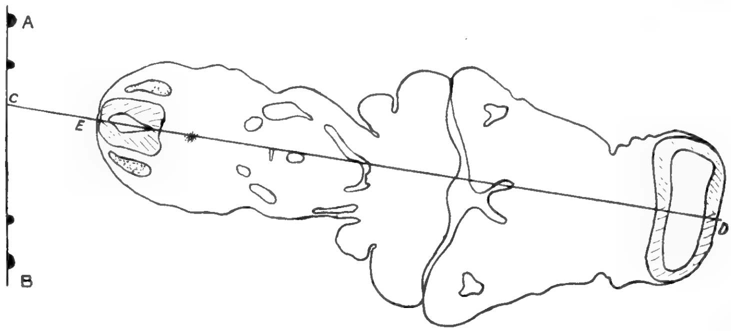

Fig. 1.—Section of human embryo, with orientation line A B, median sagittal plane C D.

then building up, upon the outline so obtained, first one half of the embryo and then the other half, in modelling clay.

1. *Linear Reconstruction of the Median Sagittal Section.*—To those who are familiar with all the methods of linear reconstruction, this procedure presents no difficulty.

It is only necessary to bear in mind that as the embryo is asymmetrical in the majority of cases, the median plane of the embryo in the section drawings does not coincide in all cases with the line of the median sagittal section.

The difficulty involved in this is overcome in the following way. The drawing of a typical section is taken, and upon it the line of the median axis of the embryo is drawn (fig. 1, E D). This axis is prolonged to meet the "orientation" line, which it intersects at the point C.

On the drawings of each of the other sections a line is then inserted similar to the line C D, that is, it begins at the point C on the orientation line, and is at the same angle to the orientation line A B.

The simplest way of doing this is to copy the "ritzer" line and the line C D on tracing paper, and then to superimpose and copy the tracing on the other section drawings.

Figs. 2 and 3 show how such a line falls in some of the other sections.

In making the linear reconstruction, the line C D is used in all sections, and the distances C E and C D are used to obtain the outline required (fig. 4).

2. *Building up the Model.*—The linear reconstruction on millimetre paper is fixed to a flat board, and a thin sheet of glass is placed on it. Modelling clay is then placed on the glass plate and distributed over the outline and moulded exactly to the margin of the subjacent reconstruction. Then, beginning at the head or tail end, the surface of the clay is moulded

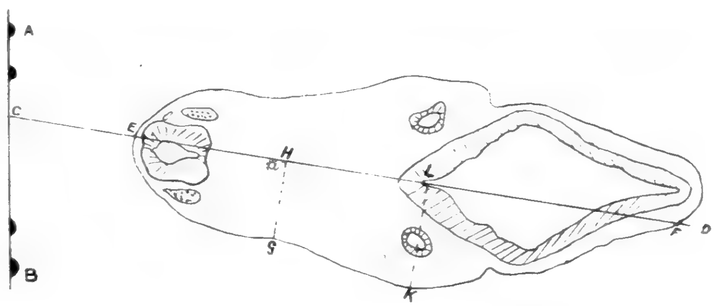

FIG. 2.—Section of embryo, with the orientation line A B, and the line C D, which gives the plane of the mesial sagittal section of the whole embryo at this level.

to the surface contour of the outline of each section. At first it is not necessary to take every section, but every fifth or tenth section. The procedure will again be explained most simply by a concrete example.

Suppose the line E F in fig. 4 is the level of the section in fig. 2; then the surface of the clay along that line is to be moulded to the outline E G K F in fig. 2.

This is done by measuring lines such as G H and K L and levelling the clay at these points to that height.

A sufficient number of points must be taken to ensure that the elevations and depressions of the surface are correctly represented.

An instrument like a knitting needle is employed, the length of G H, L K, etc., measured off on it, and the instrument is plunged into the modelling clay at the corresponding point, and the clay at these points is raised the required level.

When the principle is grasped, there is not the slightest difficulty in carrying out its practical application, and individual workers can easily devise suitable instruments for helping them in special points. One or two differently shaped modelling tools, of metal or wood, are useful.

After the first rough outline has been obtained, the model is again revised, using every section if the outline varies appreciably from section to section, until an accurate result has been obtained.

3. *Making the Permanent Model.*—The clay model is then embedded in plaster of Paris, a uniform thickness of plaster being spread over the surface to a depth of from half to one inch.

After it has set, the plaster case containing the clay model is lifted off the glass plate, and turned over.

On the surface now exposed there is the outline in clay of the median sagittal section, and a plaster case surrounding it.

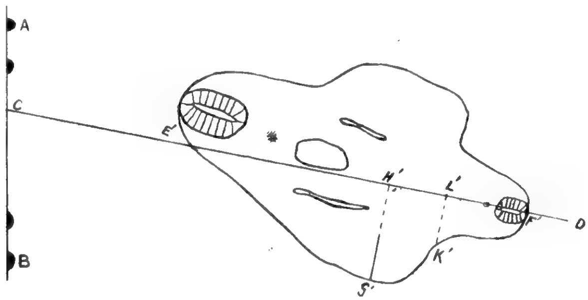

Fig. 3.—Section of same embryo near tail end showing how the line C D falls in this case.

The clay surface can be treated in a variety of ways.

If a complete model of the whole embryo is required, the outline contour is built up in clay in practically the same way as before, the level of the various sections being easily identified, and the level of the plaster being used instead of the glass plate to measure the depth.

It may also be used as a basis for modelling, in relief, the cavities of the body, or as a basis for building up some selected structures, *e.g.* pharynx, heart, etc.

There is no special difficulty in carrying out either of these alternatives, but it is important to have a clear idea of what structures it is desired to include in the model before starting.

After this side has been finished, it is also embedded in plaster. There is therefore now a complete plaster mould from which casts can be taken, in plaster or other medium, and painted as desired.

The details of the plaster casting differ in no way from the ordinary steps.

One or two practical details may be added.

Modelling clay is cheap, and can be obtained from dealers in artists' materials. To keep it moist, it should be placed in a large jar, and covered with a damp cloth.

The surface of the glass plate should be rubbed over with vaseline before the plaster of Paris is put on it, to prevent the glass and plaster adhering.

Modelling tools of different shapes can be obtained from ironmongers or artists' dealers. One with a flat, curved end is useful.

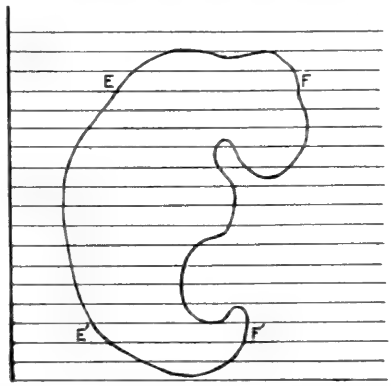

Fig. 4.—Linear profile reconstruction of median sagittal section from horizontal sections.

A model of a portion of an embryo can be easily made, by exactly the same method,—using the outline on the sagittal section of that portion only, and measuring its diameters from section to section.

Dissectible models cannot be easily prepared by this method, except by a somewhat lengthy process, but the advantage of the method is that it affords a rapid means of obtaining an accurate plaster model of any structures which one may desire to see in the solid, with their relations to adjacent structures.

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CONGENITAL ANOMALIES OF THE FIFTH LUMBAR VERTEBRA AND THEIR CONSEQUENCES. By J. APPLETON NUTTER, B.A., M.D., C.M., *Montreal.* (*From the Department of Anatomy, M'Gill University.*)

THE vertebral column has of late years proved of increasing interest to the surgeon. With the perfecting of the X-rays has come much greater opportunity for study, and congenital anomalies are known to play a far more important rôle in the consideration of the spinal column than would have been conceded but a few years back. The anatomy of the last lumbar vertebra and of the lumbo-sacral articulation has in the opinion of the writer not received the attention it merits. A careful study of numerous X-rays of the lumbar spine has on many occasions revealed perplexing conditions, which have been cleared up only by attention to the vertebral embryology and its variations. It was with the hope of adding to our knowledge of this region of the spine that the present study was undertaken.

Attention must be drawn to the insecurity of the lumbo-sacral articulation. In the erect position of the body this has a downward and forward inclination of some 30°, thus furnishing a strong tendency for the heavy trunk to slide downwards into the pelvis. To add to the insecurity due to gravity, one finds free movement at this part of the vertebral column. Such movement is made possible partly by changes in the intervertebral substance, which, bearing as it does the weight of the body, is nevertheless not flattened out by the superincumbent weight. With its semi-solid nucleus under great pressure it resembles a water-pillow. If it, however, permits free movement for the spine, it does not afford a corresponding amount of security. Nor are the various ligaments which bind the last lumbar vertebra to the sacrum in themselves of sufficient strength to prevent gradual displacement forward under the action of gravity. Indeed, almost the whole strength of the articulation depends upon the inferior articular processes, which are gripped firmly between the articular processes arising from the sacrum. A sliding of these two pairs of processes upon each other affords the main movement of the articulation. During forward bending of the trunk, the inferior articular processes move upward upon the sacral articular processes. This movement in itself, if carried beyond normal limits, can result in a dislocation of either one or both articular processes, with consequent forward displacement of the vertebra. Such a forward displacement of the body alone or of the entire fifth lumbar vertebra is termed spondylolisthesis.

It will be remembered that the general rule for vertebral ossification calls for three primary centres, which appear toward the end of the second month of fœtal life. One is for the main part of the vertebral body; the remaining two form the two halves of the neural arch, with a small portion of the body. Soon after puberty a number of secondary centres appear which do not become wholly united before the twenty-fifth year. The neural arch of the fifth lumbar vertebra is said to have normally two centres of ossification in each half, the line of division passing between the superior and inferior articular processes. This point marks the spot where laminar deficiency is to be found, as is well shown in all the specimens.

It is in the comparison of parts known in human anatomy under the general name of transverse processes that the main difficulty of establishing homologies exists. The transverse processes of the cervical vertebræ possess a foramen which in all but the seventh transmits the vertebral artery. If we examine a cervical rib we shall see that the foramen is still there, and that it separates the rib, which lies in front of it, from the transverse process proper, which lies behind. The part of a cervical transverse process in front of the vertebrarterial foramen is therefore generally admitted to correspond to the first part of a rib, while the part behind the foramen corresponds to the transverse process proper.

In the thoracic region the ribs articulate with the transverse processes and lie in front of them. There are, however, no foramina here.[1] In the lumbar region the transverse processes are elongated, and it is held that their outer part corresponds with the first part of the ribs. No foramen is normally present here, as rib and transverse process proper are fused together. We shall, however, see that this foramen is at times found even in the lumbar transverse process, and that it is analogous to the cervical foramen.

The whole number of vertebræ may be diminished or increased by one. The first sacral, normally the twenty-fifth vertebra, may be the twenty-fourth or twenty-sixth. It is believed that such numerical variation is the result of an error in segmentation.

A want of development of the bodies, which may be only half the normal height on either or both sides, is found almost exclusively in the lumbar region. Such a condition has most far-reaching results when an asymmetrical vertebra is formed at the lumbo-sacral junction. In such

[1] A foramen in this part of the twelfth thoracic vertebra is by no means uncommon.

case the vertebra in question may be either the fifth lumbar or a supernumerary vertebra. A case illustrative of this will be cited later. There may be an intermediate or transitional form, the so-called lumbo-sacral vertebra, in which one side is united to the sacrum and the other has a free transverse process as seen in a lumbar vertebra. The explanation of this is simple. The position and form of the sacrum depend upon the innominate bones which articulate with it. If the innominate bones become by chance asymmetrically placed, a vertebra may show sacral characteristics on the side where it articulates with the innominate, and a free transverse process where no such articulation exists.

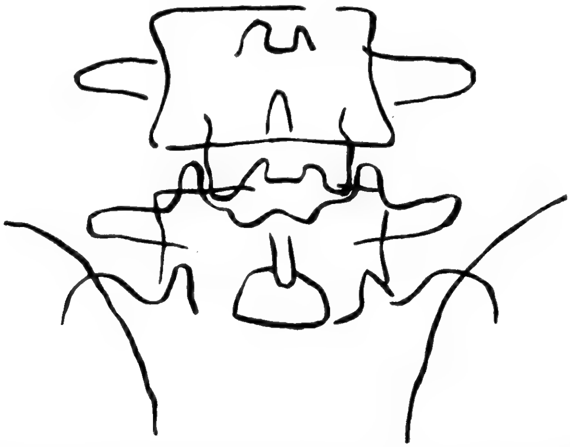

FIG. 1.—Tracing of skiagram of normal lumbo-sacral junction. Last two lumbar vertebræ, upper portion of sacrum, and adjoining iliac crests shown.

Anomalies of the last or fifth lumbar vertebra may be classified, as has been suggested by Manners-Smith (*Journal of Anatomy and Physiology*, vol. xliii.), under four headings, which we shall increase to eight.

1. Foramina in relation to the Transverse Process.

Under this first heading we have to deal with anomalous foramina in and near the transverse processes. That most frequently seen is one behind the root of the transverse process and close to the superior articular process. This seems to agree exactly with a retrotransverse foramen found in the sacrum of the ornithorhynchus. A nearly complete foramen of this type can be seen in the specimen from the M'Gill Museum of Anatomy showing defective ossification of one lamina.

The foramen (fig. 2), however, which primarily interests us is one by which the transverse process is pierced near the middle of its root. This foramen is without doubt analogous to that seen normally in the transverse processes of the cervical vertebræ. It will be remembered that this cervical foramen is considered to divide the transverse process into its own component

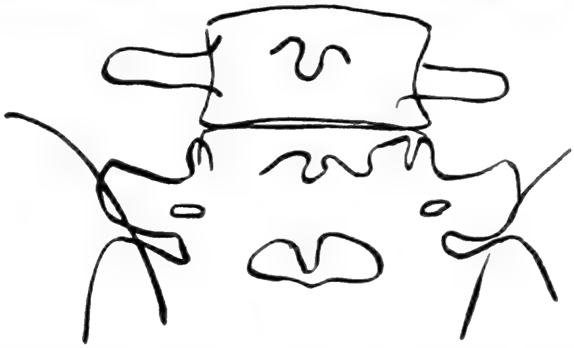

Fig. 2.—Fifth lumbar vertebra shows sacralisation of transverse processes, which show foramina in their roots. Strikingly suggestive of cervical foramina.

parts, the rib element being anterior. It is not, therefore, an undue assumption on our part to conceive of this foramen in the lumbar transverse process as pointing to its twofold origin, in that it originally was made up of rib and transverse process.

2. Bifurcation of the Transverse Process (figs. 3 and 4).

This differentiation or resolution of the transverse process into its component parts is much more plainly seen when carried to the extent of actual bifurcation of the process. The gap shown is merely an enlarged foramen, which separates the true transverse process above from what corresponds to the rib below. The latter may and often does articulate or even fuse with the sacrum. Such bifurcation may vary in extent from a mere suggestion to the well-marked specimen shown in one of the X-ray tracings.

3. Enlargement of the Transverse Processes, so-called Sacralisation (figs. 4 and 5).

One of the commonest anomalies seen in the fifth lumbar vertebra is the so-called sacralisation. By this term is meant that the transverse processes are much increased in size, most unlike the ordinary lumbar transverse processes, and resemble the lateral masses of the sacral segments.

Fig. 3.—Bifurcation of the transverse processes of last lumbar vertebra, with resolution into costal elements (A and A′) above, and transverse elements (B and B′) below, the latter articulating with sacrum and probably with iliac crests.

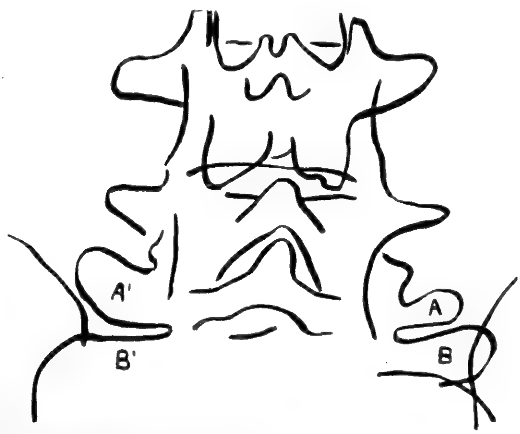

Fig. 4.—Asymmetry at lumbo-sacral junction. A and A′, the costal elements of the fifth pair of lumbar transverse processes, correspond, as do B and B′, the corresponding transverse elements. B′ has become sacralised owing to the higher position of the innominate bone of that side, and is shown fused with the sacrum. B, on the side of the more caudally placed innominate bone, remains separate, though articulating with the sacrum.

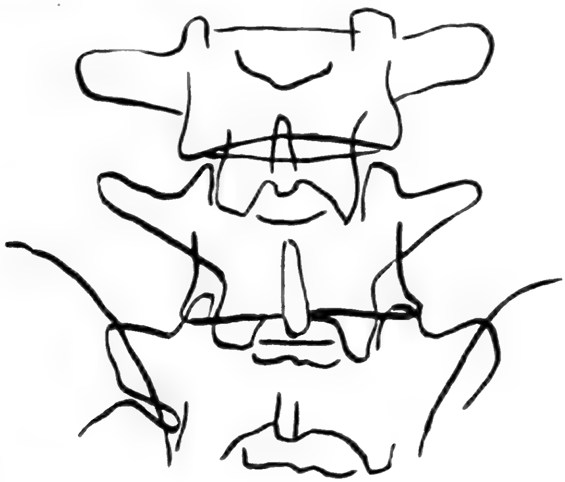

FIG. 5.—Shows relatively common overgrowth of the transverse processes of the last lumbar vertebra (so-called sacralisation). Note the short, thick processes, that on the left side at least articulating with the sacrum.

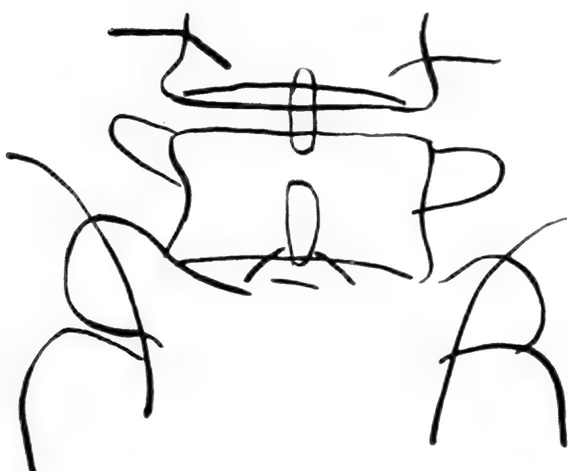

FIG. 6.—Shows marked sacralisation of the transverse processes of the fifth lumbar vertebra, with abnormal articulation with the sacrum on the right.

Such a change is very common indeed, and when one-sided has been mistaken in the X-ray for some pathological condition.

4. Abnormal Articulation with the Sacrum and Ilium (figs. 3, 6, 7).

Another anomaly to be mentioned while speaking of the transverse process is that of its articulation or fusion with the ala or lateral portion of the sacrum. This articulation is frequent and distinct, and was named the "lumbo-sacral transverse articulation" by the late Professor Dwight of Harvard University. A transverse process can articulate with the sacrum,

Fig. 7.—Both transverse processes sacralised. Both articulate with sacrum, and probably with iliac crests. Congenital imperfection of neural arch, with failure to unite posteriorly.

or even with the iliac crest, without having assumed sacral characteristics. This, however, is uncommon, and is unlikely to be congenital—rather acquired. It is generally in the case of sacralised transverse processes that we find abnormal articulation with the sacrum, and in some instances even fusion.

From the surgical view-point we may consider such enlargements of the transverse processes as of importance almost wholly confined to the production of scoliosis. Z. B. Adams in the *Journal of the American Orthopedic Association* for November 1910 reports such an instance. In his case the patient, a young girl, suffered from scoliosis. This was by X-ray shown to be caused by the impinging of a partly sacralised transverse process against the ilium or sacrum, thus forcing the vertebral column to the other side. Removal of the offending process gave immediate and marked improvement.

It is probable also that such an impinging, if repeated, might be the cause of a persistent pain in the back or referred to the region of the sciatic nerve. A bursa, which if inflamed would produce characteristic disturbance, would naturally be formed at the site of this abnormal articulation.

5. Asymmetry of the Body of the Vertebra.

Such a condition has been already noted to occur almost exclusively in the lumbar region. There may be practically complete absence of one

Fig. 8.—Asymmetry of the neural arch of the fifth lumbar vertebra, the two laminæ having very different appearances. In a traumatic case this skiagram might easily be mistaken to indicate fracture of the neural arch.

lateral half of the body. When found at the lumbo-sacral junction the asymmetrical body may be that of the fifth lumbar, or may be supernumerary. Joachimsthal in the *Deutsche medizinische Wochenschrift*, 15th September 1910 ("Ueber angeborene Wirbelanomalien als Ursache von Rückgratsverkrummungen"), reports a case of congenital scoliosis in a child of three years. The lumbar spine was inclined to the right. An X-ray revealed the cause to be a supernumerary half-vertebra interposed between the fifth lumbar and the sacrum. This was developed only in its left half, which naturally had the effect of tilting the spinal column to the right. In addition the body of the fifth lumbar vertebra showed marked diminution of its left half, and that of the fourth the same deformity to a slight extent. The X-ray apparently showed no trace of any other portion of the supernumerary vertebra save that of its body.

6. Imperfect Ossification of the Laminæ (figs. 9, 10, 11, 13).

All these anomalies so far discussed, though potentially productive of scoliosis and back or leg pain, are unlikely to offer a menace to life. We now, however, come to an anomaly that is of vital importance to all of us, namely, imperfect union of the laminæ, the result of unfinished ossification of the neural arch.

The instability of the lumbo-sacral articulation has already been pointed out. The importance of the articular processes in affording secure anchorage to the vertebral column has been demonstrated. It has been shown that

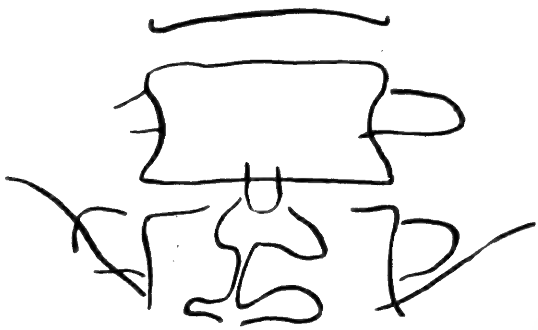

Fig. 9.—Ossification defect in the left lamina of the fifth lumbar vertebra, with failure of the neural arch to unite. Laminar asymmetry well marked. Analogous to spina bifida, but easily mistaken for fracture.

each side of the neural arch has two centres of ossification, and that these meet one another at a point between the two articular processes. When deficient laminar ossification occurs, and it is most commonly bilateral, the body of the vertebra rests most insecurely upon the sacrum, and must trust to frail supports—mainly the intervertebral substance—to keep it from sliding downward and forward over the promontory and into the pelvis.

The pictures are here shown of a specimen (fig. 12) now in the M'Gill Pathological Museum. The case was reported by Dr A. H. MacCordick and the writer in the *Journal of the American Orthopedic Association* for November 1912. It was known to many at the Montreal General Hospital. A young Englishman was struck down by a blow in the back from a falling beam. His back was broken and his spinal cord crushed. After two years of suffering it was at post-mortem discovered that this man's fifth lumbar vertebra had been imperfectly ossified (fig. 13). His laminæ, as can be seen, were incomplete, the anchorage at his lumbo-sacral articulation was

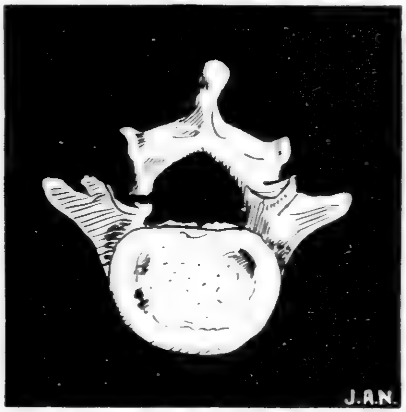

Fig. 10.—Fifth lumbar vertebra from M'Gill University Museum of Anatomy showing unilateral ossification defect between superior and inferior articular processes.

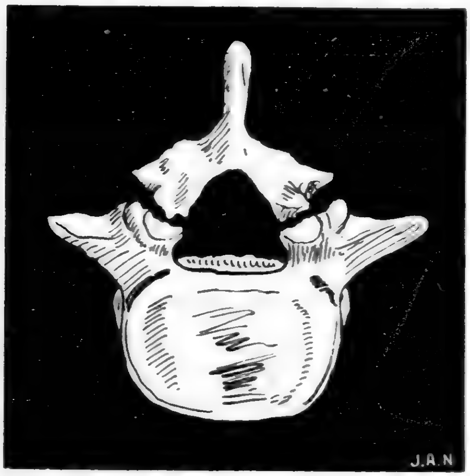

Fig. 11.—Fifth lumbar vertebra from M'Gill University Museum of Anatomy showing double ossification defect in the interarticular portions of the neural arch.

thereby weakened, and the blow upon his back was sufficient to drive forward the last lumbar vertebra upon the sacrum, producing spondylo-

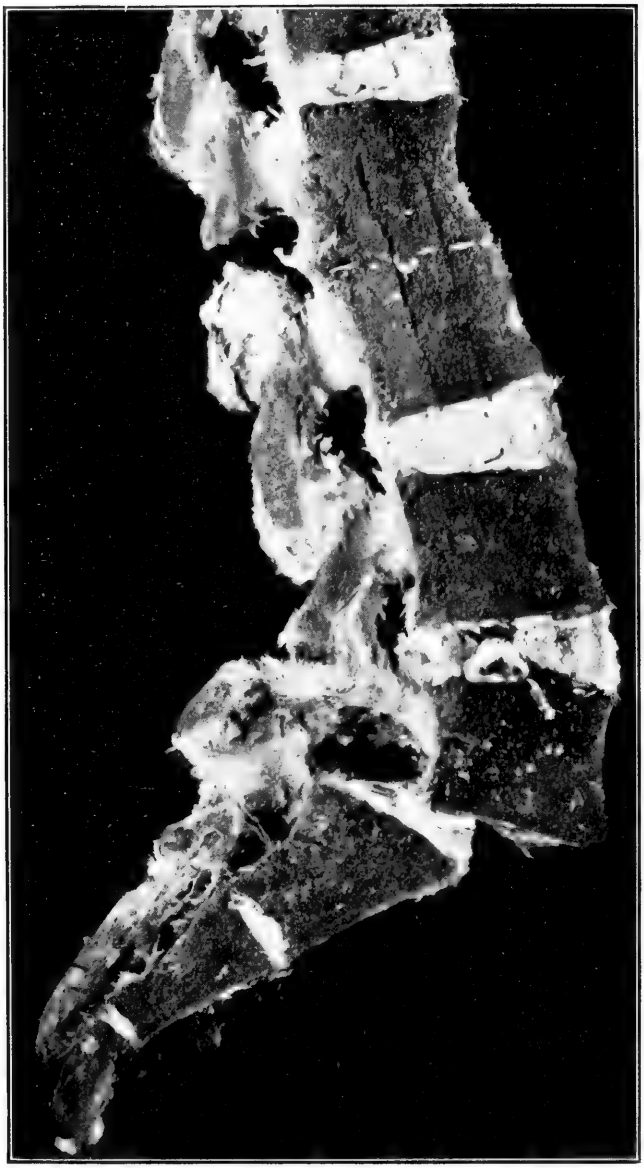

Fig. 12.—Case of traumatic spondylolisthesis. Note displacement forward of body of fifth lumbar vertebra, due to weakness of its neural arch through imperfect ossification. Fifth lumbar vertebra shown in fig. 13.

listhesis and crushing of the spinal cord. It is quite possible, if not probable, that in his case the blow might not have produced such fatal results had his fifth lumbar vertebra been of normal strength in all its parts. Statistics are not at hand to determine how many of us are going through life with spines imperfectly ossified, awaiting the blow that when directed against our weakened laminæ shall at once break our backs. Two other specimens of congenital deficiency in the neural arch are to be found in the Anatomical Museum of M'Gill University. In one specimen the deficiency is bilateral, as is more common. The other shows it upon one side only.

Do not suppose that the evil effects of a congenitally weakened vertebra

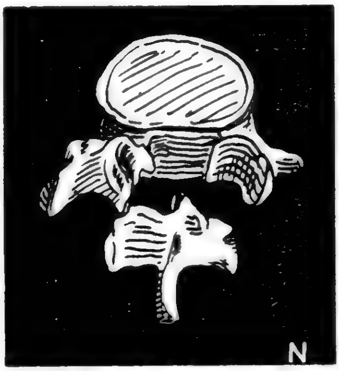

FIG. 13.—Fifth lumbar vertebra from case of traumatic spondylolisthesis. Note imperfection of both halves of neural arch, leading to displacement forward of the body and partial fracture of the left pedicle.

are to be seen as the result of sudden and violent trauma alone. A study of the deformity produced by a displacement of the body of the fifth lumbar vertebra forward upon the sacrum (so-called spondylolisthesis) was recently undertaken. Such a deformity narrows markedly the inlet of the pelvis, offering a serious impediment to labour. Its study hitherto has been largely confined to the members of the obstetrical faculty. An inquiry into its ætiology has proved most interesting in the light of the subject now under consideration. Here, again, we find that a congenitally imperfect neural arch is by far the commonest cause of the displacement forward of the spine. The existing weakness of the anchorage is, however, increased by the softening of the ligaments incident to menstruation and pregnancy. As a consequence, the body of the last lumbar vertebra becomes displaced forward by slow degrees. Trauma, no more severe than that associated with heavy work, may be sufficient to produce spondylolisthesis, especially in women subjected to repeated pregnancies. It is thus seen that a weakened neural arch at this particular spot is a constant menace to its possessor, and to a much greater extent if the possessor be a woman.

7. Spina Bifida or Hydrorrhachis

is, as a rule, associated with defect not in one but in several adjoining vertebræ. Mention should, however, be made of this congenital malformation of the neural arches, with its accompanying hernia of the spinal membranes. As is well known, it is most commonly found in the sacral and lumbar regions. It is due to a more or less complete lack of closure of the spinal canal posteriorly. The neural arches may be partially or completely absent. When these are present in part it will be found that the lamina of either side has failed to unite with its fellow. In rare instances the sac is found to protrude between completely formed arches.

8. Congenital Changes in the Articular Processes.

Goldthwait ("Lumbo-Sacral Articulation," *Boston Medical and Surgical Journal*, 16th March 1911) insists upon the instability of the fifth lumbar vertebra, and its absolute dependence upon its inferior articular processes. Stress is laid upon variation in the articular processes themselves. There is, indeed, considerable movement of these upon the sacral articular processes, so that a small-sized process would not require much movement to become dislocated from its sacral anchorage. In like manner these processes afford much less stability when they resemble the dorsal articular processes in being directed antero-posteriorly instead of laterally. (See also Goldthwait, "An Anatomic Explanation of many Cases of Weak Backs, etc.," *Journal of the American Orthopedic Association*, February 1913.)

A CASE OF COMPLETE ABSENCE OF BOTH INTERNAL CAROTID ARTERIES, WITH A PRELIMINARY NOTE ON THE DEVELOPMENTAL HISTORY OF THE STAPEDIAL ARTERY.

By A. G. Timbrell Fisher, M.B., Ch.B., M.R.C.S., L.R.C.P., *Demonstrator of Anatomy and of Surgical Applied Anatomy, University of Bristol.*

Complete absence of both internal carotid arteries must be a very rare condition in man, as a careful review of the literature at one's command does not reveal any record of such an arterial anomaly, although a more thorough investigation might have brought to light instances of its occurrence.

The case to be described was noticed during the post-mortem examination of a man aged thirty-nine who died from cerebral hæmorrhage. Dr Scott Williamson, pathologist to the Bristol General Hospital, kindly sent the brain and part of the base of the skull with attached neck parts to the Anatomical Department of Bristol University for a more detailed examination of the condition present, and through the kindness of Professor Fawcett this duty devolved upon myself.

Comparative Anatomy.

In Ruminants (8), of which the sheep may serve as a type, the internal carotid artery, properly so called, is absent. Its place in the cranium is taken by a small oval network lying at the side of the sella Turcica under the dura mater—the rete mirabile. There are three originating arteries of the rete as a rule. One of these, the spheno-spinous artery, arises from the internal maxillary at the same point as the inferior dental artery, and enters cranium through foramen ovale. The other two originating arteries arise from internal maxillary in common with the ophthalmic artery and pass backwards through a supra-sphenoidal canal. Towards the middle part and above, the rete reconstitutes itself into a trunk which traverses the dura mater and divides into the anterior, middle, and posterior cerebral arteries. In the ox the rete forms a more circular mass surrounding the sella Turcica; the occipital arteries assist in its formation.

In Carnivora such as the dog the internal carotid artery enters the carotid canal at its posterior opening, and, running forwards, leaves the cranium at the carotid foramen by making a considerable bend. It then re-enters the cranium, having received a branch from the external carotid, and anastomoses on the side of the pituitary fossa with the spheno-spinous artery and returning branches of the ophthalmic artery. In this way a plexus is formed which probably represents the rete mirabile of Ruminants and Pachyderms, and from which the cerebral arteries proceed. The function of the rete mirabile appears to be to prevent cerebral congestion in grazing animals, whose heads are dependent for long periods.

In Fishes (9) two carotids, usually described as anterior and posterior, or as internal and external, can generally be seen arising on each side from the anterior afferent branchial arteries, although they are subject to a good deal of variation.

From Amphibia onwards, the internal and external carotids arise by bifurcation of the common carotid.

Absence of a Single Internal Carotid Artery in Man.

Wyeth (1) mentions a case in which the left internal carotid artery was absent and no carotid canal was present. The anastomoses were not described. Wyeth calls attention to a somewhat similar case described by Eugene Peugnet (2), and states that a skull was seen by Koberwein with only one carotid canal.

Mrs Flemming (3) has recorded absence of the left internal carotid artery. In this case "three branches came off from the arch of the aorta, viz. innominate, left subclavian, and between them a small branch which had the distribution of the left external carotid. No internal carotid artery was present on the left side; on the right side the common carotid divided as usual. The arrangement of the arteries at the base of brain was as follows:—The right internal carotid divided into a right middle cerebral and a trunk which anteriorly divided into right and left anterior cerebrals. The basilar artery divided into the right posterior cerebral and a trunk three-eighths of an inch long which divided into the left posterior cerebral and left middle cerebral. The latter was connected by a slender branch with the left anterior cerebral, thus completing the circle of Willis." The ophthalmic artery on the left side arose from the middle cerebral. No carotid canal was present.

Quain, in his classical *Commentary on the Arteries*, describes a case of absence of the left internal carotid artery, and through the kindness of Professor Thane I have been able to examine the original specimen. To quote Quain's own words, on the left side (fig. 1) "the carotid artery furnishes the usual branches of the external carotid and divides into temporal and internal maxillary arteries. In the place of an internal carotid, of which there is no trace, two tortuous branches derived from the internal maxillary join within the skull to form a single vessel which lies to the inner side of the fifth nerve. The artery so constructed being, however, smaller than the usual size of the internal carotid, the deficiency is compensated by the artery of the opposite side, which is of large size." This case is of more than usual interest because it is so similar to the condition present in Ruminants (*vide supra*). The single large trunk lying to the inner side of the fifth nerve occupies the position of the rete mirabile in the sheep, and the arteries springing from the internal

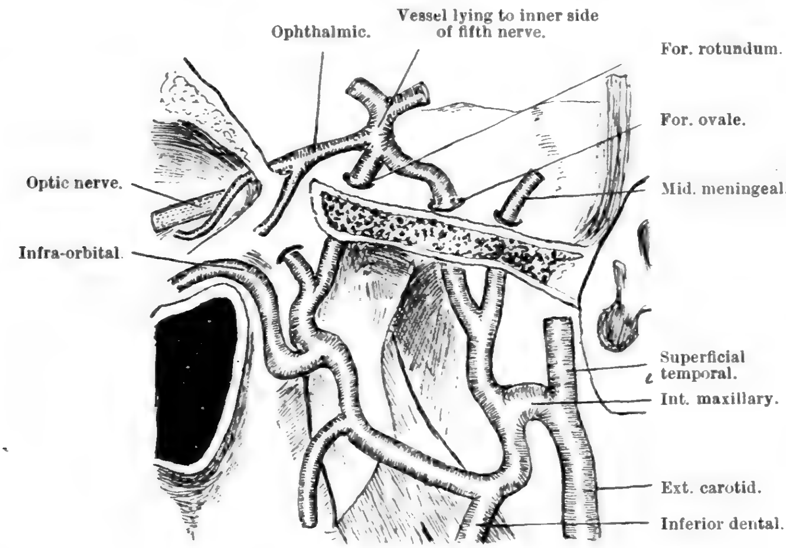

Fig 1.—Absence of left internal carotid (Quain).

maxillary and entering the cranium through the foramen rotundum and foramen ovale remind one quite forcibly of the originating arteries of the rete, which also spring from the internal maxillary.

Quain also refers to a case described by Tode (4) in which the right internal carotid was absent, and the carotid canal was very small—sufficient only "to allow the passage of a bristle."

In Wernitz's (5) list of cases, absence of the right internal carotid artery is mentioned associated with hydroanencephalus.

Case under Consideration.

Turning now to the case under consideration, it may be mentioned in the first place that the condition did not lead to any symptoms during life, although it may have hastened its end. Increased strain must have been thrown upon the artery which ruptured and caused death, owing to the abnormal features presented by the circle of Willis. The kidneys were arterio-sclerotic, but there was very little arterio-sclerosis evident in the arteries of the base of the brain.

Arrangement of Cerebral Arteries (fig. 2).

The basilar artery, nearly double its normal calibre, ended slightly to the right of the mesial plane at the upper border of the pons by dividing into

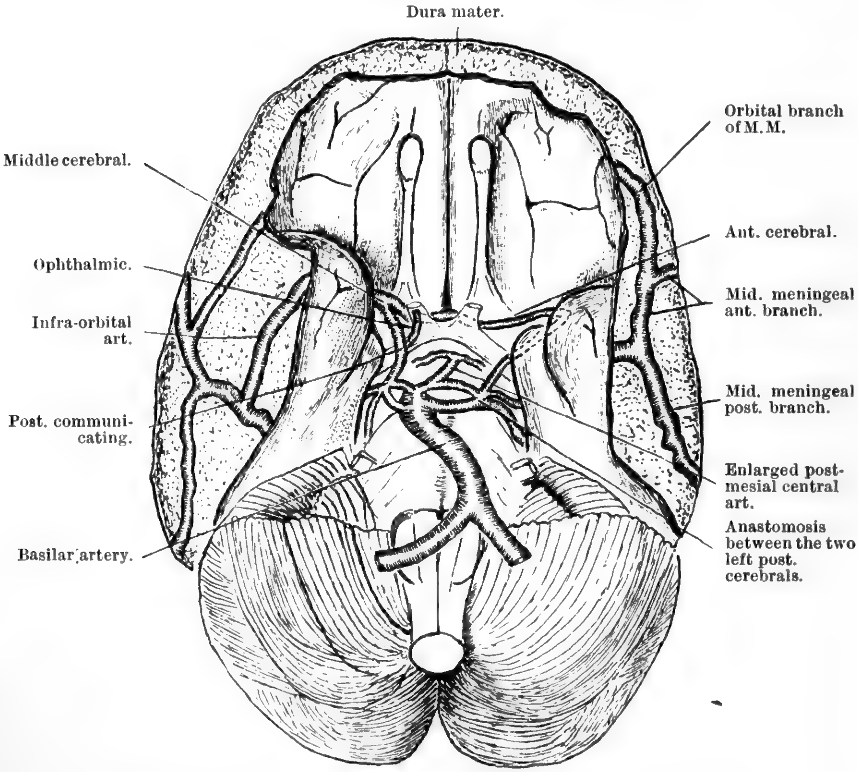

FIG. 2.—Absence of both internal carotid arteries. Showing arteries at base of brain and in dura mater.

the posterior cerebrals. A supernumerary posterior cerebral was given off just before the terminal bifurcation. The two left posterior cerebrals are longer and of greater calibre than those of the right side. On each side the two posterior cerebrals are joined together by anastomosis a short distance from their origin; they then divide and subdivide and form a wide-meshed rete situated on the crus cerebri, which distributes the ordinary branches of the posterior cerebral. The distally situated posterior cerebral on the left side gives off an enormously enlarged postero-mesial central artery. This at first sight seems to be a continuation of the basilar; it divides into two branches which come off at right angles and enter the locus perforatus posticus. Subsequent dissection showed that they traversed the subthalamic region and finally entered the posterior part of the internal capsule, and it was evidently the rupture of this artery on the left side that caused death.

On each side, from the point of anastomosis of the two posterior cerebrals, a slender artery proceeds forwards and outwards, occupying the position of the posterior communicating artery in the normal brain. On examining transverse sections of these latter arteries, they were seen to be almost entirely occluded by concentric fibrosis. On the right side, however, the fibrosis occurs in that part which extends between the origin of the ophthalmic artery and the posterior cerebral. These slender arteries divide at the locus perforatus anticus, further out on the left side than on the right side, into anterior and middle cerebral arteries. The latter are joined by the anterior communicating artery, thus completing the circle of Willis. On the right side the common trunk of the anterior and middle cerebrals gives off an ophthalmic artery in the middle of its course, and both give off an anterior choroidal artery near their termination.

Antero-mesial and antero-lateral central arteries are given off in the usual way by the anterior and middle cerebral arteries, and seem normal in number, size, and distribution. It is probable that the circulation in the anterior and middle cerebrals was mainly carried on through the anastomoses of the posterior and middle cerebrals through their temporal branches.

Condition of Brain.

The brain weighed 1080 grammes; the left temporal lobe presented a general shrinking without any alteration in the configuration of the convolutions, which were atrophied mainly at the expense of the grey matter, and were firm and hard, with the arachnoid and pia mater closely adherent. This atrophy is interesting, as atrophy of the right temporal and parietal lobes has been noticed with small internal carotid arteries by Klebs (6).

The Dura Mater (fig. 2).

From the anterior division of the middle meningeal artery a branch of considerable size runs almost directly forwards. This branch, which is a very much enlarged orbital (Quain) or lacrimal (Macalister) branch of the middle meningeal, does duty for the ophthalmic artery on the left side, but on the right side is an accessory ophthalmic. In accordance with this fact, the orbital branch of the left middle meningeal is nearly double the size of that on the right side. An examination of the base of the skull shows that both these arteries pass through the outer part of the sphenoidal fissure. From the trunk of the middle meningeal on the right side another branch runs forwards and slightly inwards. An examination of the base of the skull shows that this branch is also present on the left side, and that in each case it passes through the foramen rotundum.

The Base of the Skull.

The depth of the middle fossa is greater on the right side than on the left, in accordance with the atrophy of the left temporal lobe. There is no carotid canal present in the petrous portion of the temporal bone on either side. The orbital and infra-orbital branches of the middle meningeal, already referred to, produce very deep grooves leading to the outer part of the sphenoidal fissure and to the foramen rotundum respectively. The groove for the orbital artery was not occupied by the ophthalmic division of the fifth, and lay some way to the outer side of the groove for the infra-orbital artery, which, however, was also occupied by the second division of the fifth nerve. An enlarged meningeal branch of the ascending pharyngeal artery enters the skull through a foramen Vesalii on each side, and is distributed to the dura mater of the cavernous sinus. Unfortunately, the orbits were not preserved, and the intra-orbital course and relations of the ophthalmic arteries could not be ascertained.

The Condition in the Neck.

The external carotids are considerably enlarged and tortuous, and give off their usual branches, finally dividing at the usual level into superficial temporal and internal maxillary arteries. The ascending pharyngeal and occipital spring from a common stem.

Developmental Considerations.

Before giving the facts referred to a developmental explanation, it may perhaps not be out of place in this connexion to review shortly a few well-known facts concerning the development of the internal carotid and stapedial arteries. In this it will perhaps be safe to follow closely the very clear account given in the section devoted to the subject in Keibel and Mall's *Embryology* (7), founded on researches by de Vriese, Tandler, and others (fig. 3). The internal carotid consists morphologically of three elements—a root portion derived from the third arch; an intermediate portion derived from the dorsal aorta between the third and first arches; and a distal portion, which is the continuation of the dorsal end of the first arch towards the developing brain. According to de Vriese and others, in all early embryos the internal carotid artery, after giving off the ophthalmic artery, can be

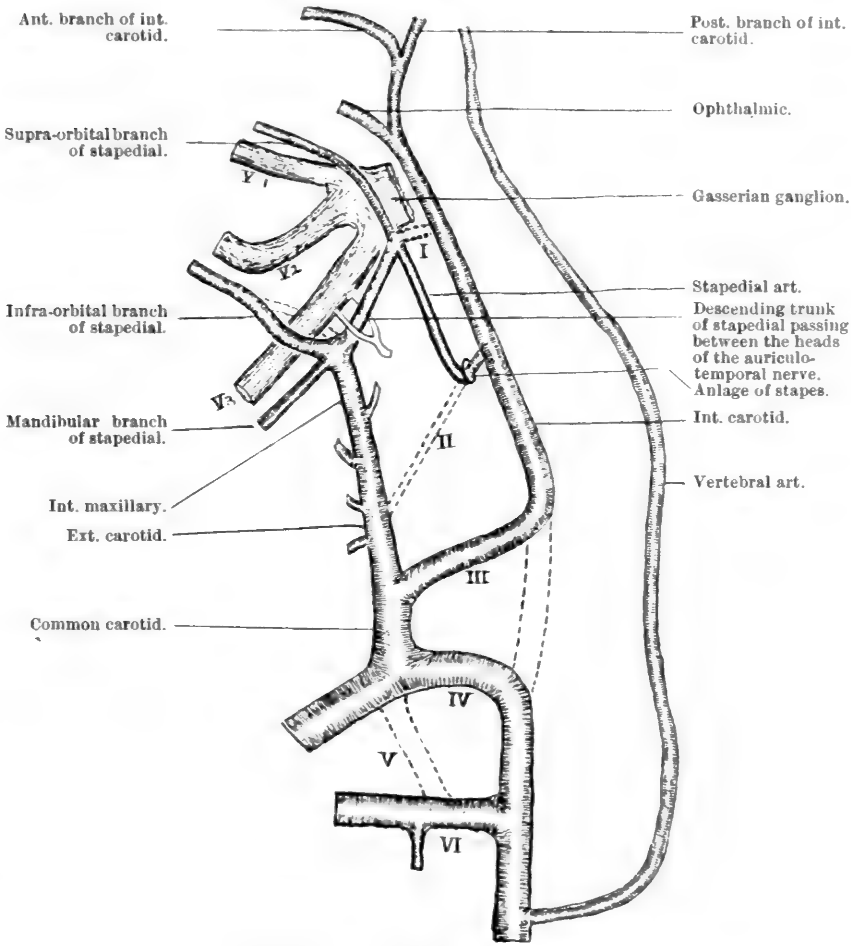

Fig. 3.—Illustrates the development of the internal carotid and stapedial arteries (after Tandler).

I–VI = aortic arches. V_1, V_2, V_3 = divisions of fifth nerve.

seen to divide into an anterior and a posterior branch, of which the latter is by far the more important, and sweeps back to join the cerebral vertebrals. The anterior branch, after giving off the anterior choroidal, runs by the side of the fore-brain, and finally meets its fellow of the opposite side just behind the nasal pit. This vessel is the anterior cerebral. It gives off in its course a number of branches, which are afterwards concentrated to form the middle cerebral. The posterior cerebral artery is at first represented by a number of branches which come off the posterior terminal branch of the internal carotid. Even in the 48-mm. stage there are present a large artery to the mid-brain and a small true posterior cerebral (Mall). The double posterior cerebral in the case under consideration is thus a retention of the earlier condition. When the two cerebral vertebrals join to form the basilar, the posterior branches of the internal carotid run into this, and the posterior cerebrals appear to spring from the basilar. This appearance is strengthened by the fact that the posterior branch of the internal carotid migrates outwards at a somewhat later stage, and, now known as the posterior communicating, joins the posterior cerebral some little way from the point where the latter joins the basilar artery.

Stapedial Artery (fig. 3).

Tandler has shown that the dorsal portion of the second arch becomes the root of the stapedial artery. This vessel persists throughout life in certain animals, *e.g.* the rat, but is said to atrophy in man. When fully developed it possesses, after piercing the anlage of the stapes, three branches —supra-orbital, infra-orbital, and mandibular—which accompany the three divisions of the fifth nerve. The infra-orbital branch at first passes to the inner side of the third division of the fifth to reach the second division of the fifth. The infra-orbital and mandibular branches spring from a common stem, which becomes surrounded by the two roots of the auriculo-temporal nerve. In the 15-mm. embryo the common stem is joined by an anastomosis with the external carotid, this trunk forming the internal maxillary artery. At about the same time the trunk of the stapedial artery is said to atrophy, and therefore transmits its branches to the internal maxillary. The blood now flows in the reverse direction in the descending trunk, which becomes the middle meningeal. The orbital and infra-orbital branches of the middle meningeal, in the case which we have been discussing, are thus seen to be the persisting supra-orbital and infra-orbital branches of the stapedial artery; although, in order to explain why the infra-orbital artery is a branch of the middle meningeal, we must assume that anastomosis took place between external carotid and *mandibular* branch of stapedial.

An examination of the 20-mm. human embryo reveals the interesting fact that the descending trunk of the stapedial is not present at this stage. The stapedial can be seen to course backwards and outwards from its origin from the internal carotid artery to the anlage of the stapes which it perforates. It then runs forwards and outwards over Meckel's cartilage and, passing to the outer side of the Gasserian ganglion, gives off an ascending branch which is the middle meningeal artery (fig. 4). Having given off

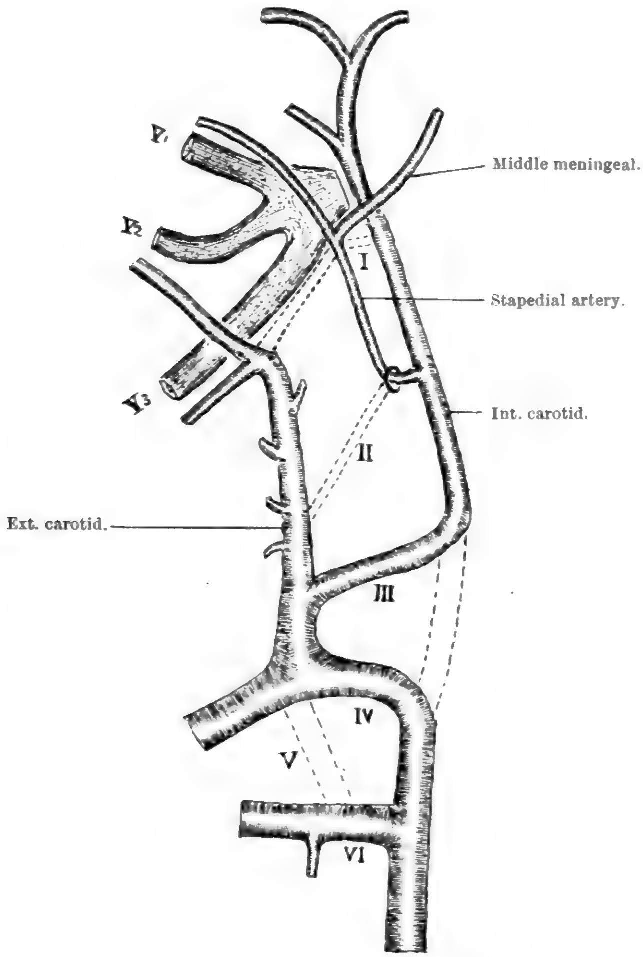

FIG. 4.—From 20 mm. human embryo: origin of middle meningeal artery.

the middle meningeal, the stapedial is then continued on to the orbit. The internal maxillary is seen to give off infra-orbital and mandibular rami. It would seem thus that the intracranial part of the middle meningeal is developed from an ascending branch of the stapedial, and at an earlier stage than the extra-cranial part. Further research may show that this lower or extra-cranial part is developed at a later stage either by a downgrowth from the stapedial artery to the internal maxillary or by an upgrowth from the internal maxillary to the stapedial.

In the 60-mm. human embryo, an artery corresponding to the stapedial of the earlier stage can be traced without any lack of continuity from the internal carotid to the middle meningeal arteries. At such a stage as this, one may tentatively suggest that the portion of the artery proximal to the stapes is the tympanic branch of the internal carotid, and the portion distal to the stapes is the petrosal branch of the middle meningeal. It is a well-known fact that the petrosal or Fallopian branch of the middle meningeal enters the petrous bone at the hiatus Fallopii and supplies twigs to the tympanic cavity; these anastomose with the tympanic branch of the internal carotid. In young rats which have been specially injected, the stapedial artery is seen to emerge from the hiatus Fallopii and then give off the middle meningeal in addition to its other branches. These observations are of a preliminary nature, and are the subject of further investigation.

To sum up shortly the condition present with regard to the absence of both internal carotids: they in all probability developed, and then at a very early stage, probably at about the 5-mm. period, they began to atrophy, at about the point where they divide into anterior and posterior branches.

Order of process of atrophy:—

(*a*) Continuation forwards of internal carotid distal to first arch.
(*b*) Dorsal aorta between first and second arches.
(*c*) Dorsal aorta between second and third arches.
(*d*) Third arch.

Before concluding, I must express my thanks to Professor Fawcett for his advice and help, and for permitting me to examine embryos from his collection.

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A CASE OF CONGENITAL ATRESIA OF THE DUODENUM, ACCOMPANIED BY VOLVULUS OF THE ILEUM.

By Reginald J. Gladstone, M.D. Aberd., F.R.C.S. Eng., *Lecturer on and Senior Demonstrator of Anatomy, King's College, London.*

The early and accurate diagnosis of the condition which has given rise to symptoms of obstruction of the bowel in a newly born child, is of considerable importance with regard to the possibility of relieving the obstruction by operation. Congenital atresia of the duodenum is a fairly

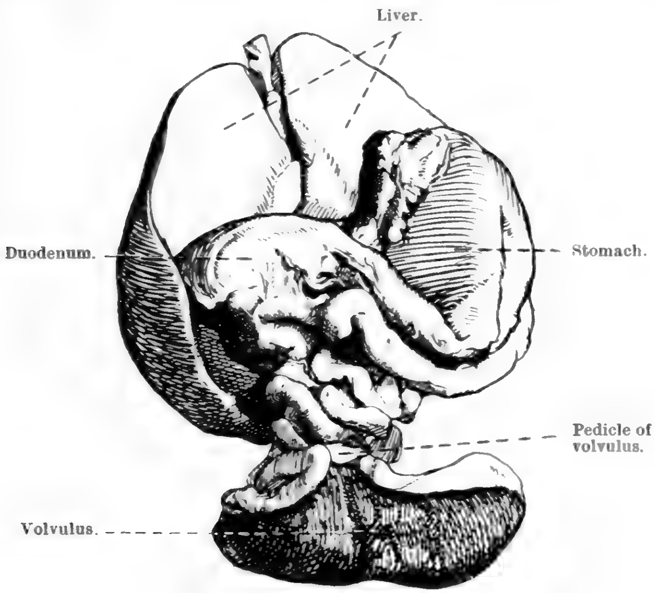

Fig. 1.

common cause of obstruction, and it is thus of interest from the practical as well as from the scientific standpoint.

The specimen which I shall now describe occurred in a male child and was sent to me by Mr W. Maxwell Penny, who kindly furnished me with the following particulars of the case. There was a considerable quantity of liquor amnii, and the child when born appeared small and ill-developed. It soon showed evident signs of obstruction; the condition of the child, however, did not admit of an operation being performed at the time, and it died on the seventh day after birth.

External examination of the body showed distension of the abdomen, and escape of meconium from the anus. On opening the abdomen, I saw a distended portion of the bowel, of a dark green colour, stretching transversely across the abdominal cavity. This proved to be a volvulus of the ileum 18 cm. above the ileo-cæcal junction, and involving about 10 cm. of the gut. The peritoneum was smooth and glistening, and showed no obvious signs of peritonitis (fig. 1).

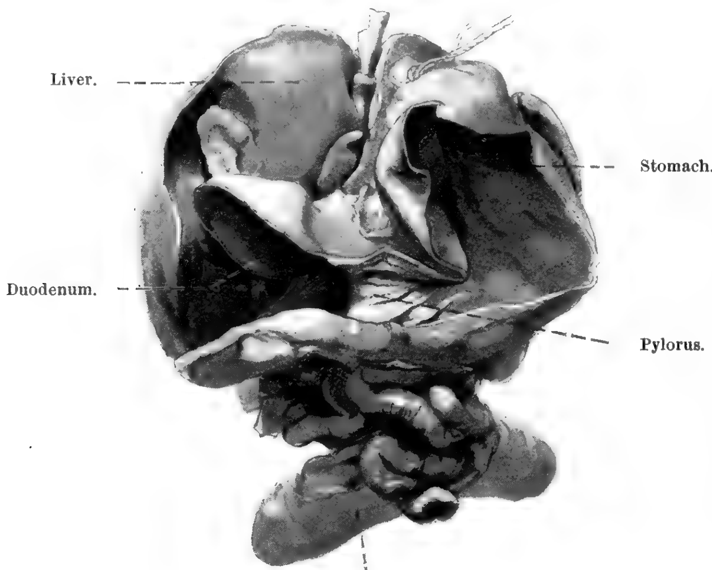

Fig. 2.

On further examination I found the stomach and upper part of the duodenum were also distended, and that there was a complete break in the continuity of the intestine at the junction of the common bile-duct with the duodenum (fig. 3). The duct was connected by a Y-shaped extremity with both segments of the duodenum. On slitting it up I found that the upper limb of the Y-shaped duct, which was connected with the proximal segment of the duodenum, ended blindly, and that the pancreatic duct was connected with the lower limb. The superior mesenteric vessels emerged from beneath the distended upper portion of the duodenum. Fig. 2 shows the stomach and duodenum opened from the front. The pylorus and the relation of the duodenum to the liver and gall-bladder are well seen. No meconium was present in the stomach, or upper part of the duodenum, but it was present below. The gall-bladder was empty and compressed against the under surface of the liver by the distended portion of the duodenum.

The causation of atresia of the intestine has of late been studied chiefly by Tandler, Kreuter, and Forssner. Tandler in 1892 demonstrated that a proliferation of the epithelial lining of the duodenum takes place in embryos of from thirty to sixty days, and that the lumen thus becomes more or less completely obliterated. In an embryo of 8·5 mm. he recorded

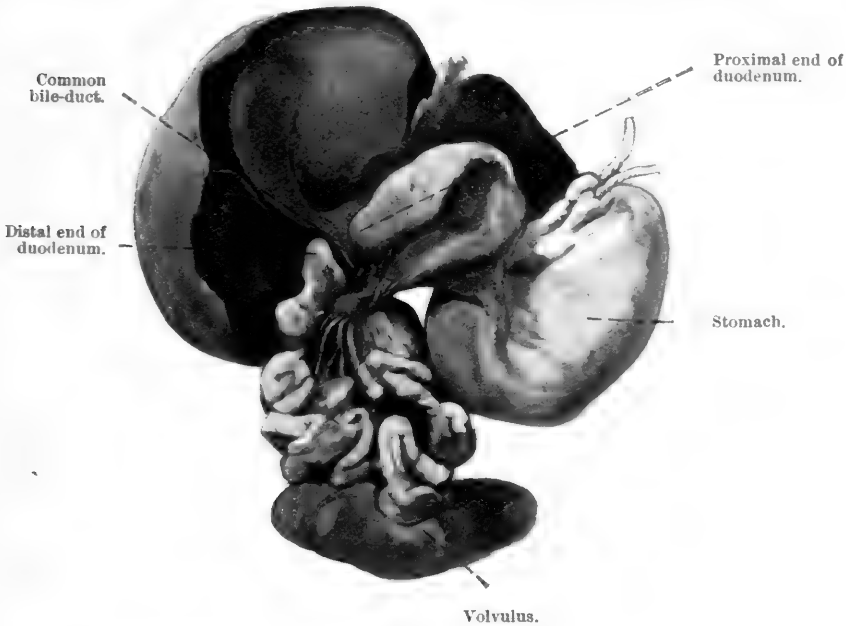

FIG. 3.

a complete obliteration between the outlets of the dorsal pancreas and the common bile-duct. Tandler considered that the cause of the occlusion was the resistance exerted on the expanding epithelium by the surrounding mesenchyme. Since the time when Tandler first put forward the theory that the atresia of the duodenum which occurs in the embryo may sometimes persist up to the time of birth, and cause obstruction, it has been shown that this proliferation of the epithelium may take place in other parts of the intestine, and may even involve a considerable tract of the alimentary canal. Atresia is, however, much more common in the duodenum (one-third of the total number of cases) than in other parts of the small intestine, and it is especially common at the entrance of the common bile- and pancreatic ducts. It thus appears to me that some external condition may contribute to the obliteration of the intestine, *e.g.* a fibrous remnant of the right vitelline vein in the lower half of the 8-shaped anastomosis round the duodenum. A very few cases are apparently due to fibrous bands, the result of ante-natal peritonitis.

Through the kindness of Professor Waterston I am enabled to show a photograph of a section through the intestine in a 6-mm. human embryo (fig. 4), which illustrates the proliferation of the intestinal epithelium de-

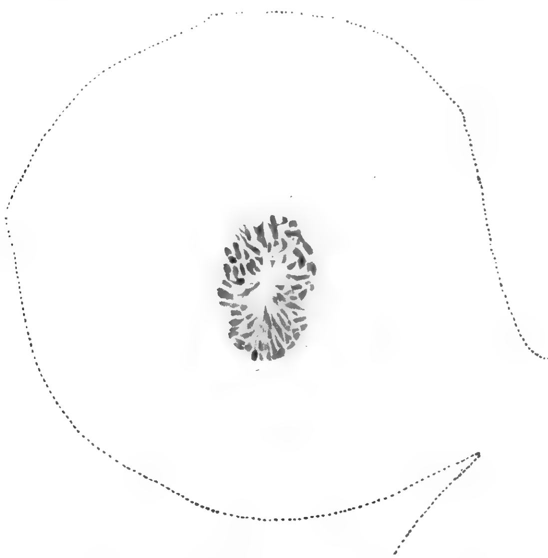

Fig. 4.—Proliferation of epithelium in the small intestine of a 6-mm. human embryo. The dotted line indicates the position of the serous covering of the intestine and its mesentery. From a specimen belonging to Professor D. Waterston.

scribed by Tandler and Forssner. The section passed through the intestine just below the vitello-intestinal junction. The lumen as shown in the photograph appears as a mere speck. The proliferation is also well marked in the duodenal region, but the lumen is here quite distinct.

The cause of the volvulus in the specimen which I have described was probably an irregular peristalsis, set up by the obstruction. An interesting case of intestinal obstruction in a new-born child which was associated with volvulus was described in 1905 by Grosse and le Lorier. The child was delivered at the eighth month. During its expulsion great quantities of greenish amniotic fluid came away. After birth the child vomited much green fluid resembling the liquor amnii in colour, and the authors considered that the greenish colour of the amniotic fluid might have been due to the vomiting of the child *in utero.* It was noted, however, that meconium passed *per anum,* and the staining of the liquor amnii may be accounted for in this way, without presupposing intra-uterine vomiting of the child. Distension supervened on the fifth day. Le Lorier operated. The stomach and nearly six inches of small intestine were distended, the lower part of the intestinal tract being empty. There was a volvulus of the distended bowel held down by two coils of empty gut. All the signs of general peritonitis were present. A constricting band was divided and an anastomosis established between the two blind ends of the intestine. The child died two hours afterwards. This case was believed to have been one of "intra-uterine tuberculosis of the fœtus," and that the adhesions had developed several weeks before birth and, further, that one of them had completely severed the bowel.

Ante-natal peritonitis will not, however, account for those cases in which a considerable length of the intestine is obliterated, and in which there are no signs of peritonitis. These are obviously due to a congenital defect in development.

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OBSERVATIONS UPON CASES OF ABSENCE OF LACRIMAL BONES AND OF EXISTENCE OF PERILACRIMAL OSSICLES.

By HUGO FLECKER, M.B., *lately Demonstrator in Anatomy, University of Sydney.*

INTRODUCTION.

THIS investigation was carried out in the Anatomical Department of the University of Sydney under the direction of Professor J. T. Wilson.

The total number of skulls examined in connexion with the investigation was 391. Of these, only 204 were entire or nearly so on both sides with respect to the lacrimal regions. Of the remainder, 64 were complete on the right side only, and 52 on the left; there was thus a total number of 523 orbits investigated. Those with both sides damaged are not taken into account in the figures given. The skulls were obtained, mostly, from the collections of the Australian Museum, Sydney, and the University of Sydney. Of these, about 42 per cent. were Melanesian, 20 per cent. Australian, 8 per cent. Polynesian, 21 per cent. were not geographically classified at all, whilst the remainder were mixed European. Thus at least more than 70 per cent. are of Oceanic origin (including Australian), which fact probably accounts for the marked disparity between my own figures and those of various other observers who have based their observations on skulls, the great majority of which were European. It is usual to base the percentages upon the total number of skulls examined, whether with orbits broken or not; but, as I have ignored those damaged on both sides, the percentages are shown with respect to the number of skulls having, at least, one orbit intact; thus my figures tend to be higher than those of most other observers. A more satisfactory method would be to base the percentages upon the total number of intact orbits. I have also included in my tables the results of the application of this method.

It is by no means always easy to recognise the presence or otherwise of a supernumerary ossicle and to demonstrate whether such exists quite apart from the surrounding bones; in fact, it is often impossible to do so without complete disarticulation. In fortunate cases an ossicle is quite movable and free in its bed; in other cases, though apparently distinct on the surface, it may be merely a superficial process of an underlying bone. A difficulty, too, is often experienced in recognising sutures, as they need to be distinguished from post-mortem fractures, and especially lines of absorption so common in old skulls, and which, in some cases, completely circumscribe a portion of the lacrimal. Vascular furrows, such as the lower end of the sutura notha (which was formerly regarded as an articulation), are sometimes deceptive. These usually present the appearance of a channel rather than a mere apposition of two bones, and do not penetrate the whole thickness. In certain very translucent lacrimal bones, the lines of attachment of intercellular septa are apt to be mistaken for sutures.

Hiatuses, which very frequently exist, especially in old skulls, are generally due to absorption from encroachment of the subjacent air-cells, and in such cases are filled up by mucoperiosteum during life. In a few cases a rudimentary lacrimal bone, or perhaps some ossicle, has fallen out. Post-mortem fracture and caries can be recognised, as a rule, by the character of the edges. Lastly, failure of two adjacent bones to meet, as has happened in cases described under superior and inferior lacrimo-ethmoidal ossicles, leaves sometimes a hiatus with perfectly smooth edges and perhaps filled up by membrane during life.

I shall, first of all, submit a summary of the results of this investigation. The details of the investigation of the several conditions dealt with in the summary will occupy the remainder of the paper.

Summary.

A. *Absence of Lacrimal Bones.*

I have met with definite complete absence in three cases, or 0·9 per cent. of skulls; once on both sides (native of New Britain), and twice on the left side only (negro and native of New Britain). Of the latter, in one case, the right lacrimal was rudimentary, and in the other, there was a hiatus from which a rudimentary right bone had evidently dropped out. Thus, in every case, the tendency to abolition was present on both sides.

In two other cases I met with hiatuses from which I was unable to be sure whether or not rudimentary lacrimals had dropped out. In a sixth case a hiatus existed on the right and a rudimentary bone on the left side.

B. *Perilacrimal Ossicles.*

The following are usually described :—

(i.)	Superior Lacrimo-ethmoidal	} = Retrolacrimal.
(ii.)	Inferior Lacrimo-ethmoidal	
(iii.)	Lacrimo-ethmoidal	
(iv.)	Ossicle of Lacrimal Groove	= Prelacrimal.

(v.) Ossicle of Nasal Canal . . . . ⎫
(vi.) Ossicle of Hamulus . . . . . ⎬ = Infralacrimal.
(vii.) Ossicle of Infraorbital Margin . . ⎭

I would add, though it cannot be definitely settled that they exist as quite distinct ossicles, the following species of which I can find no description:—

(viii.) Middle Lacrimo-ethmoidal.
(ix.) Fronto-lacrimal.
(x.) Inferior Maxillo-lacrimal.

Though not strictly perilacrimal, I have also noticed the following as quite distinct ossicles:—

(xi.) Maxillo-frontal (not that of Macalister, which is an ossicle of the lacrimal groove and articulates with lacrimal).
(xii.) Fronto-ethmoidal.

(i.) *Superior Lacrimo-ethmoidal.*—I met with this bone five times, equal to 1·5 per cent. of skulls, being relatively nearly four times as frequent as Thomson found it. He, however, examined a collection of skulls the greater portion of which were broken. My cases were one each from Australia, Melanesia, and Polynesia, and two had not their origins marked; all, like those of Le Double (five in number), were unilateral.

(ii.) *Inferior Lacrimo-ethmoidal.*—I came across this ossicle fifteen times, or in 4·7 per cent. of skulls, being nearly eight times as frequently as Thomson met it. Of these fifteen, five each were from Melanesia and Australia, being 3·6 and 7·9 per cent. respectively of the total skulls of these regions; two from Polynesia, or 8 per cent.; and three were not marked. Thus it appears to be relatively more frequent among Australian and Polynesian skulls; also in Melanesian skulls, though not to the same extent. Of all other skulls (twenty-five of which have the localities marked upon them), there are only three cases of inferior lacrimo-ethmoidal, or 3·1 per cent. None of the three are marked as to their origin, and it is probable that most of the unmarked skulls are Oceanic.

In one case only, that of an Australian, was the presence of this ossicle bilateral; of the others, nine were on the right, and five on the left.

(iii.) *Lacrimo-ethmoidal.*—I saw this ossicle eight times, or in 2·3 per cent. of skulls, being slightly less frequent than Bianchi and Ottolenghi found it, and about eleven times as often as Thomson met with it. Omitting two, the orbits of which were damaged on the opposite sides, only one was bilateral; and of the others, three were on the left and two on the right.

This bone is often described as a part of the os planum (lamina papyracea) divided by a vertical fissure. Sometimes, as in one of my cases, the ethmoid is divided into three separate ossicles by two vertical sutures. Similarly, the ethmoid has been described as being divided into four and even five ossicles. When the anterior angles are separated off by oblique sutures, a superior or inferior lacrimo-ethmoidal ossicle is formed.

Comparison of Post-lacrimal Ossicles.—In only one instance did I note the coexistence of two different post-lacrimal ossicles in the same skull, viz. a superior lacrimo-ethmoidal on the right, and a lacrimo-ethmoidal on the left. A superior lacrimo-ethmoidal on one side and an inferior lacrimo-ethmoidal on the other are reported. Macalister records on one side superior and inferior lacrimo - ethmoidal, and ossicles of lacrimal groove and nasal canal, and Le Double reports the first two only on one side. Only once I met with inferior lacrimo-ethmoidal on both sides, which, according to Le Double, is very rare.

Excluding the middle lacrimo - ethmoidal, I have found the post-lacrimal ossicles twenty-seven times, equal to 8·4 per cent., whilst Thomson has met with them in only 1·1 per cent. of cases.

Le Double states that the lacrimo-ethmoidal is more common than the superior lacrimo-ethmoidal, and that the latter is more frequent than the inferior lacrimo-ethmoidal, whilst Thomson found just the reverse. I have found the inferior lacrimo-ethmoidal fifteen times, the lacrimo-ethmoidal eight times, and the superior lacrimo-ethmoidal five times.

From observation of so many cases I am of Le Double's opinion that. with few exceptions, the post-lacrimal ossicles are either formed from cartilage in the membranous interval behind the lacrimal, or are developed as dismembered portions of the os planum of the ethmoid. I regard it as improbable that the inferior lacrimo-ethmoidal is formed by irregular clefts running up from the lower border of the ethmoid, cutting off a portion of the latter.

(iv.) *Ossicle of Lacrimal Groove.*—I only met with this ossicle twice (equal to ·6 per cent.); in neither case was the source of the skull indicated. Each was on the right side, and in both cases the opposite sides were not available. With the single exception of Legge, I find it much less frequently than other observers, and it is probably considerably rarer in Oceanic than in European skulls. Of twenty-two cases reported by Luschka, Le Double, Romiti, and Bianchi, fourteen were bilateral, so this condition is apparently more frequent than the unilateral.

(v.) *Ossicle of Nasal Canal.*—I have come across this ossicle fifty-six times, equal to 17·5 per cent., or a little less frequently than other observers. However, it is sufficiently common to be worthy of mention in text-books of osteology.

From an analysis of the varying relations of this ossicle to the vertical, longitudinal, and transverse fissures, when such exist, I have been unable to formulate any definite conclusions as to their connexions with one another, as they are extremely variable.

(vi.) *Ossicle of the Hamulus.*—Altogether I came across this ossicle forty-six times, or in 14·4 per cent. of skulls. Excluding twelve, the orbits of which were damaged on the sides opposite to which the ossicles were present, of the remaining thirty-four, nine were bilateral, eleven on the right and fourteen on the left being more frequently on one than on both sides. As my results show a much higher frequency than those of Macalister, Thomson, and Le Double, I have estimated the frequency of

TABLE I.—TO SHOW NUMBERS, SOURCES, AND CONDITION OF LACRIMAL REGION OF THE SKULLS EXAMINED.

	No. of Skulls.	Entire on Right and Left.	Entire on Right Side Only.	Entire on Left Side Only.	Total No. of Orbits.
Africa	7	6	1	...	13
Europe	5	3	1	1	8
America	4	1	2	1	5
Asia	9	5	1	3	14
Oceania Australia	63	47	11	5	110
,, Melanesia	137	82	32	23	219
,, Indomalaysia	2	...	...	2	2
,, Polynesia	25	13	6	6	38
,, Micronesia	2	1	...	1	3
Not marked	65	46	10	9	111
Total	319	204	64	51	523

the Oceanic cases in order to compare with those not Oceanic (excluding those whose locality is not stated). Thus it was 16·5 per cent. in the former to only 4 per cent. in the latter, hence I conclude it is very probable that the os hamuli is considerably more frequent in Oceanic than in other skulls.

Though both the ossicle of the canal and the os hamuli in typical cases are easily distinguishable from each other, there are many cases where it is by no means easy to identify them; in fact, one can, through a series of skulls, observe a fairly close gradation from the one type to the other. Such a condition suggests that the two may have a similar mode of development, and I see no reason why the ossicle of the canal, even when it coexists with the os hamuli, should not be developed from the lower

Table II.—Showing Geographical Sources of the Numerically Stronger Categories of Lacrimal and Perilacrimal Varieties met with in the Investigation.

Locality.	B (i.) Superior Lacrimo-Ethmoidal.				B (ii.) Inferior Lacrimo-Ethmoidal.				B (iii.) Lacrimo-Ethmoidal.				B (v.) Ossicle of Nasal Canal.				B (vi.) Ossicle of Hamulus.			
	No. of Skulls.	No. of Orbits.	Percentage of Skulls.	Percentage of Orbits.	No. of Skulls.	No. of Orbits.	Percentage of Skulls.	Percentage of Orbits.	No. of Skulls.	No. of Orbits.	Percentage of Skulls.	Percentage of Orbits.	No. of Skulls.	No. of Orbits.	Percentage of Skulls.	Percentage of Orbits.	No. of Skulls.	No. of Orbits.	Percentage of Skulls.	Percentage of Orbits.
Europe	...	...	...	...	...	...	...	...	...	...	...	...	1	1	20	12·5	...	...	...	...
America	...	...	...	...	...	...	...	...	...	...	...	...	1	1	25	20	...	...	...	...
Africa	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Asia	...	...	...	...	...	...	...	...	...	...	...	...	1	1	11·1	7·1	1	1	11·1	7·1
Oceania Australia	1	1	1·5	·9	5	6	7·9	5·4	2	2	3·1	1·8	9	11	14·2	10	11	13	17·7	11·8
,, Melanesia	1	1	·7	·4	5	5	3·6	2·2	3	3	2·1	1·3	30	35	21·8	16·0	22	25	16·0	11·4
,, Indomalaysia	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
,, Polynesia	1	1	4	2·6	2	2	8	5·2	...	...	...	...	2	2	8	5·2	4	5	16	13·1
,, Micronesia	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	50	66·6
Not marked	2	2	3·0	1·8	3	3	4·6	2·7	3	4	4·6	3·6	12	16	18·4	14·4	7	10	10·7	9·0
Total	5	5	1·5	·9	15	16	4·7	3·0	8	9	2·5	1·7	56	67	17·5	12·8	46	56	14·4	10·7
	Right side . 1 Left side . 4				Right side . 9 Left side . 5 Bilateral . 1				Right side . 2 Left side . 3 Bilateral . 1 Excluded because damaged on opposite side . . 2				Right side . 9 Left side . 16 Bilateral . 11 Excluded because damaged on opposite side . 20				Right side . 11 Left side . 14 Bilateral . 9 Excluded because damaged on opposite side . 12			

Additional Notes to Table II., relating to the distribution of skulls manifesting other categories of lacrimal variations omitted from the Table.

- A Absence of lacrimal bone. One case Negro; two Melanesian.
- B (iv.) Ossicle of lacrimal groove. Localities unmarked.
- B (vii.) Ossicle of infraorbital margin. Nil.
- B (viii.) Middle lacrimo-ethmoidal. One case Asiatic; one Australian aboriginal; one unmarked.
- B (ix.) Fronto-lacrimal. Three cases Australian aboriginal; one Melanesian.
- B (x.) Inferior maxillo-lacrimal. One case from New Britain, the other three unmarked.
- B (xi.) Fronto-ethmoidal. Two cases, both Melanesian.
- B (xii.) Maxillo-frontal. One case only, Melanesian.

part of the fibrous band which stretches from the anterior to the posterior lacrimal crest in the same way that the os hamuli is.

(vii.) *Ossicle of Infraorbital Margin.*—I did not meet with any indubitable instance of this type.

(viii.) *Middle Lacrimo-ethmoidal.*—Of the three cases, one was in an Asiatic, another in an Australian, and the third was not marked; two were on the right side, and the third on the left side.

(ix.) *Fronto-lacrimal.*—Of the four cases of which I took notes, all were Oceanic, viz. three Australian and one Melanesian. In two cases the ossicle appeared to be derived from the lacrimal, a third from the frontal, while the origin of the fourth was indeterminate.

(x.) *Inferior Maxillo-lacrimal.*—I have notes of four cases, and the only one with the locality marked on it comes from New Britain.

(xi.) *Fronto-ethmoidal.*—I have seen two cases, both right-sided, which were very well marked. The skulls were Melanesian.

(xii.) *Maxillo-frontal.*—The only case I have seen was in a native of Pentecost Island, New Hebrides, where the ossicle existed on both sides. Moreover, it was freely movable and very well marked.

Discussion of the Various Conditions above Summarised, together with Description of Cases.

A. *Absence of Lacrimal Bone.*

Like all other bones of the skull, the lacrimal bone tends in later life to fuse with its neighbours, and this occurs by far the most frequently with the nasal process of the maxilla in front. When such happens it progresses from above downwards, so that often the anterior maxillo-lacrimal suture can be recognised below, even when it is obliterated above. In such cases the lacrimal retains its thin papyraceous and often translucent texture, whilst the nasal process remains thick and opaque, and at the site of the obliterated suture there is a sudden change from the one to the other. The anterior lacrimal crest undergoes no change whatever. The part of the lacrimal in the lacrimal groove is very often fenestrated.

Apart from such cases, and often in very young subjects where all other sutures are very distinctly marked, there is no trace of a lacrimal bone whatever, its place being taken generally by the thick nasal process of the maxilla extending beyond the posterior lacrimal crest to articulate with the anterior border of the os planum. In such cases, a suture can usually be made out between the orbital plate and nasal process of the maxilla, and the anterior lacrimal crest is quite rounded. Such absence often occurs on both sides; but in cases where it is unilateral, on the opposite side the lacrimal is either rudimentary or there exists a hiatus from which possibly a rudimentary lacrimal has fallen out.

The following table represents the frequency as met with by different authors (mostly from Le Double):—

Author.	No. of Cases.	No. of Skulls.	Percentage of Skulls.
Adachi	6	121	5
Zabel	3	200	1·5
Bianir	5	350	1·4
Macalister	2	150	1·3
Le Double	1	100	1
Flecker	3	319	·9
Merkel and Kallius . .	1	1000	·1
Total	21	2240	·9

Of ten cases reported by Adachi, Le Double, and myself, six were bilateral, three on the left, and one on the right, so that absence occurs apparently more frequently on both sides than on one side only.

Whether the absence is due to actual non-appearance of the centre of ossification or to the centre being crushed out by or fused with the more actively growing nasal process of the maxilla, it is difficult to ascertain; but considering the frequency of abortive bones on the sides opposite to those on which the lacrimal bones are absent, the latter seems the more probable.

In my three cases the missing lacrimals were replaced mainly by the nasal process of the maxilla together with a small part of either the orbital plate of the maxilla or of the os planum. Le Double describes three other types of replacement of the absent bone. The suture between the orbital and nasal processes of the maxilla occupies the usual position of the inferior maxillo-lacrimal suture, when the hamulus is ill-developed.

Description of Cases.

Case 1, A 18956, *Australian Museum.*

Native of Blanche Bay, New Britain. Replaced on each side by nasal processes of maxilla only.

Case 2, 296, *Anatomy Department, University of Sydney.*

Adult male negro. Sutures fairly distinct. Lacrimal replaced on left entirely by thick process of maxilla articulating with thin os planum behind posterior lacrimal crest. On right side lacrimal is rudimentary.

Case 3, S 310, *Australian Museum, Sydney.*

Skull from Gazelle Peninsula, New Britain. Replaced entirely on left by nasal process of maxilla extending behind posterior lacrimal crest. On right is hiatus, from which rudimentary bone has evidently dropped out.

Case 4, A 18966, *Australian Museum, Sydney.*

Native of Rapanui, Easter Islands. Hiatus in front of ethmoid on both sides, from which it is difficult to determine whether a rudimentary bone has not dropped out.

Case 5, S 1055, *Australian Museum, Sydney.*

Native of Ontong, Java. Hiatus on right in front of ethmoid; on left are two others, where, possibly, rudimentary bones have dropped out.

Case 6, 2, *Anatomy Department, University of Sydney.*

Female, adolescent, from Chatham Isles. Sutures very distinct. Replaced on right side mainly by thick nasal process of maxilla and thin descending process of os planum. Between the two is a hiatus, from which a very rudimentary bone has evidently dropped out. On the left side the lacrimal is rudimentary.

B. *The Perilacrimal Ossicles.*

(i.) *The Superior Lacrimo-ethmoidal* is a small triangular ossicle with its base upward, articulating with the frontal above, the lacrimal in front, and the ethmoid behind.

Ossification.—The lacrimal bone is formed in membrane covering the ethmoid cartilage externally. The date for the appearance of the first centre, as stated by different observers, varies from as late as the fifth month to as early as the eighth week. Macalister, in ten embryos of eight weeks, found it nine times on both sides, once on the left, but never found it in a younger specimen. Only once did he find it missing in an older specimen (nine weeks).

At the end of the fifth month the lacrimal part, usually pierced by numerous foramina, is entirely ossified; it is separated from the os planum by a membranous interval. Ossification extends forward to the anterior border, and behind to the posterior lacrimal crest, which is recognisable by the twelfth week, and then extends behind the lacrimal crest to meet the os planum. At eight months all the sutures are well formed, except the lacrimo-ethmoidal, in the upper two-thirds of which cartilage is still visible. It is from this cartilage that the superior lacrimo-ethmoidal ossicle is developed. It therefore resembles the ethmoid, and differs from the lacrimal in being developed from cartilage and not directly from membrane.

Macalister states that normally there is only one centre of ossification for the lacrimal, and that supernumerary ossicles usually are developed from separate abnormal centres. Macalister, too, describes the superior lacrimo-ethmoidal ossicle as being a dismemberment of the ethmoid. Apparently he makes no distinction between this ossicle and the lacrimo-ethmoidal, and he regards the latter as an enlarged superior lacrimo-ethmoidal separating the lacrimal from the ethmoid.

Description of Cases.

Case 1, ***Anatomy Department, University of Sydney.***

Youth, locality not stated. Canine teeth not yet erupted. Sutures very distinct. Ossicle on right triangular; base 2 mm., articulates with frontal; anterior border 3 mm., articulates with os planum. The bone appears very distinctly to be a part of os planum. On left side ethmoid divided into three pieces by two vertical sutures. (Case 2, Lacrimo-ethmoid.)

Case 2, 26, ***Macleay Museum, University of Sydney.***

Female skull, locality not marked. Form of equilateral triangle with sides 4 mm. On left side.

Case 3, 1173, ***Australian Museum, Sydney.***

Native of New South Wales. Ossicle takes form of equilateral triangle with sides 4 mm. On left side.

Case 4, 2159, *Anatomical Museum, University of Sydney.*

Adult skull from Acid River, New Guinea. Sutures fairly well marked. Ossicle is on left side; approximates form of equilateral triangle, with sides measuring about 4 mm. Lower angle rounded.

Case 5, S 994, ***Australian Museum, Sydney.***

Juvenile from North Island, New Zealand. On right, along the greater part of fronto-ethmoidal suture, is a long hiatus about an inch in length, and from 2 to 4 mm. wide. It is probably due to failure of union of frontal with ethmoid. Its boundaries are quite smooth, and probably the gap was filled up by membrane during life. The ossicle present is L-shaped (inverted), with one limb (8 × 2 mm.) wedged in between lacrimal and ethmoidal, and the other (6 × 2 mm.) bounding the anterior part of the hiatus above.

(ii.) *The Inferior Lacrimo-ethmoidal* is a small triangular ossicle with its base downward, articulating with the orbital plate of the maxilla, and its anterior and posterior edges with the lacrimal and os planum respectively. Though typically triangular, it varies a great deal in form and size from a very small circle to a large square or rectangle. In two cases it was duplicated on the same side.

Macalister states that this ossicle is not usually ethmoidal in origin, but that it is a part of the infraorbital plate of the maxilla, which is irregularly cleft in this region. Though I have noticed the frequency of these clefts and also of an ascending process of the orbital plate of the maxilla, such an origin seems to me very improbable. Moreover, these clefts are usually more or less parallel, and do not tend to run into each other at all; and even if they did meet, the base of the triangle would not be a straight line or nearly so, as is usually the case.

In at least two cases I have seen the ossicle surmounting an ascending process of the maxilla which is itself irregularly cleft, but not in such a way as to form another ossicle. It appears to me that the inferior lacrimo-ethmoidal, like the lacrimo-ethmoidal and superior lacrimo-ethmoidal, is formed in the membranous interval behind the lacrimal, and may be regarded as a disjointed part of the ethmoid.

In cases where the ossicle articulates with the frontal above, resembling a lacrimo-ethmoidal as in two of my cases, the ossicle is situated on an ascending process of the orbital plate of the maxilla. In one case the frontal articulated with the orbital plate of the maxilla, separating the ossicle from the ethmoid.

Description of Cases.

Case 1, B 10390, *Australian Museum, Sydney.*

Native of Queensland. On left is square ossicle, with sides 4 mm., apparently derived from ethmoid. On right are two triangular ossicles, the upper being the larger, with sides measuring 6, 6, and 3 mm., and the sides of the lower being 3, 3, and 2 mm.

Case 2, 762, *Anatomical Museum, University of Sydney.*

Skull of an anencephalic fœtus, measuring about 7½ cm. from posterior border of foramen to symphysis menti. A small triangular gap exists between adjacent angles of maxilla, ethmoid, and lacrimal, filled in by membrane, each side measuring 4 mm., closest to maxilla, and 2 mm. from os planum. It seems that ossicle is derived either from an entirely distinct centre or from the orbital plate of the maxilla.

Case 3, 1232, *Australian Museum, Sydney.*

Native of Wide Bay, Queensland. A youth aged about fourteen. On left is a somewhat large triangular ossicle with anterior and posterior borders 8 mm., and base 6 mm. Apparently derived from ethmoid, like the lacrimo-ethmoidal ossicle. Same skull as Case 4, Fronto-lacrimal.

Case 4, B 7065, *Australian Museum, Sydney.*

Old native of Cobar, New South Wales. Anterior lacrimo-maxillary suture synostosed. Small triangular ossicle, with longer sides 4 mm., and base 1 mm.

Case 5, A 18953, *Australian Museum, Sydney.*

Old native of Easter Isles. Tiny circular ossicle, 1 mm. in diameter, surmounting ascending process of maxilla.

Case 6, S 1052, *Australian Museum, Sydney.*

Adult native of New Caledonia. On left is a small circular ossicle measuring 3 mm. in diameter. Sutures are well marked.

Case 7, A 14330, *Australian Museum, Sydney.*

Native of Arorai Island, Gilbert Group. Two small circular ossicles in apposition on left side, measuring 1 and 2 mm. in diameter respectively. They surmount a slight ascending process of the maxilla.

Case 8, S 321, *Australian Museum, Sydney.*

Native of New Britain. On left side is large quadrangular ossicle 10 × 4 mm., with long axis antero-posterior. Hiatus in upper part of lacrimo-ethmoidal suture. Apparently detached part of lacrimal. Upper border of lacrimal fused to frontal bone.

Case 9, Sie. XIII. 1651, *Macleay Museum, University of Sydney.*

Native of Cape York, Queensland. Sutures quite distinct. Large square ossicle, with sides 6 mm. on right, surmounting an ascending process of maxilla and separating the lacrimal from the ethmoid, thus simulating a lacrimo-ethmoidal ossicle.

Case 10, S 300, *Australian Museum, Sydney.*

Adult skull from New Guinea. Sutures well marked. Ossicle situated on the left on an ascending process of maxilla. It articulates above with the frontal, separating the lacrimal from the ethmoid, thus simulating lacrimo - ethmoidal. Ossicle is somewhat quadrilateral, measuring 2 × 3 mm. In front it articulates with the posterior superior angle of the lacrimal bone by a point only. On the right side the ascending process of maxilla just meets the descending process of the frontal bone.

Case 11, S 318, *Australian Museum, Sydney.*

Native of Gazelle Peninsula, New Britain. Large square ossicle, with sides 5 mm.; the upper and posterior borders articulate with the ethmoid, of which the ossicle appears to be a detached part.

Case 12, 15, *Macleay Museum, University of Sydney.*

Locality not marked. On the right is a long lacrimo-ethmoidal 1 × 6 mm., separated from the ethmoid by a large descending process of the frontal articulating with a still larger ascending process of the maxilla along a line running obliquely from before, downwards and backwards.

Case 13, D, *Anatomical Museum, University of Sydney.*

Adult skull from Solomon Islands, with tendency of sutures to fuse. On right side are two absorption foramina in the ethmoid, also a hiatus due to absorption between the adjacent upper borders of lacrimal and ethmoid. There is a very small inferior lacrimo-ethmoidal, roughly circular, with diameter 2 mm., surmounted by hiatus about 4 mm. long; the ossicle surmounts a slight ascending process of the orbital plate of maxilla, and appears to be formed as detached part of os planum.

CASE 14, 1230, *Australian Museum, Sydney.*

On the left is a large, long ossicle, 10 × 4 mm., with long axis vertical. A large hiatus, 15 × 4 mm., exists between the maxilla and ethmoid. The ossicle does not reach the hiatus, which extends into the middle meatus of the nose, and, like that described as Case 5, Superior Lacrimo-ethmoidal, its margins are quite smooth.

CASE 15, 4, *Anatomical Department, University of Sydney.*

Male aboriginal of Australia. Ethmoid synostosed to all surrounding bones except lacrimal. Pulley of superior oblique ossified. Small circular ossicle in notch of ethmoid, with diameter 2 mm.

(iii.) *Lacrimo-ethmoidal.*—This is generally a comparatively large ossicle, square or oblong in shape, and wedged in between the lacrimal and os planum in front and behind, and the frontal and maxilla above and below.

The following table represents the frequency as met with by different observers:—

Author.	No. of Cases.	No. of Skulls.	Percentage of Skulls.
Bianchi	9	286	3·1
Flecker	8	319	2·5
Ottolenghi	6	265	2·3
Thomson	2	1037	·2
Total	25	1907	1·3

In most instances this ossicle appears to be part of the ethmoid separated off by a vertical fissure. Macalister figures it as an enlarged superior lacrimo-ethmoidal. In one case I found it separated from the ethmoid by the meeting of an ascending process of the maxilla with a descending process of the frontal.

Altogether I have noted this union of process of the frontal and maxilla behind the lacrimal in ten different skulls. Two were broken in the opposite orbit; of the remainder, four were bilateral, three on the right and one on the left side only. In one case this union occurred behind the lacrimo-ethmoidal, in another in front of the same ossicle, and in two others behind the inferior lacrimo-ethmoidal.

Thomson expresses the view that perhaps the superior and inferior lacrimo-ethmoidal may fuse with the frontal and maxilla respectively, giving rise to the appearance of union of ascending and descending processes of these two bones behind the lacrimal. Owing to the rarity of the co-existence of these two ossicles, compared to the frequency of union of such processes, I believe such an explanation unlikely.

Description of Cases.

Case 1, 18, *Macleay Museum, University of Sydney.*

Male skull, locality not stated. On both sides are quadrilateral ossicles measuring 6 × 3 mm.; on left divided into two by horizontal suture.

Case 2, *Anatomy Department, University of Sydney.*

Same skull as Case 1, Superior Lacrimo-ethmoidal. Ethmoid divided into three by two vertical sutures cutting off two quadrilateral ossicles in front, each measuring about 5 × 2 mm. surmounting a slight ascending process of maxilla.

Case 3, S 317, *Australian Museum, Sydney.*

Native of New Britain. Youth aged about fourteen. Well-marked ossicle on right side measuring 8 × 6 mm. with long axis vertical. Apparently part of ethmoid. Small gap exists between ossicle and maxilla.

Case 4, 20, *Anatomy Department, University of Sydney.*

Hog Harbour, New Hebrides. Quadrilateral ossicle with long axis vertical, measuring 8 × 4 mm. Apparently either is developed as a separate bone altogether or from the ethmoid.

Case 5, 20, *Macleay Museum, University of Sydney.*

Female skull, locality not stated. Large square ethmo-lacrimal, with sides measuring 6 mm. Is on left side.

Case 6, 493, *Anatomical Museum, University of Sydney.*

Skull of young Australian male aboriginal. Sutures very distinct. Ossicle roughly quadrilateral; upper border 5 mm., posterior 5 mm., lower 4 mm., sloping forward and upward, surmounting ascending process of maxilla, and anterior 2 mm. sloping downward and backward.

Case 7, S 3513, *Australian Museum, Sydney.*

Native youth of Mallicollo Island, New Hebrides, artificially distorted; wisdom teeth not yet fully erupted. On left side ossicle directed obliquely downward and forward. Ethmoid considerably higher than lacrimal, probably due to the distortion. Upper border of ossicle directed also obliquely downward and forward, measuring 12 mm., anterior border 4 mm., lower 8 mm., posterior 10 mm. Apparently is detached part of os planum.

Case 8, A 5114, *Australian Museum, Sydney.*

Adult native of Point Darwin, Northern Territory. Oval-shaped ossicle with long axis vertical; axes measuring 5 and 3 mm. respectively. Separated from lacrimal by articulation of maxilla and frontal behind the lacrimal.

(iv.) "The Ossicle of the Lacrimal Groove" (Le Double); "Nebenthränenbein" (Luschka); "L'osso accessorio della fossa lacrimale" (Taruffi); "Maxillo-frontal" (Macalister).

This is usually a quadrilateral ossicle, articulating with the frontal above, the lacrimal behind, and the maxilla in front and below. It presents a lacrimal and a facial surface separated by the anterior lacrimal crest. According to Luschka it lies very loosely attached in its bed. Luschka notes also that the facial part is not usually present, which statement is contrary to what Le Double describes. One of my cases had a facial surface, the other had not. One was firmly united, the other very loosely attached in its bed.

The following table represents the frequency noted by different writers:—

Author.	No. of Cases.	No. of Skulls.	Percentage of Skulls.
Luschka	7	60	11·6
Canestrini and Woschen	2	34	5·8
Le Double	4	100	4
Budge	6	184	3·2
Krause	3	100	3
Romiti	1	40	2·5
Bianchi	10	425	2·3
Macalister	10	1020	·9
Flecker	2	319	·6
Legge	3	760	·3
Total	48	3042	1·5

The sutura notha grooving the nasal process of the maxilla should not be mistaken for an articulating suture. It is produced by a small branch of the infraorbital artery grooving the bone; it is quite superficial and does not penetrate the entire thickness of the nasal process. Usually it can be traced from the lower margin of the orifice of the nasal canal upwards, and it is very constant.

Description of Cases.

Case 1, 45, *Macleay Museum, University of Sydney.*

Juvenile skull, sutures very distinct. On the right is a thin, right-angled triangular squame, with sides measuring 4, 4, and 6 mm. respectively, overlying nasal process of maxilla; base articulates behind with anterior border of lacrimal near its upper extremity; the hypotenuse looks upwards and forwards, and the third side looks downwards. Is perfectly free in its bed. The anterior angle just reaches the anterior lacrimal crest.

CASE 2, *Skull in own possession.*

Ossicle roughly oblong, 4 × 2 mm. Articulates behind with maxilla and frontal, above with frontal, and below with part of nasal process of maxilla in the lacrimal groove. All these sutures are distinctly marked. The anterior, however, is not quite so evident, owing to its squamous edge overlapping the facial part of maxilla. The anterior lacrimal crest is continued up the centre of the ossicle. Same skull as Case 1, Inferior Maxillo-lacrimal.

In a broken skull, belonging to a student, which I am now unable to obtain, I saw the ossicles on both sides, articulating in front with the nasal bones, differing from those usually described. The anterior lacrimal crests are continued up over the ossicles.

(v.) *Ossicle of the Nasal Canal.*—This is a small ossicle situated at the lower margin of the lacrimal. Rousseau describes four surfaces—a free external or orbital, lying as a rule, below the hamulus and above the orbital plate of the maxilla; a second surface forms with the lacrimal bone, the outer and upper part of the nasal canal; a supramaxillary articulates below with the orbital plate of the maxilla; and the fourth is usually overlain by the hamulus, with which it generally coexists. When the hamulus is ill developed, this surface forms part of the upper margin of the nasal canal.

Among the 319 skulls I have met this ossicle fifty-six times, equal to 17·5 per cent. Other observers find it in the following proportions:—

Gruber in the majority of cases.
Rousseau in from 50 to 60 per cent.

Macalister	traces in 55	„
„	distinct in 32	„
Bianchi	in 25	„
Krause	in 20	„

According to Le Double, the ossicle corresponds to the commencement of the vertical infraorbital fissure, and to the part of the maxilla in front and above the transverse infraorbital.

The sutura verticalis is that running upward from the infraorbital or accessory infraorbital canal; while the sutura longitudinalis is that stretching from the most posterior part of the root of the infraorbital canal forwards. Both show a very great variation in direction. Both may run almost parallel to each other outward until they become covered by the molar: both may run almost parallel to each other inward towards the inner margin of the orbital plate of the maxilla, while every intermediate stage can be found. Most frequently the sutures run inward. They may run towards each other and meet, when frequently a third suture (sutura transversa) runs inwards towards the lacrimal. The meeting of the suturæ longitudinalis and verticalis may be anywhere from under cover of the malar to the inner edge of the orbital plate of the maxilla, while very frequently they do not meet at all.

Of the sixty-seven orbits in which I found the ossicle of the canal, in thirty-nine these sutures were either absent or unrecognisable in the proximity of the ossicle of the canal. Of the remaining twenty-eight, in ten cases both the suturæ longitudinalis and verticalis ran to the ossicle without uniting; in two cases the sutura transversa was formed running towards the same; in eleven cases the sutura verticalis, and in one only the sutura longitudinalis ran to the ossicle of the canal. Those cases where the sutures do not run to the ossicle are included in the first thirty-nine. From these figures almost every possible relation of these sutures to the ossicle is present, and I can find no evidence of any definite or constant connexion of the one to the other.

Macalister states "When the hamulus exists the ossicle is excluded from the lacrimal canal by it, and I have never found it (ossicle of canal) stretching beneath the hamulus so as to come into the wall of the tube." Nevertheless, I have frequently found an ossicle of the canal, under cover of the hamulus, so loose that on gently pressing the external surface of the ossicle, the internal surface protrudes in very definite relief in the lachrymal canal.

Instances of this type are too numerous to be worthy of individual description.

(vi.) *Ossicle of the Hamulus.*—This is an ossicle sometimes met with at the upper margin of the opening of the lacrimal canal, and it usually coexists with an ill-developed hamulus. It represents, according to Macalister, a separate centre of ossification arising in a constant fibrous band stretching between the lower ends of the anterior and posterior lacrimal crests. Though I met with this ossicle in 14·4 per cent. of skulls, Le Double only found it in 2 per cent., whilst Macalister and Thomson each found it in 1½ per cent.

As distinctive points between the ossicles of the canal and hamulus it is stated that—

(1) The former lies on the maxilla and indents it, not the lacrimal, as does the latter.

(2) The ossicle of the canal usually coexists with a well-developed hamulus in the majority of cases, whilst the os hamuli generally is present with an ill-developed hamulus. Macalister records a case where the ossicle of the canal completely separated the lacrimal from the orbital plate of the maxilla.

Though the above characteristics are quite sufficient for recognition of the majority of cases, there still remain a few cases in which the decision must be arbitrary, as I find almost every degree of variation between the two types. The first-mentioned distinction, I believe, is only a matter of degree as where two bones come into contact with each other, one generally must leave at least a slight impression upon the other. The difficult cases to identify are those in which, with an ill-developed hamulus, an ossicle is met with at the upper margin of the nasal canal, then the distinction between the two must be purely arbitrary.

Of the sixty-seven cases of ossicle of the canal, in fifty-two was it completely under cover of the hamulus; in eight it was only partially so, and in seven the hamulus was not sufficiently well developed to be over it. In such cases as the latter the continuation of the curve of the lower end of the posterior lacrimal crest would usually pass quite above the ossicle, and would not be continuous with its upper border as in the case of the os hamuli when such exists.

In many cases the two ossicles coexist in the same orbit. Their recognition, then, is a matter of no difficulty, as the upper one is always the os hamuli.

Instances of this type are too numerous to be worthy of individual description.

(vii.) *Ossicle of the Infraorbital Margin.*—I did not meet with any indubitable instances of this type.

(viii.) *Middle Lacrimo-ethmoidal.*—In several cases I have met with small ossicles in the lacrimo-ethmoidal suture about half-way between its upper and lower extremities. Though fairly well marked in one case, the others are not sufficiently definite to be recognised absolutely as a distinct ossicle. However, as they cannot be classed with the other post-lacrimal ossicles, I would propose to label it "Middle Lacrimo-ethmoidal." It is probably developed in the same way as the other ossicles in front of the os planum.

Description of Cases.

Case 1, 39, *Macleay Museum, University of Sydney.*

Locality not stated. On the left side is a circular ossicle, 2 mm. in diameter at the junction of lower quarter and upper three-quarter of the lacrimo-ethmoidal suture. Is quite free superficially.

Case 2, 1184, *Australian Museum, Sydney.*

Skull of Mongol. Many of the sutures are obliterated. There is a small oval ossicle with axes 4 and $1\frac{1}{2}$ mm., long axis vertical at junction of lower third and upper two-thirds of lacrimo-ethmoidal suture.

CASE 3, 1157, *Australian Museum, Sydney.*

Female aboriginal, New South Wales. On right side, near the middle of lacrimo-ethmoidal suture, is an ossicle measuring 2 × 4 mm. with long axis vertical, evidently part of ethmoid. Probably has a deep connexion with ethmoidal, but is quite free superficially. Same skull as Case 2, Fronto-lacrimal.

1142, *Anatomical Museum, University of Sydney.*

In a fourth skull, where the sutures were particularly well marked, was the appearance of a triangular ossicle with its sides measuring 8, 6, and 4 mm. fused with the ethmoid for a very slight extent below and behind. It was on the left side, a little below the middle of the lacrimo-ethmoidal suture.

(ix.) *Fronto-lacrimal.*—Though ossicles are not usually described in the fronto-lachrymal suture, I have made notes of four cases. I have been unable to find any definite evidence as to the mode of development of these ossicles, whether from the frontal or from the lacrimal, but considering the high frequency of irregular processes extending from the frontal, perhaps it may be part of that bone. Three of the cases at least could not be so isolated as to be demonstrated absolutely as a distinct ossicle.

DESCRIPTION OF CASES.

CASE 1, Sic. xiii. 1652, *Macleay Museum, University of Sydney.*

Native of Cape York, Queensland. On left side is a long narrow ossicle measuring 8 × 1½ mm. in the lacrimo-frontal suture, apparently quite distinct from either the frontal or the lacrimal. Sutures are quite well marked.

CASE 2, 1157, *Australian Museum, Sydney.*

Same skull as Case 3, Middle Lacrimo-ethmoidal. The ossicle measures 3 × 2 mm., and possibly has a deep connexion with the lacrimal.

CASE 3, 38, *Macleay Museum, University of Sydney.*

Native of Mabiac Island, Torres Straits. Ossicle measures 3 × 2 mm., and probably has a deep connexion with the frontal.

CASE 4, 1232, *Australian Museum, Sydney.*

Same skull as Case 2, Inferior Lacrimo-ethmoidal. On the right side is a small circular ossicle measuring 2 mm. in diameter at the junction of the posterior third and the anterior two-thirds of the fronto-lacrimal suture. Is probably a part of the lacrimal.

(x.) *Inferior Maxillo-lacrimal.*—In several cases I have seen ossicles situated along the inferior maxillo-lacrimal suture behind the line of the hamulus, and behind the usual situation of the ossicle of the canal Such an ossicle is not usually described, but as it may possibly be of a different nature from the ossicle of the canal, I have given it the name of the suture in which it lies. It has the appearance of the ossicle of the canal placed a little further back than usual, but it does not, as far as I can ascertain, take any part in the formation of the lacrimal canal.

Description of Cases.

Case 1, ***Skull in own possession.***

Same skull as Case 2, Ossicle of Lacrimal Groove. Ossicle is somewhat quadrangular, measuring **3** × 1 mm., with long axis antero-posterior. The hamulus is well developed. The ossicle lies behind the coronal plane of the posterior lacrimal crest, and appears to take no part in the formation of the lacrimal canal. Though the ossicle indents the lacrimal and not the maxilla, very likely, like the ossicle of the canal, it is a part of the latter and is probably developed in the same way.

Case 2, 34, ***Macleay Museum, University of Sydney.***

In left orbit is an oval ossicle measuring 3 × 1½ mm., 3 mm. distant from the lower end of the lacrimo-ethmoidal suture.

Case 3, 39, ***Macleay Museum, University of Sydney.***

On right side is a tiny ossicle measuring 2 × 1 mm. in the right maxillo-lacrimal suture, and it is probably a part of the inferior turbinal.

Case 4, 530, ***Australian Museum, Sydney.***

Native of New Britain. On the right side, between the adjacent borders of the lacrimal and ethmoid, is a hiatus. In the posterior part of the inferior maxillo-lacrimal suture is a long squamous ossicle, wedged in between the lacrimal and orbital plate of the maxilla. It measures about 8 × 1 mm.

(xi.) *Fronto-ethmoidal.*—In two cases I have met with ossicles running across the fronto-ethmoidal suture. They are most definitely marked. One was in a Fijian native, and the locality of the other was not stated.

Description of Cases.

Case 1, 1194, ***Australian Museum, Sydney.***

Locality of skull not marked. A well-defined square ossicle, with sides measuring 3 mm. exists in the fronto-ethmoidal suture, about 4 mm. from the posterior superior angle of the lacrimal.

Case 2, ***Macleay Museum, University of Sydney.***

Native of Fiji. Sutures very distinct. Distinct fronto-ethmoidal ossicle measuring 4 × 3 mm. behind the upper end of the lacrimo-ethmoidal suture.

(xii.) This is an ossicle which I have met with in only one case in the suture between the nasal process of the maxilla and the frontal bone. It differs from the ossicle of the lacrimal groove (maxillo-frontal of Macalister) in not articulating with the lacrimal. It is a particularly well-defined specimen.

ONLY CASE, A 14326, *Australian Museum, Sydney.*

Native of Pentecost Island, New Hebrides. On right side is a small ossicle measuring 2 × 3 mm. in the fronto-maxillar suture, midway between the lacrimal and nasal bones. On the left side, in the same suture but nearer the lacrimal bone, is a similar freely movable ossicle which is slightly larger.

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SOME POINTS IN THE NOMENCLATURE OF THE EXTERNAL GENITALIA OF THE FEMALE. By FREDERIC WOOD JONES, D.Sc., *The London School of Medicine for Women.*

THE present communication is intended as an introduction to a study of the development and morphology of some of the cloacal derivatives of the mammalia.

Some such preliminary survey is necessary, since there is so great a lack of definition concerning some of the terms in common use that the correct comparison of similar parts in different forms becomes difficult, and detailed description often well nigh meaningless. I imagine that this state of affairs arises directly from the extraordinary wealth of names which has accumulated in the literature of the female genito-urinary orifices. It is only necessary to turn to the authors of the seventeenth century to appreciate what a multitude of names had then been bestowed as general terms for the whole external genitalia. Thomas Gibson (1688), after giving a long list of classical and popular terms for the pudendum, says that it is known by all these "and many other names that fancy has imposed upon it." One of these more popular terms is worthy of some note. In describing the pudendum, Helkiah Crooke (1651) gives many synonyms, but puts them all aside with the brief sentence: "We will call it the lap"; and with this name he heads his chapter.

It is surely a rare transition for a word, when once so used, to acquire a more polite significance with the passage of time—the change of usage being commonly in the opposite direction. Such a use of the word, however, makes the term "dew lap" more easy of understanding, for I imagine that the definition of the dew lap as "the flesh that hangs from the throat of oxen, which laps or licks the dew on grazing" (Ogilvie), does not represent its true significance, and that a parallel may possibly be found in "dew claw."

Among the many synonyms used by the older anatomists, note must be made of "vulva," "fossa navicularis s. scaphoides," and "vestibulum." All these terms have been used to signify the whole of the external genitalia of the female, comprising that depression which lies between the two labia majora (labio scrotal folds, outer genital folds, labia externa, labia magna pudendi, alæ, alæ magnæ, etc.). A great deal of interest, and much confusion, is attached to the word vulva or volva. Its original use was without doubt restricted to the womb, and though in lay usage it was commonly confined to the uterus of lower animals, it became the orthodox term for the uterus of women, and as such it is used by Galen and others. At a later period the term became applied to the external genitalia, but if this transition came about by a mere extension of meaning, or by way of the word valva, —the folding doors or flood-gates,—does not seem quite clear (on this point see Bartholin and Crooke).

Be this as it may, the word vulva, although having least claims to do so, has been alone retained in modern literature as the accepted term for the external genitalia of the female; and, since this word has monopolised such a meaning, successive generations of anatomists have been at great pains to delimit parts of the vulva to which other words, originally denoting the whole of the pudendal cleft, could be applied.

Fossa navicularis and vestibulum are the two terms which have been most commonly retained in descriptive anatomy. Both are terms which have lost their original significance, and consequently there is much uncertainty, even to-day, as to the exact parts of the genitalia to which either is properly applied. It is correct to say that in the text-books which are in everyday use among students of anatomy and gynecology these terms bear variable meanings.

Fossa navicularis s. scaphoides was used by the older anatomists (see Th. Bartholin) as a descriptive term for the whole vulva, because the depression between the two labia majora is shaped somewhat after the fashion of a boat; and it should be noted that in its original use the long axis of the imaginary boat is in the long axis of the pudendal cleft.

This use of the word survived for long, and still remains current; for instance, Dr F. H. Ramsbotham states that the fossa navicularis "contains within its precincts the clitoris with its prepuce, the nymphæ, the vestibule, and the meatus urinarius" (p. 40). See fig. 1.

The almost exclusive employment of the word vulva as the scientific term for the pudendal cleft caused a modification in the use of the term fossa navicularis; and it was restricted to the posterior part of the cleft (James Keill), or with more precision to that part of the cleft where the labia minora fall short posteriorly. In more modern usage its significance has become still more limited, but still it is far from precise. According to different authorities the term fossa navicularis may denote:—

(1) The space between the hymen, or the orifice of the vagina, and the bond which is supposed to unite the labia minora posteriorly (Luschka and others). See fig. 2.

(2) The space between the hymen, or the orifice of the vagina, and the

bond which is supposed to unite the labia majora posteriorly (Winslow, Sappey, Broca, and others). See fig. 3.

(3) The space between the hymen, or the orifice of the vagina, and the "fourchette," such fourchette being a derivative of neither labia majora or labia minora (Farre and many gynecologists).

(4) The space between the bond which is supposed to unite the labia majora and the bond which is supposed to unite the labia minora, which bond may or may not be called a fourchette (John Lizars, etc.).

(5) The space between the bond which is supposed to unite the labia majora and a fourchette which is not derived from the labia minora (Gray and others). See fig. 4.

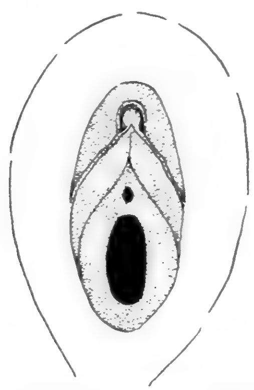

Fig. 1.—The fossa navicularis (stippled area). The area as defined by most early anatomists (Bartholin, etc.) and partially by many modern gynecologists (Ramsbotham, etc.).

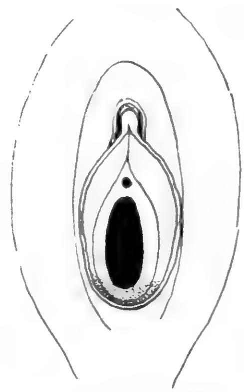

Fig. 2.—The fossa navicularis (stippled area). The area as defined by most gynecologists and many anatomists (Luschka, etc.).

(6) By a strange variant (I know not if by mere printer's error) as the space in front of the vagina limited anteriorly by a fourchette and posteriorly by the orifice of the vagina (Robert Knox).

It should be noted that in all these different delimitations the fossa navicularis is so disposed that the long axis of the imaginary boat is at right angles to the long axis of the pudendal cleft.

A like change has taken place with regard to the word vestibulum. First meaning the outer court into which the chambers of the bladder and the uterus both opened, its use has become steadily more restricted and confused. In its original and correct sense it was in common use with anatomists and gynecologists: "the vestibulum or fossa navicularis is a smooth depression between the nymphæ and perineum; it leads to the urethra above and the vagina below" (Archibald Robinson). Such a use of the word is retained in the latest edition of Morris's *Anatomy*, but, of course, it is not there a synonym for the fossa navicularis. See fig. 5.

With the restriction of the term fossa navicularis to the hinder part of the pudendal cleft, the vestibulum became the recognised term for the anterior part, and such is its accepted use to-day; but even now the term is ill defined. By different authorities the word vestibulum is stated to denote:—

(1) The triangular space between the labia minora extending as far back as the margin of the orifice of the vagina (Gray, Farre, and others). See fig. 6.

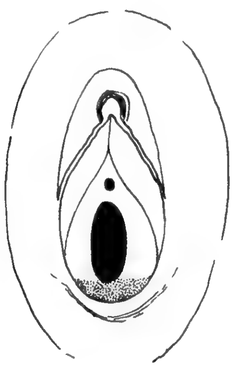

Fig. 3.—The fossa navicularis (stippled area). The area as defined by Winslow, Sappey, Broca, Monro, Cloquet, and many other anatomists.

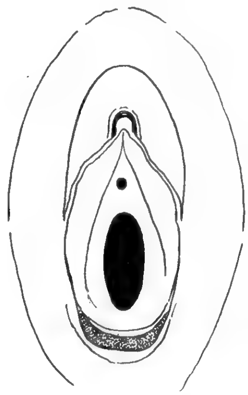

Fig. 4.—The fossa navicularis (stippled area). Area in which the anterior boundary is the "fourchette," which may or may not be derived from the labia minora (Gray and others).

(2) The triangular space between the labia minora extending as far back as the urinary orifice or a line drawn through the centre of this orifice (Sappey, Lewers, etc.). See fig. 7.

(3) A still more limited area which stretches from below the clitoris to the entrance of the urethra. This definition is found most usually in works on gynecology, and such a vestibulum might well correspond to the "bride masculine du vestibule" of Pozzi, or the "habenulæ urethrales" of Waldeyer.

Considerably more difficulty is experienced when we attempt to define exactly what is meant by the fourchette, for this word appears to be one that is surrounded by uncertainty. Its use may be summarised as follows:—

(1) The term fourchette may signify a posterior junction of the labia

majora: *i.e.* it may be a synonym for the commissura inferna of Bartholin, the inferior commissure of Winslow, the posterior commissure of many authors, the frenulum labiorum of Verheyen, or the frenulum pudendi of Cunningham (*Practical*, Ed. 2). See fig. 8.

(2) It may signify a posterior junction of the labia minora and so be a synonym of the frenulum vulvæ of Luschka, or the frenulum labiorum pudendi of Cunningham (*Practical*, Ed. 5). See fig. 9.

(3) It may signify a fold unconnected with either of these, derived from the anterior edge of the perineum (Robert Knox and others); or

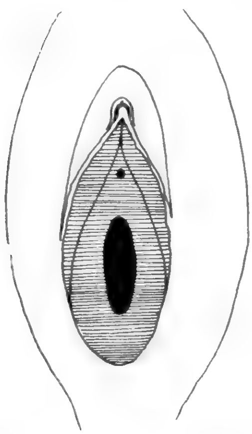

FIG. 5. — The vestibulum (shaded area) as defined by earlier anatomists, adopted by many gynecologists, and retained by some anatomists (Archibald Robinson, Alfred von Behr, Morris, etc.).

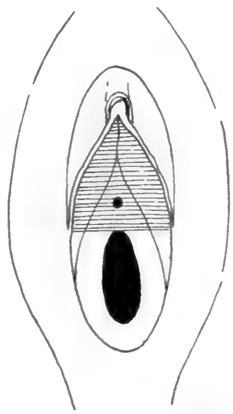

FIG. 6. — The vestibulum (shaded area) as defined by many gynecologists and anatomists (Farre, Gray, etc.).

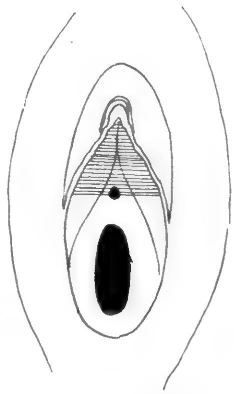

FIG. 7.—The vestibulum (shaded area) as defined by many gynecologists and anatomists (Lewers, Sappey, etc.).

(4) A fold further within the pudendal cleft, but still not a direct derivative of either of the genital folds (Farre and many gynecologists). As such it has been named the "fourchette," "the fork" (Keill, 1703), "the skinny ligament" (Crooke, 1651), or "frenulum pudendi" (Gray, 1882). See fig. 10.

The actual constituent of the external genitalia from which the fourchette is derived and with which it is anatomically continuous is therefore a matter of considerable uncertainty.

The uncertainty is increased by an attitude frequently manifested by authorities on gynecology, that to a certain extent the demonstration of the fourchette and fossa navicularis is a matter of manipulation during examination. This idea finds free expression in the works of many authors. "The fossa navicularis only assumes the form of a boat-shaped depression when it is stretched laterally by an index finger placed in it on each side" (Galabin, p. 5).

"The fossa navicularis is first formed, and gets its boat shape, when they (labia majora) are separated from each other. On stretching them from side to side we see the posterior commissure advance until it reaches the level of the posterior border of the entrance of the vagina. Thus a fold

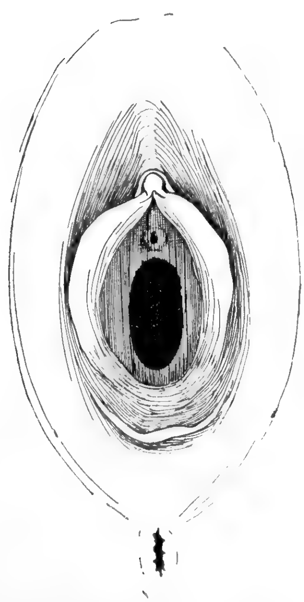

Fig. 8.—The fourchette. Type I. in which the labia majora meet to form a free edge, the labia minora falling short posteriorly.

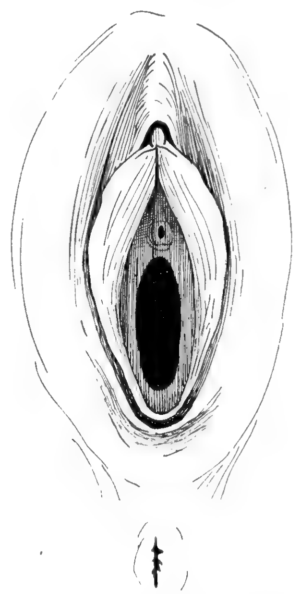

Fig. 9.—The fourchette. Type II. in which the labia minora meet to form a free edge; the labia majora may or may not form a junction at a posterior commissure.

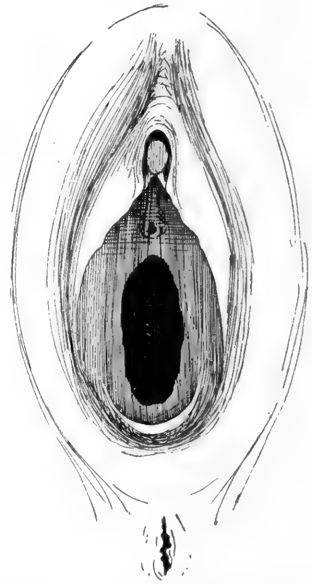

Fig. 10.—The fourchette. Type III. in which the free edge is derived from neither labium.

and a hollow are formed. The fold is the fourchette: the hollow is the fossa navicularis" (Garrigues, p. 40). I think that although such expressions would seem to make the issue more confused, they are in reality the clues for understanding the true nature of the fourchette: especially so when taken in conjunction with a further statement of the last author that, "in virgins the fourchette projects a little forward, even without stretching."

It would seem that concerning the fourchette there is only one point of agreement among all authors, and that is that at the posterior limit of the pudendal cleft there is a projecting margin which is more or less pronounced in the virgin, but which loses much of its prominence in women who are not virgins, and commonly disappears altogether after the birth of the first child.

According to Bartholin, "inferior commissura labiorum in virginibus tensa est"; or to Crooke, "in those that have brought forth the skinny ligament is much more lax and loose."

What, then, is the anatomical structure which produces this sharp posterior edge of the virgin pudendal cleft?

According to many modern authors it is the backward extension of the labia minora around the vaginal orifice.

Now it must be admitted that the degree of development of the labia minora varies enormously; but I am convinced that for them to be prolonged so far back as to meet behind the vagina is a somewhat unusual event even in the fœtus. A consideration of the true morphology of these folds does not warrant the conclusion that, even in an abbreviated form, it should be their normal condition to meet behind the vaginal orifice. Indeed, it is a comparatively recent innovation into anatomical description that makes such a meeting normal. That they extend backwards "reaching about half the breadth of the orifice of the vagina" (Gibson) is a common description of the older anatomists, which is still retained in some modern text-books (Morris), and which applies to the virgin and non-virgin condition. In a very large proportion of female fœtuses it is quite obvious that although the labia minora fall short about half-way down the vaginal orifice, there is yet a sharp margin at the back of the pudendal cleft. In some cases, it is true, there is an apparent continuation of the line of the labia minora further back than the mid-point of the vaginal orifice, and in some there is an apparent meeting of their backward continuation at the posterior margin of the cleft; but this condition I do not think is the normal one, and it is one that is certainly accentuated by manipulation.

Just as the older anatomists were definite about the failure of the labia minora to meet posteriorly, so many authors are definite about the failure of the labia majora to meet in a posterior commissure or fourchette. "Inferiorly the labia majora do not meet or run together, but terminate apart in front of the perineum" (Robert Knox, p. 508).

Concerning the labia majora, there is ample reason for suggesting that they do not end by becoming united behind the vaginal orifice in front of the anus. It is, I think, merely the unnatural position, and the straining open of the pudendal cleft on examination which makes such a meeting apparent. In the natural position of the parts, with the thighs approximated, the skin ridges which compose the labia majora run straight backwards and fail by becoming of diminishing prominence at a variable distance on the perineum towards the anus.

If, then, neither labia minora nor labia majora normally meet behind the pudendal cleft at a median bond of union, what other anatomical structure may form the basis of the fourchette?

In the *London Dissector* (J. Scratchley), which reached its eighth edition in 1832, the student was taught that "the perineum anterius projects forwards forming a kind of valve" (p. 89), and such appears to me to be the proper statement of the facts. It is the anterior margin of the "perineum," free of either genital fold, that forms the fourchette, and the disappearance of the fourchette after the first labour represents the minimum—and normal—rupture of the "perineum" accompanying normal labour. The definition of this "perineum" I reserve for a future paper.

There is one other point concerning which there is some difference of opinion shown in text-book descriptions and text-book illustrations, and that is the anterior origin or point of union of the labia minora. To appreciate the true morphology of these structures it cannot be made too definite that they arise as free folds upon the under surface of the clitoris, and not from the preputium of the clitoris with which their apparent continuity is only secondary.

The labia minora start upon the under surface of the clitoris and end upon the sides of the vaginal orifice: the labia majora run as prominent margins along the whole length of the pudendal cleft, but fade away before and behind by becoming merged with the general skin surface. Such, I think, should be the description of the normal disposition of these ridges.

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A NOTE ON THE SIGNIFICANCE OF CERTAIN ANOMALIES OF THE RENAL AND SPERMATIC ARTERIES.

By J. S. B. Stopford, M.B., Ch.B., *Senior Demonstrator of Anatomy, University of Manchester.*

A renal abnormality in a male subject that was recently dissected in the Anatomy Department of the Manchester University appears worthy of record, partly on account of its apparent rarity and partly on account of its developmental interest.

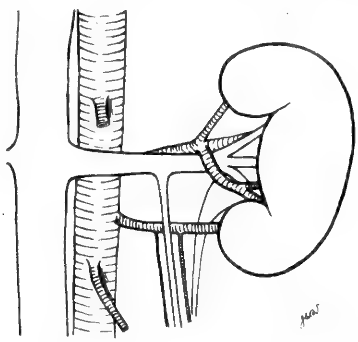
The anomaly is an apparently slight deviation from the normal condition, but it throws an interesting light on problems that are now being discussed from other points of view.

The left kidney, which was normal in size, was situated at a slightly lower level than the right, and its principal artery, arising from the aorta three-quarters of an inch below the superior mesenteric, at the same level as the right renal artery, passed laterally and, before reaching the hilum, divided into three primary branches. The upper one pierced the inner border of the kidney immediately above the hilum; the middle one, after breaking up into several secondary branches, passed into the hilum behind the pelvis of the ureter; and the lower one extended obliquely downwards and laterally across the renal vein to enter the lower part of the hilum.

An accessory renal artery, only slightly less in diameter than the principal one, was present on this side. This vessel took origin from the left side of the aorta, midway between the origin of the renal and inferior mesenteric arteries, and passed laterally in front of the ureteric pelvis to pierce the inner border of the kidney below the hilum. Two spermatic arteries were found arising from this accessory vessel. They passed downwards from their origin at the medial and lateral sides respectively of the point where the left spermatic vein crossed the artery. The lateral spermatic artery was the larger and was comparable in size to the right spermatic artery, a branch of the aorta leaving this trunk at the root of the right renal artery. No aortic spermatic artery could be found on the left side.

There was an additional point, which, although not quite so apparent, was of considerable interest both on embryological and morphological grounds. On the left side the posterior labium of the hilum extended much further medially than the anterior, *i.e.* the hilum was semi-anterior. On the right side the normal condition was found, the anterior labium extending nearer to the middle line.

Irregularities of the renal arteries are exceedingly common, occurring, according to Thane (1), as frequently as in 25 per cent., and the commonest is the presence of an additional vessel which occurs in about 20 per cent.; whilst according to Macalister (2) irregularities are found as commonly as three times in every seven bodies. The latter observer found that the commonest illustration of plurality of vessels was one right accessory aortic branch, and the next most frequent irregularity was one left accessory aortic branch. Arthur Thomson (3), in the "Report of the Committee of Collective Investigation appointed by the Anatomical Society of Great Britain and Ireland," states that irregularities were found in 25·6 per



cent., and in 10·9 per cent. the irregularity consisted of one accessory aortic branch; this estimate was made from the examination of 419 bodies.

The above evidence is sufficient to show that one accessory aortic renal vessel occurs so very frequently that it can hardly be considered abnormal. Many have suggested that an accessory vessel, occurring below the regular renal artery, may be an important factor in the production of many cases of hydronephrosis; but it is difficult to believe that such a vessel could mechanically obstruct the ureter unless the kidney was unduly movable.

Attention has frequently been drawn by Tyrie (4), Young and Peter Thompson (5), and many others, to the association of abnormal renal vessels with a developmental arrest of the kidney, which is demonstrated either by its shape or position. The ventral position of the hilum is distinctive of many of these cases and has given rise to a good deal of discussion.

Irregularities of the spermatic artery, on the other hand, do not appear to be so common, and I have been unable to discover any account of this vessel arising from an accessory renal artery. The occurrence of a spermatic artery springing from the renal proper is a recognised abnormality, but there seems to be considerable discrepancy about its frequency. Poirier (6) states that it is rare to see it arising from the renal (especially on the right side). Thane (1) describes it as frequent, and quotes a case of three spermatic arteries occurring on one side—two being aortic and one renal in origin. Robinson and Young (7), Walsham (8), and most English and American text-books mention this variation of the spermatic artery, but do not refer to its frequency, and none apparently describes a case where this artery is a branch of an accessory renal vessel.

An accessory renal artery arising from the spermatic is not very uncommon, but I consider this case to be an illustration of two spermatic arteries springing from an accessory renal: primarily, from the direction of the main trunk as it passes laterally towards the kidney from the aorta; and secondarily (although the second criterion is notoriously misleading), from the size of the branch passing on to the kidney—there being no obvious diminution in calibre beyond the origin of the spermatic vessels. I call attention to this minute distinction for the moment, as this case hardly corresponds to the accepted description of an accessory renal artery arising from the spermatic, although, as I shall endeavour to point out later, the explanation of the anomaly in both cases is probably identical. I also emphasise this distinction between the two, at first sight, identical cases for reasons which become more apparent later.

Explanations of the multiplication of the renal arteries are not difficult to find, as the facts of both comparative anatomy and embryology at once suggest solutions. In the lower animals the renal arteries are multiple, and in birds the ovarian artery is normally a branch of the renal. Also, ever since 1880 it has been known, from the researches of His, that the aortic branches supplying the intermediate cell mass are multiple. Recently Broman (9) has shown that, at any rate primarily, these vessels are arranged segmentally. Nevertheless, the history of these vessels is not yet complete, and explanations of abnormalities in the vessels supplying the structures formed from the intermediate cell mass must remain, as Evans (10) states, speculative until our knowledge of their development is increased.

Hitherto two principal theories have been advanced:—

(1) The "splitting" of the normal renal artery. This theory now receives scanty support, as it hardly appears likely that the vessels should revert to their early condition after attaining the adult state; and recent research discredits this suggested explanation more and more.

(2) Robinson and Young (7) offered an explanation which is best expressed in their own words: "The occurrence of two spermatic arteries

is probably an indication that the testicle was developed in at least two segments of the body; and the origin of a spermatic artery from the renal or suprarenal arteries is due to the obliteration of the root of the original vessel and the enlargement of an anastomosis between intermediate visceral arteries of adjacent segments."

The latter view obviously requires considerable modification in the light of the results of Broman's work; and I offer the following as an explanation, more in accordance with recent research, of the irregularities in the arteries supplying the structures formed from the intermediate cell mass.

In 1911 Jeidell (11) confirmed the supposition that the embryonic kidney was supplied by small capillaries from the neighbouring arteries (such as the inferior mesenteric, middle sacral, etc.), so that the explanation of the abnormal renal arteries illustrated by the cases described by Young and Peter Thompson (5) and Tyrie (4) is now complete. As the kidney passes upwards, it is supplied by the mesonephric (intermediate) or lateral aortic arteries, which atrophy in turn from below as it ascends until—as Hill (12) has demonstrated (by the Schultze method of making translucent specimens)—only the normal renal artery remains by the time the kidney attains its usual adult position.

Since the arteries supplying the intermediate cell mass have been shown to be so numerous as to be segmental, each may supply branches to the tissue forming the genital gland, kidney, and adrenal cortex respectively.

Such branches have frequently been seen by several observers. Yet only four of these intermediate arteries remain in the adult—inferior phrenic, suprarenal, renal, and spermatic (or ovarian). Therefore I suggest that in the process of development of the renal arteries, the branches passing to the genital gland usually atrophy, that vessel being chosen to become the permanent renal which supplies most of its branches to the metanephros. Similarly the vessel of supply to the genital gland is chosen, and normally the branches passing from it to the other glands atrophy.

The frequent presence of an inferior suprarenal branch from the renal and the triple arterial supply to the suprarenal gland are quite in accordance with what one would expect from a consideration of the comparative size of this organ during intra-uterine life and even at birth, and its immobility during development.

The non-disappearance of branches to the genital gland from the principal or accessory renal artery will result in the irregular origin of the spermatic artery mentioned in this paper.

In a similar way accessory vessels to the genital gland may be explained, and all the abnormalities which are so frequent in this region; and I suggest, as corroborative evidence in support of this explanation, a brief reference to the arteries of the suprarenal gland. In this case the text-books describe an inferior suprarenal passing to the gland from the renal; if my hypothesis holds good, this is a persistence of the embryonic arrangement of the vessels which, as a rule, is not seen in the case of the testicle or ovary. This coincides with what one would expect, as at birth the suprarenal gland is as large as, or larger than, the kidney, and consequently may be described as attaining its relative size late.

Further, the testicle, owing first to its descent, and secondly to the ascent of the kidney, is soon separated from the latter organ, and one would not in consequence expect an illustration of the embryonic condition so frequently.

In conclusion, I beg to express my gratitude to Professor Elliot Smith for permission to publish these notes.

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A SWEDENBORG MYSTERY: THE RIVAL SKULLS.

By W. Rutherford.

A mystery that is more than curious has arisen with regard to the remains of the great scientist, theologian, and mystic, Emanuel Swedenborg, to whom Emerson devoted one of his best-known essays, and who has been, and is still, held to be one of the most extraordinary men of his age.

In the spring of the year 1908 the Swedish Government despatched a frigate to England to bear away the bones of their great thinker for burial in his native soil. They had been lying for 136 years in the vault of an obscure little Swedish church in an East London slum—Princes Square, St George's-in-the-East—and for generations had attracted very little or no attention. In fact, in the year 1817, as the church books show, the skull was abstracted from the old coffin. The same books state that two years later (in 1819) the skull was replaced: and here begins the mystery.

Half a century ago a collector of curios in Wellclose Square, close to the old Swedish church, exhibited to his friends a skull which he claimed to be that of Emanuel Swedenborg. That collector is dead years ago, but, before passing away, he handed his collection to a friend, who has kept it ever since, but was not aware that this particular skull was amongst the others. None of them were labelled, and it is only now that there has been discovered scratched into the bone of one the letters "E. S'borg."

The discoverer claims for this that it is the actual skull of Swedenborg taken from his coffin in 1817, the probability being that another skull was put into the coffin in 1819 to cover the theft.

In the meantime this alien skull has gone to Sweden and been buried with much pomp and ceremony at Upsala.

Moreover, Swedish anatomists have examined it, one professor has published a treatise upon it, and a bust has been built upon the lines of it. But the mystery still stands, which is the authentic skull—that at Upsala or the one left behind in England? There are few so remarkable at the Royal College of Surgeons, which possesses a museum of thousands. The forehead of the one in England certainly has a similarity in formation to that of the portraits of Swedenborg, and other evidences point to the probability that the discoverer is right. At the same time, no blame attaches to the Swedish men of science. They had to deal with the bones put before them, and could scarcely be expected to suspect that those bones had been tampered with in England. Then again, human skulls are, as a rule, so very similar in form that it is exceedingly easy to accept one for another, except to the eye trained in such matters.

It is not unlikely that much controversy may arise over this mystery,

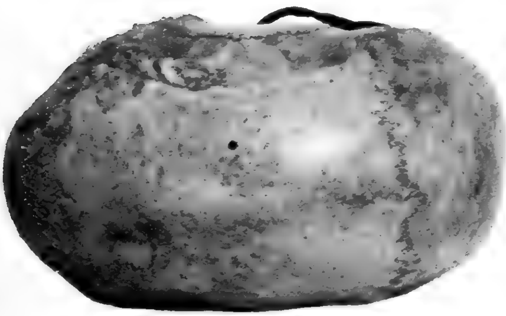

FIG. 1.—Norma verticalis.

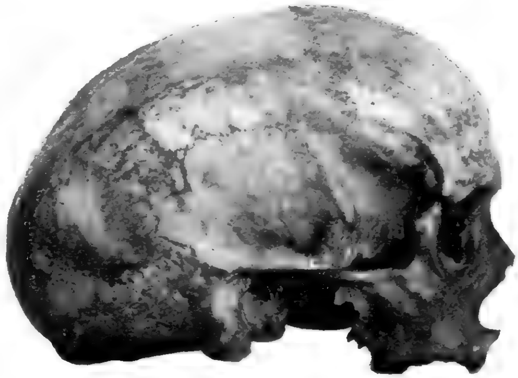

FIG. 2.—Norma lateralis.

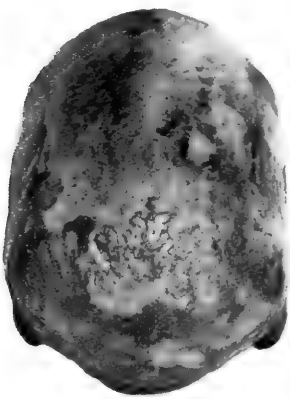

FIG. 3.—Norma occipitalis.

FIG. 4.—Norma facialis.

and it is hard to say what the end will be. Singular indeed is it that the great mystic should be mysterious still, more than a century after death.

Note.—The question of the authenticity of the skull ought to be easily settled if there be any data available as to the shape of his head. The photographs show that it is a well-marked example of the not uncommon anomaly of scaphocephalus, due to interparietal synostosis. The condition is obtrusively noticeable during life, and could not escape observation in the case of any man of public mark. The author of the paper has sent me much literature on the subject, mostly from newspapers, but I have not gathered from it that anyone had, during Swedenborg's life, recognised that he had a scaphocephalic cranium. The figures of the skull are worth reproducing, as they are not only characteristic of this deformation, but they show this unusual feature, that the bregmatic part of the sagittal suture persists for a short distance, a condition which only exists in one of the nine scaphocephalic crania in the Cambridge Museum. There is absolutely no evidence that this cranial deformity is accompanied with any specific type of mental or moral development. The two whom I have known during life were essentially commonplace persons.—A. M.

EXTROVERSION OF THE BLADDER, COMPLICATED BY THE PRESENCE OF INTESTINAL OPENINGS ON THE SURFACE OF THE EXTROVERTED AREA.

By T. B. Johnston, M.B., Ch.B., *Lecturer on Anatomy, Edinburgh University.*

Numerous methods of classification have been suggested for cases of extroversion of the bladder and its kindred anomalies. The case recorded in this paper falls into the third group of Keith's (1) classification, which is characterised by "ectopia vesicæ combined with fistulous condition of the intestine." A large number of similar cases have been recorded, and Wood Jones (2) has recently described the gross anatomy in detail. On this account the following description is purposely brief.

The child was born at the seventh month and lived for three days. At the time of birth a competent and reliable nurse failed to notice anything unusual about the placenta or membranes, and no membranous bag was attached to the margins of the extroverted area, such as is suggested by Wood Jones (2).

Gross Anatomy.—The umbilical cord was normal in appearance, and lay entirely cephalad to the extroverted area. It was median in position, and was situated 8 cm. from the xiphi-sternal junction and 7·5 cm. from the tip of the coccyx. Only the right umbilical artery was present.

The extroverted area showed, as usual in these cases, a median and right and left lateral subdivisions. The small intestine opened in the middle line (fig. 1), 3 cm. caudad to the umbilicus, and about 2·5 cm. more caudally there was a button-like elevation which could be readily invaginated to form a short blind diverticulum (fig. 2). At the caudad edge of this diverticulum there was a slit-like opening leading into the large intestine, which did not open in the perineum, although a distinct proctodœal depression was present.

On the right lateral subdivision there were two openings (fig. 1), which communicated with the right ureter and vagina respectively; no similar openings were found on the left lateral area.

At the caudal end of the extroverted area, in the middle line, there was a small tag-like elevation which resembled a small clitoris.

The stomach and liver were normal, but rotation of the intestines round the axis of the superior mesenteric artery, which normally is present in a

9·4 mm. embryo, had either been incomplete or had not taken place. This was evidenced by the fact that the superior mesenteric artery lay behind the third part of the duodenum, whereas in the ordinary course of development the gut is carried behind the vessel during the process of rotation. The small intestine measured 30 inches from the pylorus to the point where it opened on the surface. The large intestine passed backwards and downwards into the pelvis for 3 cm., and ended blindly. It was supplied upon its posterior surface by the inferior mesenteric artery.

No paired appendices were found in connexion with the large intestine,

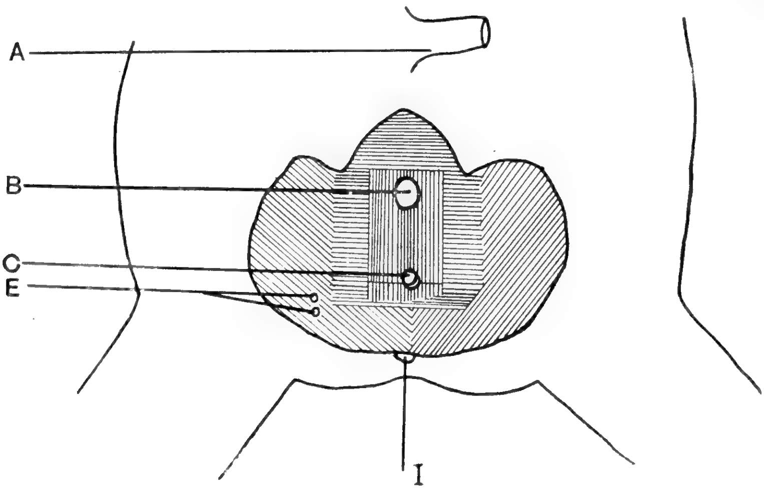

Fig. 1.—Diagrammatic representation of surface view of the case of extroversion described in the text.

A, umbilical cord; B, orifice of small intestine; C, small blind diverticulum, with orifice of large intestine at its left lower margin; E, orifices of right ureter and vagina; I, clitoris. *Note.*—Areas shaded obliquely were covered by mucous membrane of bladder: areas shaded vertically were covered by intestinal mucous membrane: areas shaded horizontally showed transitional appearances.

although these have been described as being constantly present in these cases.

The right kidney lay in the pelvis, but the left kidney was normal in position. The left ureter was enormously distended, and ended blindly in the wall of the left vagina.

The genital organs were female in character. The uteri were quite separate, and the vaginæ were only connected by an impervious fibromuscular bridge at their lower ends. So far as could be discovered, the left vagina did not open on the surface.

Spina bifida, a feature which has been described as constant in these cases, was not present.

Microscopic Appearances.—The histology of extroversion of the bladder and its allied conditions is by no means complete. Shattock (3), von Enderlen (4), and Keith (1) have all contributed to the subject, but their work deals mainly with the uncomplicated variety of extroversion of the bladder. In the case recorded in the present paper, most of the extroverted area was subjected to microscopical examination, and the results are given in some detail.

(*a*) The umbilical cord, close to the body, was perfectly normal, except

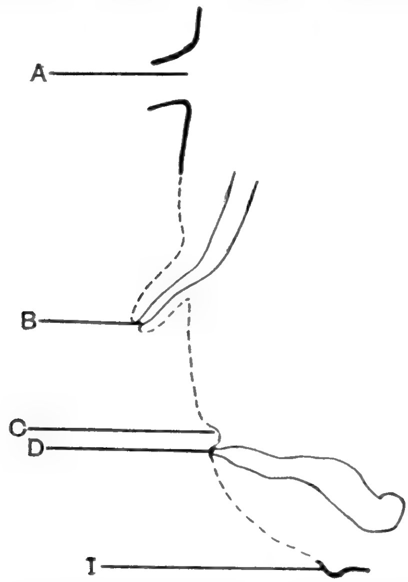

FIG. 2.—Median sagittal section through the caudad part of the anterior abdominal wall of the fœtus described in the text. (Diagrammatic.)

A, umbilical cord; B, orifice of small intestine, prolapsed; C, small blind diverticulum; D, orifice of large intestine; I, clitoris. *Note.*—The extroverted area is represented by a dotted line.

that it contained only one umbilical artery. It was surrounded by a layer of flattened epithelial cells, which constituted a complete amniotic covering. No trace of the urachus was observed, and no remains of the exocœlom were found.

(*b*) Small intestine, caudal end. Typical villi covered the surface, and the submucous and muscular coats were well developed. Very little lymphoid tissue was present in the submucosa, and it was difficult to determine, by the microscopical appearances alone, whether the part examined was jejunum or ileum. The length of the gut from the pylorus to the surface opening was 30 inches, and, as the child was born at the seventh month, it is practically certain that the caudal portion represented the ileum.

(*c*) The area cephalad to the opening of the small intestine, but caudad to the umbilicus (fig. 1), was covered, at its cephalad end, by stratified epithelium. True skin papillæ were found in places (fig. 3), but not throughout the area. The underlying substance consisted almost entirely of connective-tissue fibres. Where the papillæ were absent, the appearance of the surface epithelium and the underlying tissue supported the view that it represented skin in a slightly modified form.

Sections from the most caudad part of the area, *i.e.* close to the orifice

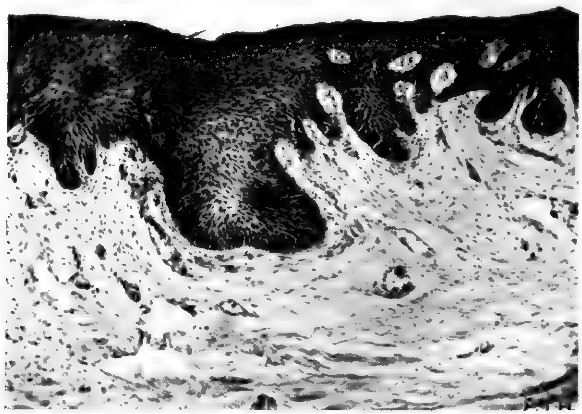

FIG. 3.—Transverse section through area immediately caudad to umbilicus, showing several true skin papillæ.

of the small intestine, showed the typical appearance of mucous membrane of small intestine.

The intermediate part of the area, which should have shown the transition between the two types, was not sectioned at the same time, and, unfortunately, was not in such a good state of preservation when cut at a later date. It was not possible to be certain whether it showed a direct transition from intestinal mucous membrane to skin, or whether there existed an intermediate portion which represented mucous membrane of bladder. The appearances found were suggestive of the latter condition, but, until some further histological evidence is forthcoming, the exact nature of the transition must remain doubtful.

(*d*) The area in the middle line between the two intestinal orifices was cut sagittally. In its cephalad part, the mucous membrane had been partially rubbed off, but it showed the bases of intestinal villi, and the glands of small intestine, lined by secreting cells. In its caudal part, the surface epithelium was well preserved. Typical villi covered the surface (fig. 4), and the number of mucus-secreting cells increased in number towards the caudad end of the area. The general appearance of the glands and the interglandular substance suggested a gradual transition from the mucous membrane of small to that of large intestine.

(*e*) The central area, to each side of the middle line (fig. 1), showed the same appearance as (*d*).

(*f*) The small diverticulum at the surface opening of the large intestine

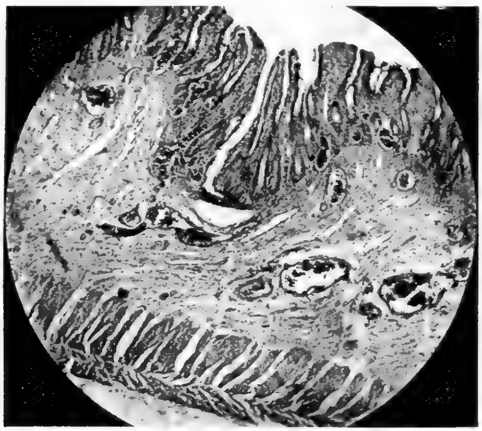

Fig. 4.—Sagittal section through area in median plane between the orifices of the small and large intestine, showing the typical muscular coat and typical villi of the small intestine.

(C, fig. 2) was lined by mucous membrane which, in its caudad part, presented all the characteristics of the mucous coat of the large intestine. In its cephalad part this area was identical with the caudad part of (*d*). No lymphoid tissue was found in the submucosa.

(*g*) Large intestine. The surface was covered by columnar epithelium, which dipped in to line simple tubular glands. The cells were practically all mucus-secreting. The general appearance was identical with that found in the large intestine of a normal fœtus.

(*h*) The lateral area was much denuded of its surface layer, which, however, was intact in places. It consisted of stratified epithelium of the type usually found in the urinary bladder. The submucous tissue contained many plain muscle and white connective-tissue fibres. All the blood-vessels were greatly engorged, and extravasated blood was found amongst the submucous tissue.

(*i*) The central area, caudad to the opening of the large intestine (fig. 5), was covered by stratified epithelium similar to that found in (*h*), but in a state of better preservation. Embedded in the submucous tissue there was a tube, the walls of which were lined by squamous epithelium. It is possible that this represented the terminal part of the left vagina, but, as the area was not cut serially, it was not determined whether it opened on the surface or with what it was connected above.

(*k*) Sections of the clitoris, uteri, and vaginæ were examined, and the identity of these structures was confirmed.

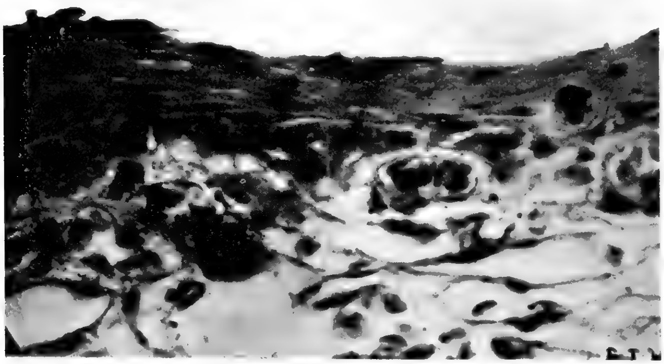

FIG. 5.—Section through area caudad to orifice of large intestine, showing surface covered by transitional stratified epithelium of the type found in the bladder wall.

Historical.—The recorded cases of extroversion of the bladder and its kindred anomalies are extremely numerous. In 1865, Förster (5) collected a number of cases of epispadias, of pure extroversion of the bladder, and of cases similar to the one described in this paper. He referred to the last group as examples of "Kloakbildung," but the term is used not in its morphological sense, but to express the fact that the urogenital ducts and alimentary canal open on the same surface. He believed the condition to be due to an arrest of development at an early period. "In diesen Fällen ist also der Enddarm, nachdem die Allantois aus ihm hervorgewachsen, allmählig wieder geschwunden und der Mitteldarm ist offen geblieben, verharrt also bleibend auf der Entwickelungsstufe der dritten oder vierten Woche des embryonalen Lebens."

Wood (6), in 1865, described eight cases of pure extroversion of the bladder, and suggested the following explanation: "An important observation has been made in these cases, that, at the time of birth, the hypogastric surface of the fœtus, from the umbilicus to the genital organs, is usually found to be adherent to the placenta or its membranes, the adhesions becoming separated by the process of parturition at the parts in which the cicatrised appearance is afterwards found. Such an adhesion explains very fully how the anterior or superficial portions only of the structures implicated are afterwards found to be deficient." With regard to the complicated variety, his view is that "these are evidently cases in which the arrest of development has taken place at an earlier period, while the fœtus still presents a cloacal formation." Later observations have failed to confirm the presence of adhesions between the extroverted area and the placenta, and, indeed, it is difficult to imagine how such adhesions could be so limited as to produce exactly similar results in each case.

In 1877, Champneys (7) reviewed the literature, and gave a brief account of the theories as to causation which had been brought forward up to that time. He groups them under the following headings: "A, Mechanical; B, Pathological; C, Developmental, or combinations of them." He criticises the views of Breschet (8), Duncan (9), and Mörgelin (10), who all held to the "Berstungstheorie" or mechanical explanation; Velpeau (11) and Phillips (12), who believed the condition to be due to destruction of the bladder and abdominal walls by ulceration; Meckel (13), Wood (6), and others, who all supported the "Hemmungsbildungtheorie." Champneys sums up as follows: "There can be little doubt that the theory which attributes the deformity to arrest of development is the correct one, because the other theories do not bear inspection, some of them being even unimaginable; because of the frequency of accompanying proofs of arrested development; and, lastly, because of the known development of the allantois." With regard to the last point, Champneys believed that the allantois arose as a bilateral structure, and that the two parts ultimately fused to form the bladder and the urogenital sinus. He supposed that failure of the ventral walls of the two allantoic diverticula to unite produced extroversion of the bladder, and that, when both dorsal and ventral walls failed to unite, the condition of extroversion of the cloaca was brought about. It is now known that the allantois does not arise as a paired structure in the human embryo, and, in any case, the explanation fails to account satisfactorily for the accompanying fissure of the abdominal wall.

In 1880, Ahlfeld (14) collected a number of cases and expressed the view that the intestinal openings on the extroverted area represent a patent vitello-intestinal duct. "Der Umstand, dass in einigen Fällen (Meckel, *Reil's Archiv.*, Bd. 9, S. 449, und Rose, *Monatsschrift für Gebürtskunde*, Bd. 26, S. 244) bestimmt angegeben wird, ein vas omphalo-mesaraicum sei vom widernatürlichen After in der Blasenwand zum Mesenterium gelaufen, beweist dass an dieser Stelle der Ductus eingemündet hat und dort abgerissen sein muss. . . . Ich halte das Zwischenstück von Darmschleimhaut nur für eine probabirte Partie bei ziemlich weiter Dottergangspalte."

In 1881, Doran (15) recorded a similar case of extroversion, and concluded that "failure of union of the visceral plates in the abdominal region, arrested development of the intra-abdominal part of the allantois, and persistence of a primitive condition of the alimentary tube in the region of the omphalo-mesenteric duct will account for the protrusion of the viscera, the condition of the bladder, and the opening of the intestine by an aperture far above its blind extremity and above the imperfect vesical elements." Doran assumed that the intestinal orifice was the patent omphalo-mesenteric duct, but the vague nature of his explanation gives no reason for its presence below the umbilicus. This case presents certain peculiarities which are not found in other examples of the condition, including what Keith (1) assumes to be persistence of the post-anal gut. Unfortunately no account is given of the histology of the region, and, without that, the identification of a tube, opening in the neighbourhood of the groin, as post-anal gut cannot be taken as certain.

Shattock (16), in 1887, writing on pure extroversion of the bladder, suggested that "the primitive cloacal invagination of the surface which normally lays open the lower end of the rectum and the lower end of the urogenital sinus, does in these cases, by an undue extension forwards and upwards, lay open the anterior wall of the urogenital sinus and the anterior wall of the bladder." In support of his view he evidenced the fact that epispadias invariably accompanies pure extroversion of the bladder.

In 1894, the same author (3) recorded the microscopic appearances of the mucous membrane in another similar case. He states that the investing epithelium shows a regular series of deep ingrowths; "it is not a papillary production or one due to outgrowths, for the free surface is in the intervals smooth for what are, microscopically, considerable distances." The general appearance is like "an adenoma arising in the intestinal mucosa, except that no antecedent gland tissue is concerned in its production." In considering these statements the reader must bear in mind that the preparation was obtained from an adult, aged 38, who had worn a urinal for 34 years, and who was the subject of suppurative inflammation of the right kidney.

In 1895, Bryce (17) published a case of complicated extroversion in a fœtus, which was the subject of retroflexion of the trunk, ectopia viscerum, and spina bifida. He criticised Ahlfeld's view that the intestinal openings, represent a patent vitello-intestinal duct, and, in the light of His' description of the development of the bladder, came to the conclusion that "cases of anus vesicalis must, therefore, be explained by imperfection in the formation of the septum," which normally divides the cloaca into a ventral, urinary, and a dorsal, alimentary, segment. In this case the ileum and a blind dilated sac—which seems to represent the large intestine—opened by a common orifice on the surface of the extroverted bladder. Bryce suggests that this sac "represents not the whole intestine behind the yolk stalk, but the much-dilated 'bursa pelvis'" (the name given by His to the cloaca interna). He believes that the primary cause of the whole series of abnormalities present in this case lies in the retroflexion of the trunk, and suggests that the persistence of a very short allantoic stalk has interfered with the growth in the pelvic region and resulted in the abnormalities found. No reason is given for the rupture of the bladder or cloaca, and though the shortness or absence of the umbilical cord might account for this particular case, it cannot account for the similar conditions found in cases like the one recorded in the present paper, where the umbilical cord is normal.

It is interesting to compare Bryce's case with the one recorded by Emrys-Roberts and Paterson (18) in 1906. The condition of the fœtus was very similar, with two important exceptions. No red mucous-membrane covered area was exposed on the surface; the ileum was normal and became continuous, with a short dilated tube which opened at its lower end into an internal cloaca. This case is quoted by Keith (1) as an example of "Extroversion of the Bladder with a Meckel's Diverticulum opening on the Surface," but the reason for identifying what is almost certainly an orifice in the large intestine as the opening of a patent Meckel's diverticulum is by no means clear. Emrys-Roberts and Paterson follow Fleischman's (19) description of the development of the bladder. In consequence, they conclude that the allantois was absent in their case and that "most if not the whole series of malformations appear to have been primarily caused by the failure in development of the hinder portion of the alimentary canal." No indication is given of the nature or of the cause of the arrest of development, but it is suggested that "the period at which arrest of development has occurred appears to be after the formation of the cloaca, but before the separation of rectal and genito-urinary passages."

In 1896, Sequeira (20) recorded a case in which a funnel-shaped orifice in the middle line communicated with the ileum and the large intestine. This he regards as a patent vitello-intestinal duct. With reference to the causation, he supports the views of Shattock, which have been mentioned above. "If, as in the present case, the vitelline duct opens at the umbilicus, it would, of necessity, be involved in this forward extension of the proctodœum."

In 1900, von Steinbüchel (21) recorded a case of extroversion in which two small openings, placed one on each side of the middle line, communicated with what he believed to be a Meckel's diverticulum. The large intestine was very rudimentary, and, according to the writer, was represented only by the cæcum. He believes that pure extroversion of the bladder is the first step, and that, at the same time, the large intestine fails to develop. Thereafter "der Ductus omphalo-mesaraicus . . . drängt sich zwischen die beiden noch getrennten anlage der Harnblase . . . und verlöthet sich mit jeder der beiden Blasenanlagen. Durch den Druck des Meconiums, der im Ductus immer bedeutender wird, da ja der Dickdarm nicht ausgebildet ist und sich an das unterste Ilium nur ein kleiner, blind endigender Darmtheil (Cæcum) anschliesst, erfolgt schliesslich in die vielleicht mittlerweile schon vereinigten Blasenhälften der Durchbruck, so dass wir symmetrisch von der Mittellinie zwei Oeffnungen, die in das Darmrohr führen sehen." The chain of events is so complicated that it is improbable that this is the correct explanation. It is curious to find that, after rejecting the Berstungstheorie with regard to extroversion of the bladder, von Steinbüchel resorts to that theory in order to explain the presence of a communication with the alimentary canal.

In 1901, Berry Hart (22) discussed the question of pure extroversion of the bladder, and came to the conclusion that its causation might be ascribed to an abnormally extensive rupture of the cloacal membrane. With regard to those cases in which the alimentary canal opens on the surface of an extroverted bladder, he was hardly prepared to accept von Steinbüchel's explanation, but he offered no other solution.

In 1904, Enderlen (4) examined the mucous membrane of the extroverted bladder in two new-born children. He found "das Uebergangsepithel der Blase mehr oder weniger gut erhalten." In adults, who were the subject of this malformation, his results were different, "Plattenepithel in verschiedener Form wechselt mit verschieden gestaltetem und funktionierendem Zylinderepithel ab." This he regarded as a metaplasia, although Keith (1) puts a somewhat different interpretation on the facts.

In 1908, Keith (1) classified the malformations of the hind-end of the embryo. He included all cases in which intestinal openings are present on the surface of an extroverted bladder in one group, to which he referred as "Ectopia Vesicæ with a Meckel's Diverticulum opening on the exposed vesical surface." In giving a brief account of the characteristic features of the condition, he says that the intestinal orifice may vary in position. "It may be situated almost in the perineum, near the posterior angle of the exposed mucous area." How the orifice of a Meckel's diverticulum comes to open at a point so far distant from the umbilicus is not explained. Further, he states that "the depression into which the ileum and cæcum open . . . is usually lined by a villous mucous membrane," but he does not mention the grounds on which this observation is based. He is of opinion that the condition is due to an arrest of development occurring at about the period shown in the Graf Spee embryo "Gle," and suggests that the allantois fails to become differentiated. As a result "the hind-end of the embryo, with the primitive streak, rests directly on the yolk-sac, instead of being separated from it by the allantois and the cloaca, as in the Graf Spee embryo. The primitive streak thus comes to rest directly over that part of the yolk-sac where the unseparated rudiment of the cloaca is situated. If an opening were to occur in the primitive streak, the yolk-sac and endodermal cloaca would open on the hypogastric region of the embryo, and give rise to the condition seen where ectopia vesicæ is combined with a fistula opening into the intestine." Later he says, "It is plain . . . that ectopia vesicæ is due to a non-fusion of the lips of the hypogastric stretch of the primitive streak." Keith believes that the active agent is chorionic inflammation during the third week of embryonic life, "when the chorionic circulation is being established, and that is just when the lips of the primitive streak are in a state of fusion, a fusion which is to secure the anterior closure of the bladder and lower belly wall." In referring to Enderlen's work he omitted to mention that in the only cases of new-born children which Enderlen examined the mucous membrane was typical bladder epithelium. Keith cut sections of the junctional area between the "part supposed to be yolk-sac or its stalk" and the bladder. The former he found "lined by a double layer of columnar epithelium, while that supposed to be vesical mucous membrane was covered by a stratified epithelium similar to that which covers the lips of the mouth." He also cut sections from the mucous membrane in a case of pure extroversion of the bladder, and found that "unfortunately all the epithelium had been lost, but it showed villous processes with depressions between their bases, recalling the structure of the small intestine, and quite unlike the mucous membrane of the normal fœtal bladder."

In 1910, Wood Jones (2) advanced a theory which is diametrically opposed to the views of Keith. He believes that "abnormal distension of the allantois and urinary tract" is the causative factor, and, consequently may be taken as a supporter of the "Berstungstheorie." Two stages are necessary for the production of the deformity. In the first instance the allantois becomes greatly distended and "encroaches on" the yolk-sac. It is not quite clear what the author wishes to be understood by the term "encroach." In his hypothetical figure he shows that after the "encroachment" the yolk-sac and allantois are thrown into a common sac, which receives the openings of the caudal end of the fore-gut and the cephalic end of the hind-gut. In the second instance this common sac ruptures on to the surface. Wood Jones calls attention to the position of the umbilical arteries relative to the extroverted area, and suggests that a study of this point should decide whether it is the yolk-sac or the allantois which ruptures. "The information to be gathered concerning the actual disposition of the membranes and vessels at the time of birth seems to be very slight, but such accounts as are available agree that a sort of skirt of membranes is attached—on the one hand around the margins of the exposed red area, and on the other to the placenta." The author concludes with the statement that "the typical human body-stalk placentation is lost, and a highly developed allantoic placentation has taken its place." No account is given of the histology of any of the parts described.

As Champneys has pointed out, the explanation of this condition must be given in the light of the currently accepted views on the development of the hind-end of the embryo. It is now generally believed that the allantois takes little or no part in the formation of the bladder, which is derived entirely from the endodermal cloaca. This view was first put forward by Keibel (24), and has recently been fully substantiated by Pohlmann (23). Both these authorities agree that the endodermal cloaca does not normally open on the surface. According to Pohlmann, the primitive streak consists of all three germ layers, and that, after the formation of the tail-fold, the mesoderm disappears, leaving the ectoderm in apposition with the endoderm as the cloacal membrane. The subdivision of the cloaca into ventral, urinary, and dorsal, intestinals egments involves the subdivision of the cloacal membrane into urogenital and anal parts, which break down, independently of each other, at a later period. Normally, the subdivision of the cloaca is effected by the tailward growth of a frontal mesodermal septum.

It may be as well to point out at this stage that the term cloaca is used to indicate that part of the primitive gut which lies caudal to the point of origin of the allantois after the formation of the tail-fold, and that, in the early stages, the terms cloaca and hind-gut are synonymous. As growth proceeds, the extent of the cloaca relative to the extent of the gut rapidly becomes smaller, so that the segment of gut derived from the subdivision of the cloaca is very much shorter than would have been the case if the subdivision occurred at an earlier stage.

Rupture of the urogenital and anal segments of the cloacal membrane is a perfectly normal occurrence at a certain period of development, and this fact, as pointed out by Berry Hart, at once suggests a clue to the causation of cases of epispadias and extroversion of the bladder. In hypospadias the urogenital membrane breaks down at the normal time and to a normal extent. If, however, the membrane ruptures cephalad to the genital tubercle instead of caudal to it, the condition of epispadias is produced; and if the rupture is excessive—the membrane is probably more extensive in these cases—pure extroversion of the bladder plus epispadias is the result. Both the conditions of epispadias and pure extroversion can therefore be accounted for on the ground of rupture of the urogenital membrane at an abnormal site but at the normal time.

It may be as well to indicate the reasons for rejecting the theories which have hitherto been advanced before attempting to offer a somewhat different explanation. For a criticism of the earlier theories the reader is referred to a paper by Champneys (7), whose own theory is rendered untenable by our present knowledge of the development of the allantois. Ahlfeld (14) and Bryce (17) both believe that abnormal shortness of the umbilical cord is the active agent, but the former holds that it is the vitello-intestinal duct which opens on the surface, whereas the latter inclines to the view that it is the cloaca only. This view, however, can only apply to those cases in which the umbilical cord is absent or unusually short, and cannot be regarded as explanatory of all the recorded cases.

Emrys-Roberts and Paterson (18) do not put forward any theory with regard to the causation of the condition, but they agree with Bryce in believing that the arrest of development occurs before the separation of the bladder and gut segments of the cloaca.

Sequeira's (20) explanation is very similar to that brought forward by Keith (1). He applies Shattock's explanation of pure extroversion of the bladder to the more complicated condition, but he omits to explain how the rupture of the cloacal membrane can pass forwards to involve the vitello-intestinal duct in the presence of the allantois. Further, it is almost certain that he believes the condition to arise after the bladder has been completely shut off from the gut, and the extension, at that period, of a rupture of the bladder to the yolk-sac or its duct would necessarily involve the opening up of the cœlom.

Von Steinbüchel (21), as already pointed out, postulates a number of anomalies, all occurring in the same embryo, together with a pathological process. The statement that the hind-gut fails to develop after its separation from the bladder is untenable, since by the time that the separation has occurred there is a relatively large segment of gut caudad to the vitello-intestinal duct. Von Steinbüchel's view appears to be much too complex to be capable of explaining every case of this anomaly.

Keith (1) adopts a somewhat different explanation. In the first place, he postulates the absence or non-differentiation of the allantois, a hypothesis which is rendered necessary by his interpretation of the intestinal orifices as the surface opening of the vitello-intestinal duct. He suggests that during the third week of embryonic life, "when the lips of the primitive streak are in a state of fusion," chorionic inflammation so alters the condition of growth that "non-fusion" follows. The statement that the fusion of the lips of the primitive streak "is to secure the anterior closure of the bladder and lower belly wall" is rather misleading, as it suggests that the ventral wall of the bladder is at first absent. Pohlmann (23) has shown that the cloacal membrane is formed by the disappearance of the mesoderm from the region of the primitive streak, *i.e.* that normally there is a decrease in substance in this area and not an increase, as the word "fusion" would lead one to suppose. It is not clear in what sense Keith employs the word "cloaca," but from the quotations given on p. 99 it would appear that the primitive streak takes no part in the formation of its walls. These views are at variance with those of Keibel, Pohlmann, and other authorities, and certainly the suggestion that the bladder is closed ventrally by the fusion of the lips of the primitive streak receives no support from the recent work on this subject. Although making the statement that "the vitelline orifice . . . may be situated almost in the perineum," Keith offers no reason for this very unexpected position of a structure which should open at the umbilicus, nor does he make any reference to the histology of the area which intervenes between the umbilical cord and the orifice of the small intestine. As will be shown later, the nature of this area is of the greatest importance in determining the nature of the anomaly.

Wood Jones (2) re-advocates the "Berstungstheorie," and believes that the whole condition is due to overdistention and rupture of the allantois. This takes place before the closure of the neurenteric canal, and so accounts for the associated spina bifida. He makes no attempt to prove that at this early stage the mesonephros is capable of active excretion, nor does he explain why the allantois ruptures into the yolk-sac instead of to the exterior. Further, rupture of the allantois would necessarily involve a tearing of the umbilical cord, and, as has been shown, that structure was perfectly normal in the case recorded in the present paper. I have been unable to trace the authority for the statement that "such accounts as are available agree that a sort of skirt of membranes is attached, on the one hand, around the margins of the exposed red area, and, on the other, to the placenta," but certainly no such condition was present in the case here recorded. There is another objection to be put forward from the purely mechanical standpoint. If the internal pressure is sufficiently great to prevent the closure of the neurenteric canal, how is it possible for the normal separation of bladder and gut to go on undisturbed, as shown by Wood Jones in his figs. 10 and 11?

Extroversion of the bladder, complicated by the presence of openings into the alimentary canal, can be most easily and most satisfactorily explained by rupture of the cloacal membrane occurring at an abnormally early period. If such a rupture occurred during or immediately after the formation of the tail-fold, it would expose the dorsal and lateral walls of the cloaca or hind-gut. As the lateral walls of the cloaca are concerned in the formation of the bladder, it is in keeping with this explanation to find that the lateral parts of the extroverted area in the present case are histologically identical with bladder wall. The central part of the extroverted area should represent those parts of the alimentary canal which are normally formed from the hind-gut or cloaca. As this area has been shown to represent the terminal part of the ileum and the whole of the large intestine, it would appear at first sight as if the above hypothesis were untenable. It is therefore necessary, before proceeding further, to endeavour to determine how large a part the hind-gut takes in the formation of the adult alimentary canal. In an embryo of 13–14 primitive segments (Embryo Pfannenstiel III., fig. 526, *Keibel and Mall's Manual of Human Embryology*) the origin of the allantois lies opposite the 14th primitive segment, practically at the junction of mid- and hind-gut. In an embryo of 23 primitive segments (Embryo R. Meyer 300, fig. 531a, *Keibel and Mall's Manual of Human Embryology*) the origin of the allantois lies opposite the 23rd primitive segment, while the caudal end of the mid-gut lies opposite the 12th segment. Opposite segments 13–22 there is a part of the alimentary canal which connects the mid-gut with the cloaca, and, from the figures given by Lewis (25), it seems almost certain that the cæcum appears on this part at a slightly later stage. Careful consideration of the available reconstruction models and figures leads to the opinion that, in the growth of the alimentary canal, the region in connexion with the yolk-sac remains practically a fixed point, and that the areas on each side are areas of active growth—*i.e.* the fore-gut and the hind-gut are responsible for practically the whole of the adult alimentary canal.

Abnormally early and excessive rupture of the cloacal membrane exposes the dorsal wall of the hind-gut, which is destined to form the terminal part of the ileum (caudal to the usual site of a Meckel's diverticulum) and the whole of the large intestine. The destruction of the ventral wall and the exposure of the dorsal wall apparently constitute a condition which greatly restricts the growth of the hind-gut, and the tailward-growing mesodermal septum fails, so that the subdivision of the cloaca is not carried out.

The presence in this and in other cases of a tubular part of the large intestine is a difficulty which requires to be considered. It is possible that it represents persistence of the post-anal gut. In Doran's (15) specimen, however, there was, in addition to a tubular part of large intestine, a small canal, lined by mucous membrane, which opened on the extroverted area and also in the groin. If Keith (1) is correct in his identification of this structure as the persistent post-anal gut, a different explanation must be sought to account for the formation of the tubular part of the large intestine.

Pohlmann (23) believes that, normally, the tailward-growing mesodermal septum is the active agent in shutting off the bladder from the gut, and he holds that the lateral folds of Rathke are more apparent than real. The subdivision is completed by the fusion of this septum with the mesodermal bar, which invades the cloacal membrane and separates it into urogenital and anal segments. It should be remembered that this frontal septum is not horizontal, but crescentic in outline, and that the failure of its central part does not necessarily involve its lateral parts. In order to account for the formation of a tubular part of the large intestine in these cases of extroversion, it is necessary to assume that the central part of the frontal septum fails to develop, and that, under these abnormal conditions, its lateral parts grow inwards and fuse with one another and the mesodermal bar in the perineum. In this way the caudad part of the bladder is separated from the caudad part of the gut, while the two remain undivided in their cephalad portions. At present this explanation cannot be definitely proved, but the conditions found suggest that it is very probably correct. It should be pointed out, however, that this same difficulty is present in the explanations offered by Keith and all the other writers save Wood Jones—who has his own views with regard to the formation of the terminal portion of the alimentary canal,—and that none of these authorities has made any attempt to overcome it.

The histological nature of the area which lies cephalad to the opening of the small intestine and caudad to the umbilicus gives strong support to the explanation offered in this paper. If the opening into the alimentary canal is really the vitello-intestinal duct, as Sequeira (20), Doran (15), Keith (1), and others hold, then the presence of skin on the surface of this area requires to be explained. The vitello-intestinal duct, when patent, invariably opens at the umbilicus, and it is impossible for it to open elsewhere, except in the event of pathological lesions. The assumption that the proximal part of the umbilical cord has been taken into the anterior abdominal wall during the process of growth would provide a way out of the difficulty, but no proof has yet been brought forward in its support. The histological findings, however, are in perfect accordance with the present explanation, for, the cloacal membrane having ruptured up to the point of the allantois, the umbilical cord is left intact, together with a small area on the anterior abdominal wall caudad to the umbilicus. If, at a later date, some observer is able to demonstrate the presence of bladder mucous membrane, intervening between the orifice of the small intestine and the umbilical cord, then the case for abnormally early and excessive rupture of the cloacal membrane will be established beyond doubt.

Summary.

(1) Epispadias is due to rupture of the urogenital part of the cloacal membrane at a site cephalad instead of caudad to the genital tubercle.

(2) Pure extroversion of the bladder, together with epispadias, is due to an excessive degree of the same rupture.

(3) Extroversion of the bladder, complicated by intestinal openings on the extroverted area, is due to rupture of the cloacal membrane. This rupture may occur at any time between the first appearance of the membrane and the completion of the subdivision of the cloaca. The period at which it takes place will determine the variety of the anomaly; thus it is suggested that the rupture occurred very early in the case recorded in this paper, and at a later period in the case described by Emrys-Roberts and Paterson (18).

(4) Spina bifida and paired diverticula at or near the surface orifice of the large intestine are not constant features of cases of extroversion of the bladder, complicated by intestinal openings on the extroverted area.

(5) The primitive hind-gut gives origin to a much larger part of the alimentary canal than is generally supposed, whereas the mid-gut forms very much less than is usually ascribed to it.

I should like to express my warmest thanks to Dr A. A. Morison, late House-Surgeon at the Royal Maternity Hospital, Edinburgh, through whose kindness I was enabled to make a thorough examination of the specimen. Dr Morison also gave me much assistance in the histological part of the work, and for that I am still further indebted to him. The micro-photographs are the work of Mr E. J. Henderson of the Edinburgh University Anatomical Department.

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JOURNAL OF ANATOMY AND PHYSIOLOGY

SPOLIA ANATOMICA. By Dr A. W. Meyer.

(*From the Division of Anatomy of the Department of Medicine, Stanford University.*)

CONTENTS.

Human.

Mammalian.

Although most of the specimens here reported and described are perhaps not unique, yet I trust that they are of sufficient interest to anatomists to deserve the attention given them. Some are still in the possession of the writer, others were not preserved after the notes and drawings had been made.

Specimens taken from the human body are grouped alone, and should really have been described and reported by the students themselves, but the exacting nature of the supervision necessary to assure satisfactory reports has deterred me from adopting this course up to the present. The mammalian specimens were obtained in the course of investigations on hemolymph nodes, or, as is the case with a few human specimens, through the courtesy of colleagues or friends. In the discussions following each specimen no attempt is made to give a complete bibliography, and only consulted references that bear directly on the discussion are given.

I. HUMAN.

1. Dorsal Lymph Nodes.

According to Eisler (1) the first dorsal nodes were reported by Lefèvre (2) in the region of the speculum rhomboideum in 1907. Since then, Florence (3) also reported the occurrence of lymph nodes over the region of the trapezius, but only as far caudally as the level of the spine of the first thoracic vertebra, in a case of inflammatory trouble. It is, of course, not at all unlikely that others have also observed nodes on the dorsum caudal to the posterior auricular and occipital groups. Since both these groups of lymph nodes are ill defined, however, and since the number of nodes composing them is subject to considerable variation in number and fluctuation in size, it is not always easy to discriminate clearly between nodes which do and those which do not belong to these groups. This must be evident, it seems to me, to anyone who has tried to palpate the nodes constituting these groups in a large number of living individuals, or who has observed them closely in the dissecting room. In the case reported here there were so many nodes, they were scattered about over such a large area and extended so far caudally, that there can be no question that they belonged to a separate group from the posterior auricular or occipital nodes. The general arrangement and anomalous character of their distribution is well shown in the somewhat diagrammatic sketch in fig. 1.

The body was that of a male Norwegian of about forty-eight years of age, who was evidently in a good state of nutrition at the time of death. There were no evidences of a general hypertrophy of the lymphatic nodes or of present or past lesions of the scalp, but, unfortunately, no data regarding the past history of the case was obtainable.

All of these nodes lay on the deep fascia, and were sufficiently well preserved and well defined to enable students who were doing their first dissection to recognise and isolate them without difficulty. Most of them, too, were sufficiently large to have been easily palpable during life. The majority were irregularly oval in outline, flattened dorso-ventrally, from 3–7 mm. across and 3–4 mm. thick. Some of them were rather dark in colour; but since the body had lain some time before being embalmed, post-mortem congestion may have been responsible for their dark colour. Unfortunately, their preservation was not such as to make a microscopical examination of any value, but a careful macroscopical examination failed to reveal any very small nodes. Most of them were firmer than usual and had a very definite or even a thick capsule.

Their unusual position naturally suggests the old question of the regeneration and especially the new formation of lymph nodes. It will be recalled that Bartels (4), who reported one case of unusually numerous cubital and brachial nodes and one of an atypically placed cubital node,

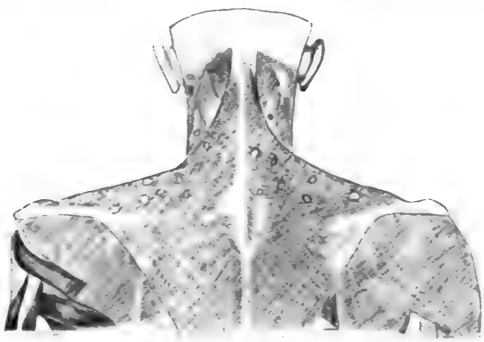


Fig. 1.—Dorsal lymph nodes.

emphasised the fact that such supernumerary and aberrant nodes probably occur only in regions where lymph nodes normally occur or in the path of large lymph vessels. Bartels, who expresses himself with much indecision on the question of regeneration, new formation, etc., in a controversy with Ritter (5), says, however, regarding the nodes reported by him: "Es sind also zwar mehr Lymphknoten also gewöhnlich und an anderen Orten also gewöhnlich vorhanden, aber sie liegen an Stellen, wo stehts wichtige Lymphbahnen verlaufen, also in diesem Sinne doch an typischen Orte." Bartel's conclusion evidently does not hold for the dorsal nodes in this and the succeeding case, for their location is very unusual and there are no especially large lymphatic vessels in the region where they were found. Nor do they lie in regions of rest, but that does not seem to me to be of special significance, although Ritter seems to think it is, in connexion with the formation of nodes under pathological conditions. Although such an origin is quite improbable, it is not denied, to be sure, that the nodes in question may not have been formed in response to some pathological stimulus, for the mere absence of gross lesions in the cadaver of an individual past middle life does manifestly not exclude such an origin. However, the mere presence of unusually numerous or even aberrant nodes in other than the customary locations cannot be regarded as indicating or as establishing a pathological origin. The conclusion would rather be the opposite. It is true that the main lymph nodes develop in certain definite regions at fairly definite times; nevertheless, the great fluctuations in size, number, and occurrence of lymph nodes in man and animals perhaps need further emphasis in this connexion.

There can be little question that these nodes were mature nodes, and had hence been present a considerable length of time, even if it could be shown that they did not develop from anlagen of prenatal life. It may be recalled that Warthin (6) stated that "in connexion with the question of lymphoid conversion of fat it should be noted here that the work of Bayer on the regeneration of lymph glands in (from) adipose tissue is also confirmed." Unfortunately, the conclusions of Bayer have been abundantly shown to be incorrect, and anyone who doubts the validity of the experimental work of Heuter (7) and Meyer (8) on the regeneration of lymph nodes is respectfully referred to the excellent investigation of Vecchi (9), who states that the observations and conclusions of the latter are confirmed. Nor is there any way of proving that they did or did not arise from a misplaced portion of the dorsal process of the so-called interscapular gland which became superficial in its position. Yet those who justly entertain serious doubts regarding Bonnot's (10) account and conclusions regarding the probable function of the "Fettpolster" of Merkel will not be likely to consider such an origin as a probable one.

(1) Eisler, in a review of (2) in *Jahresbericht u. d. Fortschritte der Anat. u. Entwkgsch.*, 1907, Teil III.

(2) Lefèvre, "Ganglions lymphatiques dorsaux," *Jour. Méd. Bordeaux*, 1907.

(3) Florence, "Au sujet d'un ganglion lymphatique de la région dorsale," *Toulouse Médicale*, 15th Oct. 1909.

(4) Bartels, "Ueber Neubildung von Lymphdrüsen in der Cubitalgegend," *Arch. f. Anat. u. Phys.*, *Anat. Abt.*, 1909.

(5) Ritter, "Zur Neubildung der Lymphdrüsen," *ibid.*

(6) Warthin, "The Changes produced in the Hemolymph Glands of the Sheep and Goat by Splenectomy, Hemolytic Poisons, and Hemorrhage," *Jour. Med. Research*, vol. vii. (N.S.), July 1902.

(7) Heuter, "Uber die Heilungsvorgange nach Reseecktion von Lymphdrüsen gewebe," *Verhndl. d. Dtsch. Path. Gesellsch.*, Berl., Mai 1904.

(8) Meyer, "An Experimental Study on the Recurrence of Lymphatic Glands and the Regeneration of Lymphatic Vessels in the Dog," *Bull. Johns Hopkins Hosp.*, June 1906.

(9) VECCHI, *Die anatomischen Grundlagen der Chirurgie der Lymphdrüsen Mitth., aus dem Grenzgbt. der Med. und Chir.*, Bd. xxiii., 1911.
(10) BONNOT, "The Interscapular Gland," *Jour. Anat. and Phys.*, Lond., vol. xliii. 1909.

2. DORSAL HEMOLYMPH NODES.

The two nodes shown in fig. 2 were located symmetrically on the scapular portions of the latissimi dorsi in the superficial fascia. a few centimeters cranially from the inferior angles of the scapulæ. They lay practically on the vertebral margins of the latter, were irregularly oval in outline, from 6–8 mm. in size, flattened dorso-ventrally, and from 3–4 mm. thick. Because of their unusual position, their dark colour, and particularly because the veins draining them were large and engorged with blood, they looked quite unlike normal lymph nodes, and were unusually

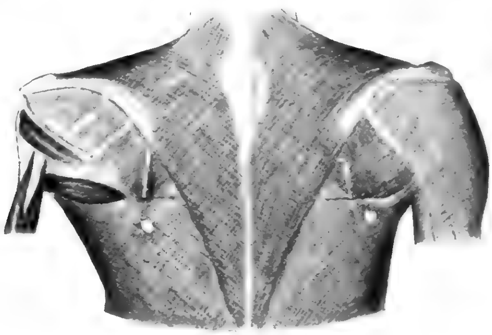


FIG. 2.—Dorsal hemolymph nodes.

conspicuous. Indeed, as far as the prominence of the vein draining them and their colour are concerned, they could easily have been taken for hemolymph nodes. The veins were tortuous, about 2 mm. in diameter, and joined the descending rami of the transverse cervical veins. The arteries, which were very small, had unfortunately been torn before special attention could be directed to them.

The body from which they were taken was that of a male Swede, fifty years old, who had died of delirium tremens. It contained no gross pathological lesions, and the patient had apparently not lost much in weight just before death. Since the body had been unusually well embalmed, twelve hours post mortem, the nodes were found in an excellent state of preservation. Three gallons of a fluid containing 10 per cent. of zinc chloride and 20 per cent. of arsenic by weight, and 2·5 per cent. of formaline and 1·25 per cent. of carbolic acid by volume, had been used in the embalming by the undertaker.

Upon microscopical examination of the sections with low-power magnification, these nodes, which were extremely vascular, seemed to contain both lymph and blood spaces. Most of this vascularity was due to dilated vessels, however, which were very numerous, and in some places composed more than half the area of the parenchyma and trabeculæ. Only slight evidences of rupture of any of these vessels were present. Both nodes have a thick connective-tissue capsule, and contain a great deal of connective tissue throughout some portions of the parenchyma, and

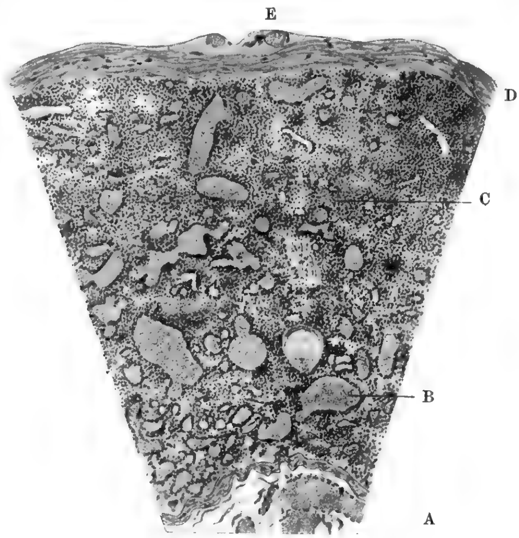


FIG. 3.—Portion of dorsal hemolymph (?) node.

E, blood-vessel in the capsule (D) ; C, hemorrhagic area ; B, lymph sinus containing blood ; A, hilum with blood- and lymph-vessels.

especially near the hilum. A definite continuous peripheral sinus was lacking in one of the specimens, but large lymph spaces and lymphatic vessels in section were found, especially near the hilum. Some of the lymph spaces contained blood, and coagulum which suggested lymph but was undoubtedly coagulated serum. There were also many hemorrhagic areas of parenchyma between vessels whose walls seemed to be wholly intact. No follicles were found in the portions examined microscopically, nor could the parenchyma be divided into cortex and medulla. Groups of leucocytes were found in some of the vessels, and also occurred in areas which simulated the blood islands of hemolymph nodes quite closely. Leucocytes were also present in excess in the hemorrhagic areas and in some of the vessels. No evidences of phagocytosis were noticed, and pigment was not present. One of the specimens contained many acidophile cells, however, with round nuclei but without granules suggesting eosinophiles. Fig. 3 represents a wedge-shaped portion from one of the sections, and gives a fair conception of the appearance of the greater portion of the sections examined.

According to the descriptions, conceptions, and conclusions of Warthin (1) and Meek (2), these specimens are undoubtedly hemolymph nodes. However, that lymph nodes are often congested and hemorrhagic in disease is too well known to need emphasis here, and it was largely because of this fact that Meek (2) came to the conclusion that there are no hemolymph nodes in man. Warthin and others came to exactly the opposite conclusion, however, and it will be recalled that Tixier and Feldzer (3) also noticed hemolymph glands constantly present near the thymus in man. The last investigators found two or three nodes, 2–6 mm. in size, on or in the connective tissue of the thymus, which they regarded as hemolymph nodes. On the other hand, Retterer and Lelievre (4), like Meek, maintained that stasis, etc., could convert a lymph into a hemolymph node. While emphasising the impossibility of distinguishing between hemolymph and lymph nodes by means of gross or microscopical examination of isolated sections, Forgeot (5) claims a rather large experience with vertebrate material, and observations made on the agonal and post-mortem appearance of lymph nodes lead me to believe that the specimens in question are nothing but extremely congested and hemorrhagic lymph nodes.

(1) Warthin, "A Contribution to the Normal Histology and Pathology of the Hemolymph Glands," *Jour. Boston Soc. of Med. Sciences*, vol. v., April 1901.

(2) Meek, "Some Morbid Histological Changes met with in the Lymphatic Glands, especially in connection with the Formation of Hemolymph Glands," *Quarterly Jour. of Med.*, Oxford, vol. iii. No. 12, July 1910.

(3) Tixier et Feldzer, "Note sur l'existence des glandes vasculaires sanguine non décrites juxta-thymiques," *Comptes Rend. Soc. Biol. Paris*, t. 66, p. 21.

(4) Retterer and Lelievre, "Procédé simple pour voir que le ganglion lymphatique possédé les hématies," *Comptes Rend. Soc. Biol. Paris*, t. 68, 1910.

(5) Forgeot, "Sur quelques particularities des ganglion hémolymphatiques des ruminants," *Comptes Rend. Assoc. Anat.*, 11 Réun., Nancy, 1909.

3. Bursæ Pharyngea.

The cysts or bursæ discussed here were all found in the cadavers of white males past fifty. Fig. 4 represents the largest of the three. The tonsils in this subject contained only a small amount of adenoid tissue and a few crypts. They were, in fact, quite sclerotic and atrophic. There was no excess of lymphoid tissue on the tongue, adenoids were not present, and the nasal conchæ presented nothing noteworthy. The specimen represented in fig. 4 was obtained in median sagittal section with a saw in the course of dissection. It measured 1·6 cm. dorso-ventrally, ·8 cm. from right to left, ·9 cm. cephalo-caudally, and was filled with a finely granular yellowish, friable, fatty mass of soft consistency. Since the volume of this bursa, as determined from a cast, was 0·9 cc., the quantity of contained material was approximately a gram, if allowance is made for reduction in size resulting from the cut of the saw.

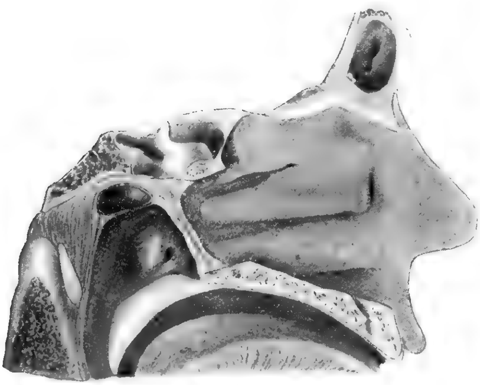


Fig. 4.—Bursa pharyngea. ½ natural size.

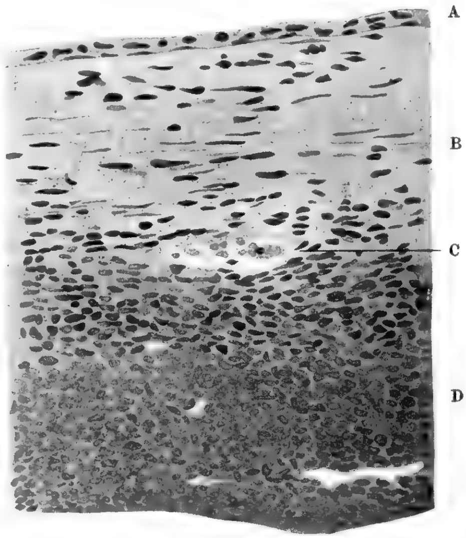


Fig. 5.—Wall of bursa pharyngea.
A, inner syncytial (?) layer; B, fibrous connective tissue; C, blood-vessel; D, adenoid tissue.

It was located directly beneath the ventral or anterior half of the basilar portion of the occipital bone, and lay in almost a horizontal plane crossing the median plane diagonally, so that the greater portion lay on the right side. It extended as far forward or ventrally on the right as the posterior or dorsal fourth of the sphenoidal sinus, but only as far as the dorsal limit of this sinus on the left. If the demarcation seen in the bone superiorly represents the original location of the spheno-occipital synchondrosis, then this bursa is practically bisected by it. The pharyngeal aponeurosis and recti capitis muscles separate it from the adjacent bone and spinal column, and the superior constrictor seems to divide into two leaflets at the dorsal extremity of the bursa, the inferior or caudal leaflet inserting directly into the dorsal extremity of it.

Because of its oblique position comparatively little obstruction was caused to the choana on the left side, but the right was seriously encroached upon. On the latter side the bursa also overlay the pharyngeal recess almost completely, and was practically in contact with the torus tubarius.

The wall of the sac was thin but well defined and smooth internally (see fig. 5). Upon microscopic examination the inner portion of the wall was found to be composed of a syncytium-like layer with elongated oval nuclei. External to this there was a much thicker layer, which formed about half the thickness of the capsule and was composed of connective tissue which contained a few blood-vessels. This connective-tissue layer was gradually replaced by an equally thick cellular layer distinctly adenoid in character. Since the cadaver had been embalmed for some years, all the finer histological characters were, of course, obliterated.

In addition to this specimen two others of like character were found in practically the same location in adults. Both were much smaller, however, and did not extend so far forward. The respective halves of the larger of these had the following measurements in millimeters :

	Right half.	Left half.
Dorso-ventral . . .	9·0 mm.	10·0 mm.
Cephalo-caudal . .	5·5 „	5·5 „
Transverse . . .	6·0 „	7·0 „

This bursa was located directly dorsal to the posterior or dorsal extremity of the sphenoidal sinus. The contents were like those in the one just described, and there was no lymphatic hypertrophy. It was found in a male subject about sixty years old. No histological examination was possible.

The third specimen was only about 3 by 4 mm. in size, but was similar to the rest in other respects.

These bursæ can evidently be regarded as having arisen from (1) the hypophysis pharyngea (Luschka, Erdheim); (2) the recessus pharyngeus medius or pouch of Rathke or Seessel (Meyer); (3) a crypt present in the developing pharyngeal tonsil; or (4) inflammatory adhesions in adenoids.

Since Pende (1) found small cysts containing amorphous, hyaline material in the pharyngeal hypophysis, I see no way in which such an origin for the above cysts can be excluded with certainty. Pende says, however, that he practically always found a connective-tissue capsule around the hypophysis pharyngea or the remnants of it, and that they lie in the spheno-vomerine fossa. The cysts here reported had a connective-tissue capsule on the *inside*, and the smaller two did not extend into the spheno-vomerine fossa. Their position is too far dorsal.

The second origin can, it seems to me, be excluded with considerable certainty, because Meyer (2) found that the bursa pharyngea of adults is firmly attached to the base of the skull and extends through the basilar fibro-cartilage in the region of Seessel's pocket (?), a conception which Huber (3) has shown to be erroneous. Moreover, Tourneux (4), on examining 274 adult crania, found only *one* complete and *four* partial cranio-pharyngeal canals, three of which opened into the naso-pharynx and one into the pituitary fossa.

According to Sokolow (5), who discusses the occurrence of this canal very thoroughly and gives a large bibliography, it was found present in 5 out of 434 adult crania of the Basel collection, or in 1·15 per cent. By averaging the findings of various investigators, Sokolow, however, reports it present in but 3/10 per cent. out of a series of 5281 skulls.

Although, according to writers of experience, the presence of the cranio-pharyngeal canal would seem to coincide approximately in frequency with that of the bursa or cysts under discussion, yet the fact that the latter were wholly free, and that there were no indications of the presence of remnants of cranio-pharyngeal canals, would seem to exclude such an origin. Their position is also too far dorsally or posteriorly. Hence, from the character of these cysts it seems highly probable to me that they arose from the median crypt found in the developing pharyngeal tonsil or from adhesions from inflammatory processes in adenoids. Moreover, French nose and throat specialists have reported cysts in this region which they consider of inflammatory origin. Unfortunately, however, none of these writers considered the possibility of the cysts in question having arisen from the pharyngeal hypophysis of Erdheim.

The fact that such cysts as here reported were never observed in the *faucial* tonsils of cadavers might, however, throw some doubt on their supposed inflammatory origin. Moreover, their deep location and the peculiar relation of the largest to the superior constrictor muscle would seem to require an explanation. However, if the marked changes produced by inflammatory processes in the relations of adjacent structures elsewhere in the body are borne in mind, the peculiar relations of the largest of these cysts to the surrounding structures becomes much less significant, it seems to me. The correctness of this supposition is made all the more probable by reference to fig. 6, which represents conditions as found in a frozen section of a formaline-hardened cadaver of a white male past middle age. In this case the adenoidal mass, which is unusually large and well preserved for this age, contains one cyst approximately $6 \times 4 \times 5$ mm. This cyst, which has a thin connective-tissue wall, is completely surrounded by adenoid tissue. Hence it is very likely that it is of an inflammatory origin, although its origin from the so-called bursa pharyngea or recess in the developing adenoid cannot be excluded with certainty. It would also be interesting to know whether similar cystic structures occur in races living in the tropics, who are said never to suffer from adenoids.

According to Lelievre and Retterer (6), the development of cysts of the pharyngeal tonsil is preceded by an epithelial hypertrophy of the tonsillar crypts. These crypts, which are lined by a normal mucosa in the beginning, are said to lose their epithelial lining, the wall of the cyst varying in different stages of the evolution of the cysts. Although they arise as a

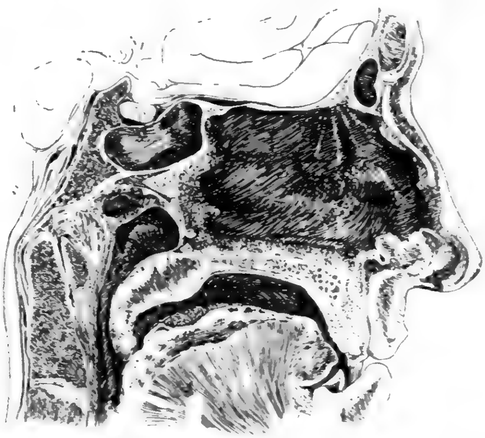


FIG. 6.—Bursa pharyngea surrounded by adenoid tissue. ½ natural size.

result of epithelial hypertrophy, they are finally transformed into retention cysts. These involutionary changes are said to end in the formations of horny (?), mucous masses containing some leucocytes.

(1) PENDE, "Die Hypophysis pharyngea, ihre Struktur und ihre pathologische Bedeutung," *Beitr. z. path. Anat.*, Bd. xlix., Hft. 3, 1910.

(2) MEYER, "Ueber die Bildung des Recessus pharyngeus medius, Bursa pharyngea, im Zusammenhang mit der Chorda bei menschlichen Embryonen," *Anat. Anz.*, Bd. xxxvii., 1910.

(3) HUBER, "On the Relation of the Chorda dorsalis to the Anlage of the Pharyngeal Bursa or Median Pharyngeal Recess," *Anat. Rec.*, vol. vi., 1912.

(4) TOURNEUX, *Base cartilagineuse du crane et organs annexes, etc.*, Thesis, Toulouse, 1910–11.

(5) SOKOLOW, *Der Canalis Cranio-Pharyngeus*, Leipzig, 1904, Thesis, Basel, 1904.

(6) LELIEVRE et RETTERER, "Kystes de l'amygdale pharyngienne hypertrophiée," *C. R. Soc. Biol.*, Paris, 1911, t. 70.

4. A Unique Supernumerary Para-nasal Sinus directly above the Superior Incisors.

Fig. 7 represents the right and larger half of a sinus found on making a median section of the cadaver of a white male approximately sixty years old. The section, which was made with a saw which cut 2 mm. wide, fell a little to the right of the median line and divided the cavity of the sinus into two unequal parts, largely because the sinus was located somewhat asymmetrically. As the drawing shows, it was located directly dorsally and superiorly to the incisor teeth, the roots of which slightly protruded into it along the anterior or ventral wall. On the left side the apex of the root of the central incisor alone reached the cavity; but on the right the roots of

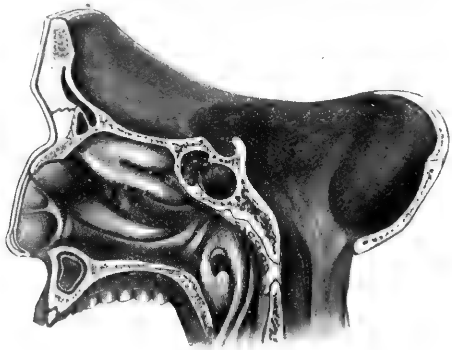


Fig. 7.—Median maxillary sinus. ⅓ natural size.

both incisors, and also that of the canine, encroached slightly upon it. Although the line of section lay to the right of the median line, the right half was considerably larger, as the following measurements show:

	Right half.	Left half.
Vertical . . .	1·6 cm.	1·55 cm.
Dorso-ventral . .	1·2 „	1·35 „
Transverse . .	1·4 „	0·80 + 2 mm. for cut.

Hence, if 2 mm. allowance be made for the cut, the total size was approximately $1{\cdot}6 \times 1{\cdot}35 \times 2{\cdot}2$ cm.

Unless the saw destroyed the communication with the nasal cavity on the right side, none was present. On the left, however, a small opening, 2 mm. in diameter, which was encroached upon only very slightly by the saw, is partially preserved in the dorsal portion of the superior wall just lateral to the intermaxillary suture. From this foramen, which opens into the floor of the inferior meatus, a groove extends caudally or inferiorly along the medial border of the dorsal or posterior wall to a point on the alveolar process just dorsal or posterior to the mid-point of the left central incisor. Unfortunately, the foramen was not noticed early enough to determine the relations of the anterior palatine vessels and nerves to it, and to the above-mentioned groove; but there can be little doubt that they lay in it, and hence very likely passed through the foramen. Moreover, since the size and position of this foramen correspond exactly to the normal foramina occurring in several other specimens, through which the anterior vessels and nerves were known to pass, it does not seem likely that the foramen in question can be regarded as the ostium of the sinus. Besides, the character of the latter and of the bony walls of the sinus was similar to those in the other sinuses, as far as inspection with the unaided eye could determine. The cavity was empty, and the lining membrane especially adherent only to the apices and part of the inner surface of the roots of the protruding teeth. The bony walls were smooth, there was no evidence of disease anywhere in the maxillæ, and all the incisor teeth, save one, were sound. This one, the upper lateral incisor on the right, was decayed several millimeters below the crown; but the root was absolutely sound and the lining membrane over it not thickened or especially adherent.

Because of the presence of all the teeth, and for other reasons, the possibility of this cavity representing a dentigerous cyst or having resulted from an abscess can be excluded, it seems to me. The other possibilities are that it is (1) an accessory maxillary sinus, (2) a bone cyst of other than dentigerous origin, (3) or an independent accessory para-nasal sinus. Since most bone cysts are said to occur in long or pipe bones, to arise in the medulla, to have no capsule, usually to contain hemorrhagic fluid, and to cause expansion of the bone at the place of location, they too can be excluded, for none of these peculiarities were characteristics of the above specimen. There was no new bone formation.

Since this sinus is separated from the maxillary sinuses on either side by an intact bony septum, and since it occupies a median position, it cannot be regarded as a sinus secundarius anterior of Gruber (1), or as a separate chamber of one of the maxillary sinuses as described by Gruber and Zuckerkandl (2). Were the cavity not so large, it might perhaps be regarded as a fused and expanded portion of the anterior palatine canals, but the presence and position of the above-mentioned furrow seems to speak strongly against this supposition. Nor does it seem probable that so large a cavity could have resulted from fusion and expansion of the cupolæ of the sockets of the teeth, even if a satisfactory explanation could be found for the presence and the character of the lining membrane and the relation of the roots of the teeth. Although no mention is made of such supernumerary para-nasal sinuses by Onodi (3), Le Double (4), Killian (5), or Schaeffer (6), it nevertheless seems very probable to me that it must be regarded as such—a simple *lusus naturæ.*

The only air cell of anthropoids comparable to the above sinus is found, it seems, in *Anthropopithecus niger.* According to Underwood (7), "this accessory air cell, which might be called a suprapalatine sinus, occupies a space intervening between the floor of the nasal passage and the roof of the palate. It is separated from the cavity of the opposite side by a thin bony partition (which is incomplete in front). The cell is about three-

Fig. 8.—Suprapalatine sinus in the chimpanzee. After Underwood. *Jour. of Anat. and Phys.* (Lond.), vol. xliv., 1910, p. 365.

quarters of an inch high in front, just behind the incisor roots, and extends backwards, becoming gradually shallower, until it terminates about an inch behind the level of the last molar" (see fig. 8).

(1) Gruber, "Sinus secondarius anterior," *Virchow's Archiv*, Bd. cxiii., 1888.

(2) Zuckerkandl, *Anatomie d. Mundhöhle*, Wien, 1897.

(3) Onodi, *Die Nebenhöhlen der Nase*, Wien, 1905. "Beiträge zur Kenntniss der Nasennebenhöhlen," *Arch. f. Anat. u. Phys., Anat. Abt.*, 1907.

(4) Le Double, *Traité des variations des os de la face de l'homme*, Paris, 1906.

(5) Killian, *The Accessory Sinuses of the Nose*, Jena, 1904.

(6) Schaeffer, "The Sinus maxillaris and its Relations in the Embryo, Child, and Adult Man," *Am. Jour. Anat.*, vol. x., 1910. "The Lateral Wall of the Cavum nasi in Man, with especial reference to the various Developmental Changes," *Jour. of Morphology*, vol. xxi., No. 4.

(7) Underwood, "An Inquiry into the Anatomy and Pathology of the Maxillary Sinus," *Jour. Anat. and Phys.*, London, vol. xliv., 1909.

5. Complete Unilateral Ossification of the Stylo-hyoid Ligament, with the Presence of Two Joints.

Although the occurrence of complete ossification of the stylo-hyoid ligament is not rare, the peculiarly jointed condition of this specimen deserves some attention. Gruber (1), in an article, "Ueber enorm lange Processus styloides," published in 1869, stated that the first one to report a case of complete ossification was Marchetti in an anatomy published in Padua in 1652 (p. 170). Recently Dwight (2) reported a number of specimens, and gave a summary of previously reported cases, with the literature on the subject.

The styloid here reported was 8·5 cm. long, and occurred on the left side in the body of a male past middle life. Since that on the right side was only 2 cm. long, it seems highly probable that there must have been some rotation or lateral displacement even of the hyoid, and perhaps also of the larynx, during life. The dissection had, however, progressed so far when the presence of complete unilateral ossification was noticed, that no observations could be made regarding its effect.

The ossification was regular throughout and the resulting bone quite uniformly cylindrical, although slightly thinner near its articulation with the lesser cornu of the hyoid. Two quite symmetrical annular thickenings are present at the opposite extremities. One is located at the point of articulation with the lesser cornu of the hyoid, and the other approximately six centimeters proximally at what was likely the place of junction of the basi- or tympanohyal with the stylohyal. On examination it was evident that the greater portions of both thickenings were due to fibrous tissue, which formed a well-defined annular band about 3–4 mm. wide and 2 mm. thick at the points of mobility. Mobility at these points was so definite and so evident that it was thought at first that the process had been broken during dissection. Such proved not to be the case, however, and it was found that there were distinct joints at these places and that the mobility was not due to the persistence of unossified portions of the ligament, as is usually the case when ossification has occurred in segments. The apposed ends were quite smooth at these joints; but, since no definite synovial cavity seemed present, they can probably not be considered as true diarthroses. It does not seem unlikely, however, that the partial joint cavities resulted from degeneration in the centre of syndesmoses with fibrous reinforcement externally. It is, to be sure, not an uncommon thing to find jointed styloid processes, and in my experience these have always had purely ligamentous unions, or, when containing small cavities, they have been syndesmoses which permitted the apposed ends of bone to play upon each other more or less. No one except Retterer (3) has reported the presence of true diarthroses, and he did not describe them, although, to be sure, the possibility of their occurrence is not therefore denied.

It is evident that in this particular case the hyoid bone must have been hindered and limited somewhat in its movements during deglutition, as in the case of Richardson (4), and it does not seem improbable that these constantly recurring movements were probably responsible for the presence of the joints. Under the circumstances, the hyoid bone could manifestly not move as directly upward as it ordinarily does, but it could move to the right and forward to some extent at least. Moreover, it is not at all unlikely that the recurring movements also prevented the process of ossification from completely obliterating the two remaining syndesmoses which made partial mobility possible. This conception is contrary to some extent to that of Retterer, according to whom the stimulating effect of movement may be the main factor in initiating ossification. Nor was the writer so fortunate in his diagnosis of the occupation of the individual as was Saint-Hilaire, as shown by the following quotation taken from Retterer's article: "Averti par l'histoire de l'organisation, dit-il, que des os n'acquièrent jamais un développement extraordinaire, qu'il ne soit occasioné par un violent exercice des muscles qui y ont leur attaché, je me persuadai ques les dimensions de l'hyoide que j'avais sous les yeux pouvaient tenir a la profession de l'individu quï avait fourni cette préparation. Je priai M. Serres de consulter les registres des hôpitaux et de vérifier si, comme je le supposais, l'hyoide qu'il m'avait envoyé ne provenait pas d'un crieur public; je transcris ici sa réponse: 'L'homme dont je vous ai fait remettre l'apophyse styloide était un marchand d'habits et de vieux galons, ayant succombé à une phthisie laryngée, maladie très commune à cette classe de marchands.'

"La chaine styloidienne ne se pouvait reconstituer, dans le sujet qui nous occupé, que du côté droit: il n'en existait de l'autre côté que les éléments comme on les observe habituellement." The writer has not been able to obtain definite information regarding the stylo-hyoid apparatus in the giraffe or in tailed amphibians whose quiet habits have been subject to repeated comments. Hence he respectfully commends the question raised by Saint-Hilaire, with the opinions of the distinguished Frenchman, to the attention of naturalists. It is interesting to note that Saint-Hilaire's conception was adopted by Retterer and an attempt made by him to give it a comparative anatomical basis, in spite of the fact that it is stated that the stylo-hyoid apparatus of mammals and the inferior vertebrates is usually completely ossified.

(1) Gruber, "Ueber enorm lange Processus styloides der Schläfenbeine," *Virchow's Archiv*, l., 1869.

(2) Dwight, "Stylo-hyoid Ossification," *Annals of Surgery*, vol. xlvi., 1907.

(3) Retterer, "Signification des anomalies de l'appareil hyoidien de l'homme," *Jour. de l'Anat. et de la Phys.*, xlvii., 1911.

(4) Richardson, "Elongated Styloid Process," *Trans. Am. Laryngol. Ass.*, N.Y., 1909.

(5) Turner, W., "Hyoid Apparatus and Epi-hyal Bone," *Jour. Anat. and Phys.*, xxxvi., 1902.

6. An Adult Heart with a Defective Muscular Ventricular Septum and Ventricular Walls.

The specimens of trilocular or bilocular hearts which have been reported from time to time have generally been obtained from fœtuses, from the newborn, from infants, or from young children who succumbed early in life as a result of the malformation. The specimen under discussion does not belong to this category, however, for it was found in the body of an individual past sixty-five who had died of a double lobar pneumonia and suffered from a number of pathological conditions in addition to double femoral herniæ. There was intense and almost universal arterio-sclerosis, which extended into the smallest branches at the periphery and which was absent only in the aorta. It was found in the common carotids and iliacs, and in all visceral branches except the splenic, although the cerebral circulation could not be examined because the brain had been removed. Both suprarenal bodies were so cystic that nothing was preserved but a remnant of the cortex and of the medulla of the right one. There evidently had been a severe multiple bursitis, as shown especially by the condition of the patellar and ischial bursæ, and a tubercular arthritis in the humero-scapular articulations with bilateral destruction of the long heads of the biceps, of the joint capsules superiorly, and erosion of the articular surfaces. Half a dozen phleboliths from 2–6 mm. in size were also found in the vesico-prostatic plexus.

The heart in its fixed condition is dilated to about one and a half times normal size. The chief increase in size is due, however, to dilatation of the left ventricle, the conus arteriosus, and the pulmonary artery. The right ventricle is but slightly enlarged, and the arch of the aorta is not markedly dilated. There is a deposit of epicardial fat from 2–4 mm. thick over the right ventricular surface, but almost none over the left. In spite of the pronounced general arterio-sclerosis the coronary arteries were only very slightly affected.

My attention was called to an apparent defect in the musculature of what would ordinarily be the ventral or anterior wall of the right ventricle (see fig. 9). This defective area was marked by a translucent spot, roughly circular in outline and 4 mm. across, which was located 6 mm. to the right of the anterior descending branch of the left coronary artery and 3·7 cm. from the apex of the heart. This portion of the wall was so translucent that it seemed to be composed of the serous membranes alone. It was surrounded by the sub-epicardial fat, and became thicker rapidly to the right, but only very gradually so to the left, as the anterior descending branch of the left coronary artery was approached. Then it became exceedingly thin again in a direction obliquely toward the apex across the artery, and about one centimeter distant from the other thin area. This second thin area was opaque, however, because of the presence of a thin superficial layer of fat.

In order to make a more thorough examination of these areas, most of the apparently normal left ventricular wall was excised. By inspection by transmitted light it was found that the translucent spot was contained in the wall of the left ventricle instead of the right, as its location had suggested. Both inner and outer surfaces were smooth, and the surrounding musculature, which was very thin, was absent over the whole area. Most of this thin membranous wall was removed later, and, although in a

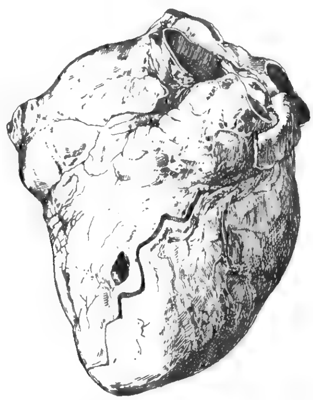


Fig. 9.—Human heart, showing membranous ventricular wall. $\frac{1}{3}$ natural size.

very poor state of preservation, was found, upon microscopical examination, to be composed only of connective tissue, fat, and the serous membranes. Both the thin-walled areas lay over a fossa which was formed by a depression in the musculature. This fossa was subdivided by a ridge of muscle which occupied the region beneath the anterior descending branch of the left coronary artery. With the exception of a small circular area about 3 mm. in size, the thin-walled area below and to the left, which was about 6 mm. in size, included a thin layer of cardiac muscle about $\frac{1}{2}$ mm. thick.

The wall of the left ventricle as a whole was thin, the papillary muscles and the numerous well-defined trabeculæ carneæ were decidedly flattened, and the cavity only about 150 per cent. of its normal size. Both aortic and atrio-ventricular orifices were dilated, but the valves were well preserved, though the former were evidently incompetent. Mühsam states, however, that there is no insufficiency in case of "maladie de Roger," unless there is an isolated hypertrophy.

The most striking thing, however, was the deflection of the incomplete ventricular septum to the right, thus forming an infundibular depression approximately 3·7 by 2·9 cm. in size, containing a large opening (see fig. 10). Since this depression, which was occupied by a post-mortem clot, was flattened ventrally or along the anterior wall, it represented a section of a funnel rather than the whole of it. Upon removing the occluding clot

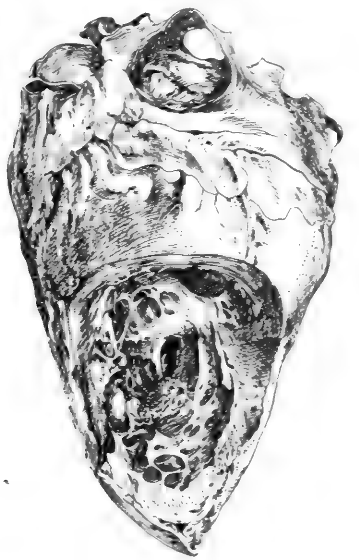


FIG. 10.—Showing the communication between the ventricles. Part of wall of left ventricle is removed. ½ natural size.

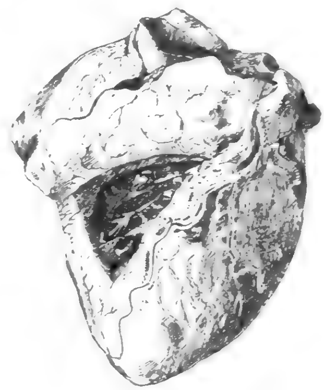


FIG. 11.—The trabeculæ shown in the figure pass anterior, *i.e.* ventral, to the ostium shown in fig. 10. Part of right ventricle is removed. ½ natural size.

it was found that the latter extended into the right ventricle through an opening 1·6 by 1·2 cm. This opening is bridged by a smooth cylindrical cord about 2 mm. thick, partly composed of cardiac muscle, which becomes gradually thicker towards each end where it attaches to the septum. Several smaller strands also extend across the defect, ventral or anterior to the above (see fig. 11). All portions of the opening and the musculature surrounding it were smooth and rounded; there was no cicatricial ring, and no excess of fibrous tissue about the trabeculæ which spanned the oval defect. One centimeter proximally from the opening the ventricular septum was fully 1·2 cm. thick and entirely muscular. The distal or apical remnant was much smaller, however, and only 5 mm. thick in the thickest portion.

Although great care was used because of the deflection of the septum, it was practically impossible to open the right ventricle sufficiently without cutting and damaging some of the trabeculæ which spanned the interventricular opening. Upon removal of the clot, part of which was still soft, the cavity of the right ventricle was seen to be small, the ventricular wall thin throughout, but especially so as the thin-walled area is approached. The trabeculæ carneæ and papillary muscles were flattened, the right atrioventricular orifice was obliquely opposite the defect in the ventricular septum, and the margins of the tricuspid valves only 1·2 cm. distant from it.

In spite of the dilatation and compression of the walls of the various chambers, the valves retained all their anatomical details. There were no signs of vegetations or ulcerations on any of them, and the chordæ tendineæ, which were extremely delicate, were normal in appearance.

The complete absence of gross pathological lesions anywhere in the musculature of this heart, and the character of the defects, seem to indicate that they must have been present a considerable length of time ante-mortem, although there was no hippocratic clubbing of the fingers and no hypertrophy of the left ventricle. The ductus arteriosus was closed, there were no evidences of syphilis or endocarditis, and there was no pulmonary stenosis, as is said to be usually the case. The entire absence of pulmonary stenosis in this case of uncomplicated interventricular defect is significant, for it confirms Vierordt's conclusion, and it seems to disprove the view that septal defects are the results of stenosis. Moreover, had intra- or extra-uterine inflammatory changes been responsible for this anomaly, one would surely expect to find valvular and endocardial changes. But even if this defect in the septum be regarded as resulting from some degenerative change in the musculature of the heart, the fact nevertheless remains that the lesion was not a recent one, and that the individual must consequently have lived some years with it and with the defective areas in the musculature of both ventricular walls. When the presence of the intense sclerosis, the high blood-pressures frequently associated with it, and the advanced age of the individual at the time of death are taken into consideration, it is difficult, indeed, to realise how life was possible under these conditions. However, even granting that the defects are acquired, since life must have been possible apparently for a period of years in an adult afflicted with such grave lesions, it seems the more likely that we are dealing with a developmental anomaly in spite of the fact that the defect is located somewhat unusually, for, according to Mall (3), "An open interventricular foramen in the adult always communicates between the aortic vestibule and the space below the medial cusp of the tricuspid valve, as is clear by observing Spalteholz's figure." It is also evident that the defect described had no direct relation to the atrio-ventricular system, as was true in a case referred to by Mall: but I take it that the absence of such an association does not throw doubt upon Mall's conclusions or exclude the possibility of the defect here reported being a developmental one.

That life is possible even for decades with septal defects seems to be clearly indicated by those cases in the literature which were observed clinically for some time. Moreover, the absence of ventricular hypertrophy in this case may in part at least be accounted for by a possible total obliteration of the septal ostium in systole. Hence one might, I think, regard this case as one of an uncomplicated congenital interventricular defect. Bellubekianz (1), after a review of the literature, and while admitting that uncomplicated septal defects are rare, says that Rokitansky was in error when he declared that other anomalies of the vascular system are always associated with congenital septal defects. He says: "Aber est ist unrichtig wenn man früher annahm das einem schweren angeborenen Herzfehler nur ein kurzes Lebensalter gegönnt sei, Wir können aus der Literatur Fälle wo unter bestimmten Umständen auch Menschen mit angeborenen Herzfehler ein höheres Lebens alter erreichen kommen."

Sokolow (2) also recently reported two cases in which the ventricular septum was absent and two in which it was anomalous. He regarded both the defects in the ventricular septum as congenital and not embolic.

Pinner (4) also reported the case of a boy of nine months who had been under observation for several weeks before death, in whose heart the ventricular septum was wholly absent, thus leaving a common cavity. However, in this case other serious anomalies were present. The absence of any protrusion in the region of the weak membranous walls, and the fact that these thin areas did not rupture, seem equally remarkable. The endocardium and visceral pericardium were entirely normal, free from coagulum of any kind, and the musculature around the thin-walled areas was hardly such as to enable it to protect the defective areas during systole by closing in around them and practically obliterating them. Had these thin-walled areas resulted from degeneration, infection, or ulceration, one would rightly expect to find an excess of connective-tissue and some scar-tissue formation, as well as valvular changes. Such was, however, not the case, and I do not know whether local atrophy occurs and whether it could account for these lesions or not.

That very thin regions in the cardiac walls do not necessarily interfere with normal cardiac function is well illustrated by the structure of the ventricle, especially of bovine hearts. In the latter there is an exceedingly thin portion of the cardiac wall, often only 2–3 mm. thick, directly at the apex, although the average thickness of the left ventricular wall is as much as 2·5–3·5 cm. I am not sufficiently informed as to the arrangement of the musculature in the bovine heart, but if this thin apical portion is situated in the centre of a vortex of fibres as represented by Mall (3) in the human heart and by MacCallum (5) in the pig's heart, it is evident that the surrounding musculature would of course close in and so prevent the full systolic pressure from being exerted upon the weak area.

(1) Bellubekianz, *Zwei Fälle von congenitalen Vitien, u.s.w.*, I.D., Berlin, 1910.

(2) Sokolow, "Zur Kausistik der angeborenen Herzanomalien," *St Pétersbourg Méd. Rechr.*, 1910.

(3) Mall, "On the Muscular Architecture of the Ventricles of the Human Heart," *Amer. Jour. Anat.*, vol. xii., 1911.

—— *Ibid.*, vol. xiii. No. 3, 1912.

(4) Pinner, *Ueber einen Fall von Cor biatriatum univentriculare*, I.D., Königsberg, 1911.

(5) MacCallum, J. B., "On the Muscular Architecture and Growth of the Heart," Welch Festschrift, *Johns Hopkins Hospital Reports*, vol. ix., 1900.

7. A Male Cadaver with Multiple Anomalies.

(*a*) The left innominate vein passed around the left side of the heart and opened dorsally and independently into the right atrium directly above, *i.e.* cranially to the inferior cava.

(*b*) The left vertebral artery arose directly from the aortic arch between the common carotid and the subclavian arteries.

(*c*) Absence of the cœliac axis, with independent origin of the vessels normally arising from it.

(*d*) Two distinct renal arteries on both sides.

(*e*) Two accessory renal veins on the left side.

(*f*) The spermatic veins on the left side joined the main renal vein intrarenally.

(*g*) Bilateral double ureters which joined a few centimeters before joining the bladder.

Since the literature on cases of multiple anomalies is such an extensive one, and since the above case throws no new light on these abnormalities, a discussion of the above case or of those in the literature does not seem justified.

8. Some Observations on the Presence of Duodenal Sphincters.

Some years since Ochsner (1) reported the finding of a special broad sphincter in the duodenum, 2–4 cm. below the duodenal papilla, to the action of which he largely attributed so-called idiopathic dilatation of the duodenum. This sphincter, according to Ochsner (2), "consists of a marked thickening of the circular muscle fibres . . . at a point below the entrance of the common duct." The presence of this sphincter was, according to Ochsner, "proved by a large number of dissections," and he adds, "A considerable variation was found in the exact position of these muscle fibres. In some instances they were arranged in a narrow circular band, forming a distinct sphincter; in other instances the thickening was diffused, making a broad circular band; and in a few instances the thickening was in two different bands, with an intervening portion in which the circular muscle fibres were of the same thickness as the remaining portion of the duodenum." Boothby (3) later failed to confirm Ochsner's observations, and strangely enough concluded that the main variation in thickness of the duodenal wall was due to differences in thickness of the mucosa. Shortly after Ochsner published his results with the unconvincing illustrations, the writer began to inspect sections and examine the duodena in dissecting-room subjects in connexion with observations on occasional supernumerary communicating branches between the left and middle colic arteries.

It is, to be sure, an easy matter to find local contractions in the duodenum. These are most common in the pars descendens, vary exceedingly in position, and are often absent altogether. On section the circular coat is found thickened, in the region of the constrictions, much after the fashion of a true sphincter. Such a thickening would, however, be the necessary consequence of a local contraction in any portion of the duodenum, or of the intestinal tract for that matter. Moreover, such contractions and similar thickenings are exceedingly common, especially in the descending, iliac, and pelvic colons, but less so in the ascending and transverse colon and the small intestine. In fact, these contractions seem to be most common in those portions of the intestine which are more intimately united to the abdominal walls. Why this should be so has long been a puzzling question to me, and no satisfactory explanation suggests itself for these contractions, or for the cases of post-mortem intussusception.

Although local contractions which suggest and the resulting local thickenings which simulate sphincters may and do occur frequently in the small intestine in dissecting-room subjects, no one would, to be sure, consider all of them to be the result of the contractions of special sphincters. Besides, it is not improbable that conditions in the duodenum are such as to make local post-mortem or agonal contractions even more frequent or violent than elsewhere. Then, too, in dissecting-room cadavers the effect of the embalming fluids must not be overlooked. The observations of Beckey (4) and Waterston (5) upon the effect of formaline upon the contraction and shape of the stomach, and of Waterston (6) upon the post-mortem effects of formaline and upon the persistence of irritability in the muscular coats of the intestine, are extremely suggestive and significant in this connexion; but one would scarcely be warranted in concluding that there are special sphincters wherever there is a predisposition to contractility, even if it can be shown, as held by Cunningham (7) for the sphincter antri pylorici of Hofmeister, that such sphincters do exist in a certain percentage of cases. Schwalbe (8), on the other hand, says that such a sphincter cannot be demonstrated. Consequently, whatever the cause of so-called idiopathic dilatation of the duodenum may be, it has not been possible to show that these local contractions of the musculature of the duodenum, which result in local thickenings which simulate sphincters more or less remotely, are after all due to sphincters, and that their occurrence is accompanied by dilatation of the proximal portion of the duodenum. Moreover, if conditions in dissecting-room cadavers can form a fair basis for judgment, the writer seriously doubts whether even considerable obstruction at the duodeno-jejunal flexure is an invariable or necessary cause of dilatation of the duodenum or hypertrophy of its musculature. This leads directly to the next item.

(1) Ochsner, A. J., "Constriction of the Duodenum below the Entrance of the Common Duct, and its Relation to Disease," *Trans. Am. Surg. Ass.*, vol. xxxiii., 1905.

(2) —— "Further Observations of the Anatomy of the Duodenum," *Am. Jour. Med. Sci.*, vol. cxxxii., 1906.

(3) Boothby, "On the so-called Ochsner Muscle of the Duodenum," *Boston Med. and Surg. Jour.*, vol. cliii., 1907.

(4) Beckey, "Contractionsphänomene des Magens und ihre Beziehungen zur Pathologie," *Frankf. Zeitschr. f. Path.*, 1911, Bd. vii. H. 3. Accessible in review only.

(5) Waterston, "The Action of Formalin and the Shape of the Stomach," *Verh. Anat. Ges.*, 24 Vers. Brussel Ergh., *Anat. Anz.*, Bd. xxxvii., 1910.

(6) —— "The Effects of Formalin Hardening and the Persistence of Irritability in the Muscular Coats of the Intestine," *Jour. Anat. Physiol.*, vol. xlv., 1911.

(7) Cunningham, "The Varying Forms of the Stomach in Man and the Anthropoid Ape," *Trans. Roy. Soc. Edin.*, 1906, vol. xli. part 1, No. 2.

(8) Schwalbe, "Beiträge zūr Kenntnis des menschlichen Magen," *Zeitschr. f. Morph. u. Anthrop.*, Sonderheft ii., 1912.

9. A Hitherto Unrecognised Agent in the Formation of Duodeno-jejunal Fossæ, a Recessus duodeni suprema.

Not very uncommonly the left colic artery gives off an ascending branch which runs cranially along the vertebral column a few centimeters lateral to the aorta and parallel to it. If this branch, which is rarely of considerable size, is joined by a left descending branch of the middle colic, a second smaller or accessory anastomotic circle is formed between these two vessels, which usually lies immediately lateral to the duodeno-jejunal flexure, raising a fold of peritoneum as it does so, or it passes across the flexure itself and gives rise to conditions which favour the formation of a retro-peritoneal fossa. In some cases in which the pars inferior of the duodenum was displaced slightly to the left and lay somewhat parallel to the vertebral column, this accessory ascending branch of the left colic lay directly on the left lateral portion of the duodenum and passed across the duodeno-jejunal flexure to join a similar anastomosing accessory descending branch of the middle colic. In some cases the loop formed by these vessels was also joined by a branch which arose directly from the aorta immediately caudal and slightly to the left of the cœliac axis.

These fossæ, which are comparable to the fossa of Landzert in their manner of formation, were usually small, yet in a few cases they were sufficiently large to contain a small portion of the duodeno-jejunal flexure or of the initial portion of the jejunum. Even in the cases in which only a portion of the flexure was included in them, the anastomotic circle was always found to constrict the lumen of the flexure. In two of these cases a loop of the flexure—mainly jejunum—was lodged so firmly in the fossa, and the anastomotic vascular loop constricted it so deeply, that considerable force had to be used to dislodge it, although no adhesions were present. In other instances only the cranial or superior wall of the flexure was constricted and contained in the fossa, but it is evident that all grades between total and partial inclusion of these portions of the intestine are possible.

These para-duodenal fossæ, while similar in origin to the fossa of Landzert, may also give rise to retro-peritoneal herniæ to the left of the duodenum, a fact which was overlooked by Moynihan, who held that those of Landzert were the only ones that could do so.

Such vascular constrictions, even if not so pronounced *intra vitam* as *post mortem*, must offer considerable resistance to peristalsis and the passage of intestinal contents. Yet in no case was any evident hypertrophy of the musculature or dilatation of the duodenum apparent. Nor was such the case in those instances where folds of peritoneum at the flexure or adherent lymph nodes surrounding the superior mesenteric artery, which had bound down the duodenum to the vertebral column, were found present. In view of these facts it does not seem probable to me that moderate or even considerable obstruction at these points is likely to result in dilatation of the duodenum, recognisable in the dissecting-room cadaver; and that, whatever the cause of dilatation may be, it is unlikely that moderate obstruction is the chief or even an important factor.

10. Two Independent Unilateral Accessory Anterior Serrati in the Male.

According to Le Double (1), a number of investigators have reported muscular slips accessory to the serratus anterior, but none of these correspond exactly to those here recorded. Hence a note may be justified. The small accessory serrati in question were 5·5 cm. long, and 3·2 cm. and 4 cm. wide respectively. Each was composed of two closely associated portions which could be isolated easily. The first and narrowest muscle arose from the second and third ribs and the external intercostal fascia between them, approximately 3 cm. lateral to the angle of the ribs, and was attached dorsal to the serratus anterior along the scapular border, beginning 1·5 cm. caudal to the superior angle of the scapula. The second broader and somewhat thicker muscle had similar attachments directly caudal to the first. It also was composed of two portions. The serratus anterior was well developed and normal in all respects. The nerve supply had been destroyed before attention could be directed to it.

(1) Le Double, *Variations du système musculaire de l'homme*, Paris, 1897.

11. Bilateral Absence of the Frontal Sinus.

Although the entire absence of the frontal sinuses is perhaps not so rare as Schaeffer (1) implies, it is to be doubted whether their absence is as common as Boege (2) reports. The latter, who gives an excellent summary of the literature, found bilateral absence of the frontal sinus in 4 per cent. of the 203 skulls examined.

The skull in which the peculiarity here reported was noticed was taken from the body of a white male 52 years old. The cadaver was entirely normal in all respects, all the other sinuses were present, and diplöetic bone was found throughout the calvarium. None of the para-nasal sinuses were especially large, supernumerary cells or sinuses were not present, and the semilunar hiatus and infundibula were normal on both sides. The latter were, however, directly continuous with a rudimentary frontal recess which ended in a slightly dilated extremity about 3 mm. superior to the naso-frontal sutures, and could hence hardly be said to extend into the ventral portion of the frontal bone (see figs. 12 and 13). There was no

FIG. 12.—Absence of frontal sinus. Median section. Lateral view. ½ natural size.

FIG. 13.—Same as fig. 12. Median view.

thinning of the latter as in the case reported by Ouston (3), and the region of the sinus is occupied by condensed cancellous bone. For the development of the para-nasal sinus, an explanation of various anomalies found, and further literature on the subject, the reader is referred to Schaeffer (1).

(1) SCHAEFFER, "The Lateral Wall of the Cavum nasi in Man, with especial reference to the various Developmental Changes," *Jour. of Morphology*, vol. xxi., No. 4.

(2) BOEGE, *Zur Anatomie der Stirnhöhlen*, Königsberg, 1902: Thesis, Königsberg, 1902.

(3) OUSTON, "Notes on a Case of Absence of Frontal Sinus," *Northumberland and Durham Med. Jour.*, vol. xviii., 1910.

(4) TURNER, LOGAN, *Accessory Sinuses of Nose*, 1901.

12. BILATERAL ABSENCE OF THE TENDON OF THE LONG HEAD OF THE BICEPS IN ONE SUBJECT, AND FIVE INSTANCES OF SECONDARY ATTACHMENT OF THE TENDON TO THE ARTICULAR CAPSULE AND TUBEROSITIES, WITH SPECIAL REFERENCE TO THE EFFECT OF THESE ANOMALOUS CONDITIONS UPON THE INTERTUBERCULAR SULCUS.

The above instances, which all occurred in adult male subjects, would perhaps scarcely deserve reporting were it not for the fact that they are of interest in connexion with the genesis of the intertubercular sulcus and the effect of pressure and tension upon the form of bones.

In the first case the biceps was fairly well developed in both arms, and the long head ended in a small, flat, independent, tendinous expansion which was inserted into the shafts of the respective humeri 2·5 cm. proximal to the distal point of insertion of the pectoralis major and immediately medial to it, but independent of it.

In the second case of bilateral, and in one case of unilateral absence, the long heads were secondarily inserted into the articular capsule by means of broad fibrous expansions and into the sulci and the tuberosities as a result of disease.

In the first or normal case there is no question that the intertubercular sulci were shallower, less concave, or rounded transversely, and shorter than is usually the case in subjects of corresponding muscular development and in skeletons of approximately corresponding weight. These differences were especially noticeable in the deepest parts of the sulci, however, where the regularly rounded groove with its smooth floor is usually seen at its best.

Hence it seems to me that it is not at all unlikely that these decided modifications of the intertubercular sulci, especially in their upper portions over the anatomical neck, suggest that pressure exerted by the tendons of the long heads of the biceps is an undeniable factor in their formation. It is true that, as in the cases reported by Joessel (1), there is not a complete absence of the sulcus in these cases, but it does not therefore follow that the pressure exerted by the tendons themselves does not exert a moulding effect on the sulcus. Moreover, Joessel admits that the sulci are shallower in cases of absence of the long head of the biceps, and this in itself is the best possible proof, it seems to me, that tendon pressures do help to determine the relief of bones. Moreover, if, as Joessel seems to think, the intertubercular sulci are produced solely by tension at the points of the muscle insertions along the ridges, it devolves upon him to show why pressure should not also have a corresponding effect. Nor does Hirsch's (2) objection that it would be remarkable if pressure were a factor, because delicate synovial membranes are interposed between tendons and bones, seem a pertinent one. That fact may be remarkable, indeed, but is it not at least as remarkable that these same delicate sheaths are and must be subjected to considerable and constantly repeated pressures as the inevitable result of muscular activity in the normal body? It is also well to remember in this connexion that there are serous membranes—and synovial membranes are, of course, not such,—or true membranes even, quite as delicate as tendon sheaths, which are subjected to considerable continuous pressure without the least damage. Such denials of the effects of pressure on the relief of bones surely cannot throw serious doubt upon the conceptions of Roux and others in this regard. Regarding the normal specimens under discussion, it is not a question of destruction of adult bone but of the moulding of immature bones during a time of their greatest plasticity—their period of growth. Moreover, transplantation experiments and cases of ankylosis have shown quite conclusively that new surroundings can and do transform bones to a surprising extent.

The five instances of attachment of the tendons of the long heads of the biceps into the articular capsule and tuberosities were not introduced directly into the above discussion, because they are pathological specimens. Yet a careful examination of them shows also that the presence of a remnant of a tendon had a formative effect in the one case in which that tendon was not wholly destroyed as a result of articular disease.

In four of these five cases the portion of the tendons between the tuberosities and the supraglenoid tubercle, *i.e.* practically all the intracapsular portions, was completely destroyed. In each case, probably as the result of inflammatory changes, the tendon obtained a secondary attachment to the articular capsule, to the distal portion of the intertubercular sulcus, and in one case also to the lesser tuberosity. In the fifth case several thin, narrow, fibrous strands of the intracapsular portion of the tendon of the long head were still present, however, although attachments had also been made to the capsule and the shaft near the tuberosities. The remaining strands of the tendon which were still attached to the supraglenoid tubercle, and which had fused with the capsule throughout their extent, nevertheless were able to mould a new sulcus somewhat anterior to the original sulcus over the anatomical neck and part of the head of the humerus, even in a region where erosion of the cartilage and bone had occurred. Such was, however, not the case in the other specimens, in which all the intracapsular portion had been destroyed. In these specimens by far the greatest portion of the intertubercular sulcus had been quite completely obliterated by the disease. Hence it is clear that the pressure exerted by a mere remnant of the tendon was sufficient to form and to mould an entirely new sulcus on the extratubercular portion of the bone—that is, over the neck and a portion of the head of the humerus eroded of its cartilage by disease. The implication is not that pressures which are adequate or effects which are evident in disease are necessarily adequate and evident under normal conditions, but merely that tendon pressures are undoubted factors in the determination of the relief of bones.

(1) Joessel, *Zeitschr. f. Anat.*, His Branne, 1877, Bd. xi.

(2) Hirsch, *Die mechanische Bedeutung der Schienbeinform*, Berlin, 1895.

—— "Uber die Beziehung zwischen dem Neigungswinkel des Schenkehalses und dem querschnitte des Schenkelbeinschaftes," *Anat. Hefte*, Bd. xi., 1899.

13. Unusual Exostoses on Two Humeri and a Femur, with special reference to the Effect of Tension and Pressure upon their Shape and Direction and their Relation to Chronic Inflammatory Processes.

Both of the exostoses on the humeri shown in figs. 14 and 15 were included in the origin of the brachio-radiales muscles. The first and larger was smooth, stout, 6 mm. thick, 1·2 cm. high in the perpendicular, 3·4 cm. long in the oblique, and arose from the lateral epicondylic ridge 6·5 cm.

Fig. 14.—Right humerus, obliquely from the side. $\frac{1}{3}$ natural size.

Fig. 15.—Left humerus, from the posterior. $\frac{1}{3}$ natural size.

Fig. 16.—Right femur, obliquely from the medial surface. $\frac{1}{3}$ natural size.

proximal to the articular surface. It had a rather blunt, rounded extremity, and was directed decidedly distally in the direction of pull of the muscle. The second and lower but more extensive one was considerably smaller, more irregular in shape, and measured $8 \times 1{\cdot}0 \times 2{\cdot}8$ cm. in thickness, height, and length respectively. It arose 2·3 cm. proximal to the articular surface, and corresponded in its general direction with the former process. It also was located on the epicondylar ridge and extended proximally over it for about 2·5 cm.

The exostosis on the shaft of the femur shown in fig. 16 was located on the medial surface, 12·3 cm. proximal to the articular surface, arising directly from the shaft where the linea aspera divides into the epicondylic ridges. It is thin, broad, and flat, perfectly smooth, has a slightly concave ventral surface, and measures 2·3 cm. in length, 3 cm. in width at the base and 2·6 at the extremity, and 3 mm. in thickness. The adductor tubercle is practically absent, but the linea aspera is well marked and the ventral curvature of the shaft of the femur somewhat accentuated.

The tendon of the adductor longus passed immediately ventral or anteriorly to this large, flat process, but the adductor magnus was attached directly dorsal to it. It is more than likely that the combined effects of these two muscles moulded this large exostosis—or perhaps, more properly speaking, this osteophyte—so as gently to curve it ventrally, thus forming an anterior or ventral concavity embracing the adductor longus. This supposition is confirmed by the character of the dorsal surface of the process.

It is not unlikely, it seems to me, that irritation, or perhaps stimulation from muscular activity, was the chief factor in the formation of some of these processes. This supposition is also supported by the fact that all three are located on bony ridges which serve for muscular attachments and the development of which is correlated to a certain extent to muscular development and activity. It should be noted, however, that one of the exostoses on the humeri and that on the femur are found on bones whose distal and proximal extremities respectively showed signs of chronic articular disease. There is, however, little reason to suppose that the disease was the sole, even if the primary, factor in their formation or that they are necessarily manifestations of localised pathological processes alone. Although such an assumption is not necessarily contradicted by the character of the osteophytes themselves, yet it is made unlikely by the occurrence and character of the exostoses in the third or wholly normal specimen. Wurmb (1), who calls attention to the relation between solitary exostoses and traumata, also reports a case in which exostoses arose gradually and wholly spontaneously; and in the cases here reported it is evident that although the exostoses are found near the extremities of the respective bones, they manifestly are not located near the epiphyseal lines. Since there was no indication of rickets in these cases, they would seem to negative Volkmann's conception of the origin of exostoses; and since the respective bones were no shorter than their companions, the hypothesis of Brenner and Meyer also fails of confirmation.

There was no layer of cartilage over any of these exostoses, and none of them contained a medulla. Hence they were probably periosteal and not cartilaginous in origin. Winters (2) states that most solitary exostoses have a periosteal origin, and that all exostoses arise in youth. It is probable, it seems to me, that a chronic inflammation—chronic arthritis in two cases—played an important rôle by producing a local periostitis where considerable traction was exerted upon the intermuscular septa and produced a congestion and irritation which stimulated bone formation, even if the conception of Weber, as reported by Winters, cannot be considered a causative factor in the formation of exostoses.

(1) Wurmb, *Ein Fall von multiplen Exostoses*, Thesis, Kiel, 1903.
(2) Winters, *Über einen Fall von Exostosis tibiae*, Thesis, Kiel, 1903.

14. Changes produced in the Structure of Bones by Ankyloses.

I fully realise that the discussion regarding the relation between form and function is not ended, and that this relationship is not always a simple,

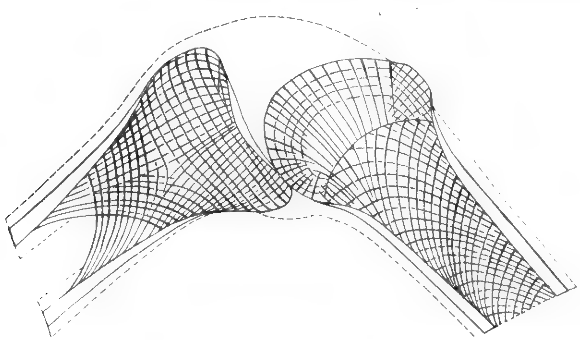


Fig. 17.—Normal architecture at apposed ends of femur and tibia. After Roux (*Arch. f. Anat. u. Phys.*, 1885, p. 140).

a self-evident, or even a necessary one. It is, however, a decidedly interesting and constantly recurring question.

It will be recalled that Roux (1) reported a case of ankylosis which he thought showed undoubted evidences of functional adaptation, especially of the spongiosa. The specimen was that of the right knee of an adult, which had become ankylosed at an angle of 80°, and in which no line of demarcation between the united ends of the femur and tibia could be found. The compacta forming the dorsal and ventral walls was decidedly thickened, and there had also been a marked readjustment of the spongiosa in both bones.

In order to illustrate these changes, the architecture in the respective ends of the normal femur and tibia are represented diagrammatically in fig. 17, and the composite modified architecture as found by Roux in medial sagittal section in fig. 18. Roux reported, however, that there was some difference in structure between the medial sagittal section and others taken to the right and to the left of it, in the case reported by him.

According to Roux, this readjustment of the spongiosa had taken place in response to and in harmony with the change in trajectories which resulted from the ankylosis, and Roux illustrated the direction of these new trajectories by means of pressure exerted on a piece of specially prepared gutta-percha. Those interested in the problem will find a discussion in Roux and also in the *Essentials of General Anatomy* by Reinke (2). Triepel (3), who reported the changes produced in the patella in a case of ankylosis, also believed that these were the results of a functional adaptation of its internal architecture to a changed environment.

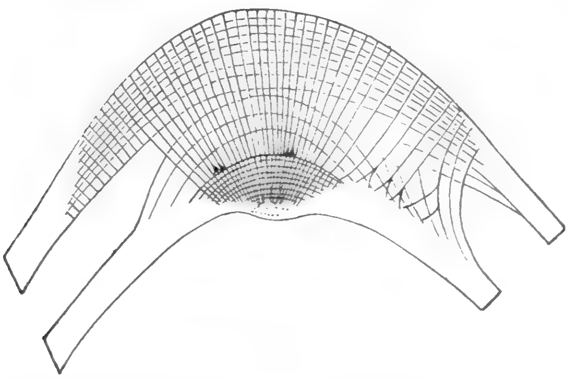


FIG. 18.—Composite diagram of the transformed spongiosa in a case of ankylosis of the knee. After Roux (*Arch. f. Anat. u. Phys.*, 1885, p. 150).

Through the courtesy of a physician, a specimen, likewise of ankylosis of the right knee, from a middle-aged white woman, was obtained in perfectly fresh condition. This ankylosis, which had resulted from a resection of the knee done two years previous to the amputation, had taken place at an angle of 155°. Since the femur had been resected about 1 cm. distal to the adductor tubercle, and the tibia 1 cm. proximal to its tuberosity, about 5 cm. in length of bone had been excised. As the specimen was anatomically entirely normal, it is not necessary to make allowances for or to consider the possible effects of pathological processes. Neither the femur nor the tibia shows a pronounced architecture, nor is this surprising when the sex and the sedentary life of the patient are taken into consideration. A slight displacement of the resected ends had evidently taken place, for, although the apposed ends of the bones were approximately of the same size, the femur projected ventrally and the tibia dorsally about 1 cm. Only slight absorption of the edges of the projecting ends of the bones had occurred, but the compacta of the region of fusion was evidently much thicker on the dorsal or posterior than on the ventral or anterior surface of the specimen. In the latter region, where a sulcus marked the line of union of the bones, the spongiosa was covered only by a very thin layer of compact bone.

On medial section it was found that the line of union, which was almost completely obliterated, was marked only by a slight condensation in the spongiosa, which extended across the specimen practically at right angles to the long axis of the tibia, but intersected that of the femur at an angle of about 12°. Upon comparing the thickness of the compacta with that found on bones of about equal size, it was apparent that it was thickened somewhat on the dorsal surface of the tibia directly distal to the line of union over the region of greatest concavity, but a corresponding thickening was not present on the ventral or convex surface of the ankylosed bones. Immediately beneath the latter surface some transformation of the spongiosa has apparently also taken place, for the original direction of the trabeculæ was modified. They were also thicker, and the cells of the spongiosa were smaller here instead of larger, as is usually the case in normal specimens. A similar though less marked condensation and thickening of the trabeculæ is also apparent in the dorsal portion of the section, where reinforced trabeculæ leave the compacta and extend gently forward, forming arches with their concavity directed proximally. Shorter trabeculæ also extend inward from the compacta on the dorsal surface. In both bones the arches formed by the trabeculæ on the ventral surface, as represented in fig. 19, have become less characteristic and evident than in the normal specimens, and have united or been transformed to form longer but less curved arches, which span the ventral convex portion of the specimen and lie roughly parallel to the external surface. These arches are not very evident because they are crowded together. They are also thickened, reinforce the union, and are comparable to those in the corresponding portion of the diagram from Roux as represented in fig. 18. Moreover, these modifications of the original structure evidently have occurred in response to functional demands, for as the weight of the body was borne on the ankylosed extremity there was a tendency to increased flexion. Hence the effect of body-weight was to compress or crush the bone dorsally on the concave side and to separate it on the ventral or convex side. These effects were absent, of course, before the ankylosis occurred, for the extremity could then be fully extended and the body-weight in extension be transmitted in a vertical direction. In response to the changed forces resulting from ankylosis, the spongiosa near the convexity evidently became readjusted and reinforced into a number of parallel arches so as to resist separation by tension, while that on the dorsal or concave surface became condensed and the spongiosa and

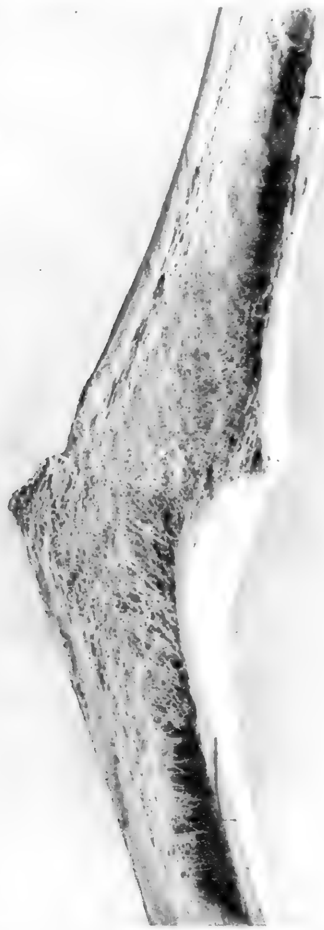


Fig. 19.—Photograph of a median sagittal section of the ankylosed femur and tibia, showing modification of the architecture. ½ natural size.

compacta thickened to resist compression or crushing. It is true that these transformations or adaptations are not very pronounced in this specimen, but it should be borne in mind in this connexion that ankylosis took place at an angle of 155°—a deviation of but 25° from the original normal extended position of the extremity. Moreover, since the patient lived a sedentary life, it could not be expected that a very radical and rapid readjustment could have taken place under such circumstances. In view of these facts, it seems to me that the above modifications of the original structure are sufficiently evident to justify the interpretation placed upon them.

(1) Roux, "Beschreibung und Erläuterung einer knöchernen Kniegelenksankylose," *Arch. f. Anat. und Phys., Anat. Abt.*, 1885, and *Gesammelte Abhandlungen*, Leipzig, 1895.

(2) Reinke, *Grundzüge der allgemeinen Anatomie*, Wiesbaden, 1901.

(3) Triepel, "Architekturen der Spongiosa bei abnormer Beanspruchung der Knochen," *Anat. Hefte*, Bd. xxv., 1904.

——"Die Knochenfibrillen in transformierter Spongiosa," *Anat. Anz.*, Bd. xxix., Ergänzg. Hft., 1906.

——"Trajektorielle Strukturen," *Anat. Anz.*, Bd. xxiv., 1903.

15. An Abnormally Large Unilateral Foramen mastoideum, Canalis mastoideus, and Sulcus emissarium mastoideum.

Merkel (1), who gives the normal size of the mastoid foramen as somewhat smaller than the "quill of a pigeon's feather," states that the anatomical collection at Göttingen contains a skull with a mastoid foramen large enough easily to accommodate the tip of the little finger. Merkel,

Fig. 20.—Foramen and hiatus mastoideus. ½ natural size.

however, concludes that such a large foramen is the result of yielding of the bones at the base of the skull as a result of rickets, with consequent encroachment on the jugular foramen and a compensatory widening of the mastoid foramen in order to accommodate the increased amount of blood which must pass through it as a result of obstruction of the jugular foramen.

While not desiring to question the correctness of Merkel's conceptions as to the genesis of the particular large foramen to which he refers, the above specimen illustrates very well that rachitis is not necessarily a factor. There was no evidence of rickets in the skeleton of the white male subject from which the specimen here reported was taken, and the jugular foramen is wholly unobstructed. Notwithstanding this fact, the inner opening of the mastoid canal, which lies in the dorsal border of the transverse sinus approximately 2 cm. lateral to the lateral border of the jugular foramen, has a diameter of 6 mm., and the oval mouth of the sulcus emissarium on the exterior a long diameter of 8 mm. (see fig. 20). This external oval mouth, which lies on a level with the external auditory meatus, forms the entrance to a deep tortuous sulcus which passes into the temporal bone somewhat diagonally upward and forward directly superior to the mastoid cells. There is also a shallower sulcus, which leads into the deeper sulcus above described.

The mastoid emissary vein on the opposite or left side of the skull was, on the contrary, almost vestigial, and the foramen and canal so small that they would not admit more than the point of a fine pin. The other emissary foramina were not unusual in any respect.

(1) Merkel, *Topographische Anatomie*, Braunschweig, 1885.

16. A Unilateral Accessory Aberrant Meningeal Artery arising from the Occipital.

The above artery, which arose from the left occipital in the retromastoid region, was approximately 3 mm. in diameter and pierced the occipital bone obliquely in the middle of the median nuchal line one centimeter 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 upward 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.

17. A Transition Form between a Horseshoe and "Kuchenniere."

The following specimen, received through the courtesy of Dr Carl Wilson of Palo Alto, was obtained by him at coroner's autopsy on the body of a white male about 23 years old. After fixation the fused renal mass weighs 300 grams. It is somewhat irregular in outline, there is marked lobulation on the concave ventral surface; but the convex dorsal surface is even, as is customary. The free poles approach each other to within

3 cm., the greater curvature being 40 cm. long and the lesser 12 cm. The total mass measures 14 cm. from right to left, is 5·8 cm. wide, and has a maximum thickness of 4·1 cm. Considering the weight of the normal adult kidney as 120–140 grams, it is evident that the weight of the composite mass is only very slightly, if at all, in excess of the combined weight of two average-sized adult kidneys. And, if we regard the size of

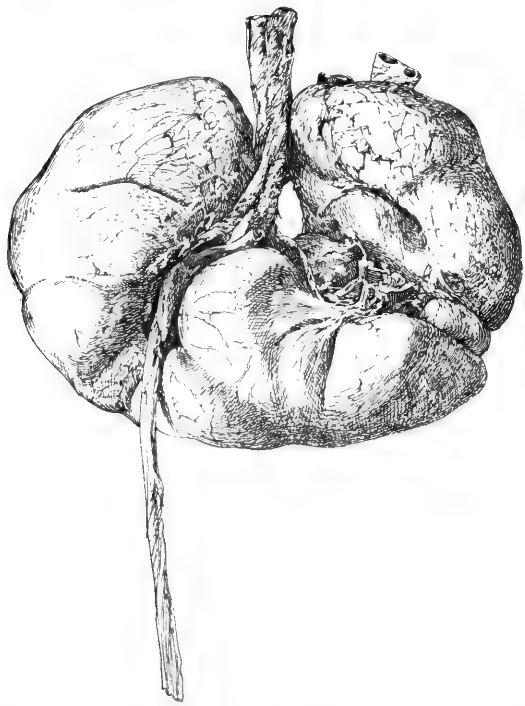


Fig. 21.—Ventral surface of composite renal mass, showing right ureter and left common iliac vein and artery.

the normal kidneys as 12 × 4–6 × 3–4 cm., the same is true regarding the size. Legueu and Papin (1), in an excellent summary of the cases in the literature and from personal observations, state that the combined mass is usually somewhat in excess in weight, and that only rarely does its weight equal that of two normal kidneys, or 300 grams, as given by them.

The sketch in fig. 21 shows that the ventral surface of the specimen is deeply grooved and fissured, divided somewhat distinctly into three portions, and shows a somewhat definite secondary lobulation. The dorsal or posterior surface, on the contrary, is quite even, except for two shallow incomplete sulci located opposite the ventral incisions. Of the three slightly unequal lobes indicated on the ventral surface, the left or smallest lobe measures 7·7 cm. in length, 5·7 cm. in width, and 3·1 cm. in thickness. The isthmus, or middle lobe, which is the largest of the three, is 8·8 cm. long, 6·3 cm. wide, and 4·2 cm. thick; and the right lobe, which is intermediate in size, measures $9{\cdot}0 \times 5{\cdot}4 \times 4{\cdot}2$ cm. Each of the two larger portions is consequently somewhat smaller than the normal kidney of the adult male. There were only two ureters, one of which was bifurcated near the renal mass. Unfortunately, the greater portion of one of the pelves and the bifurcated ureter were removed at the autopsy, making a more accurate description impossible. From the impressions on the mass, and from the disposition of the arms of the intact pelvis, it is evident, however, that the ureters crossed the ventral surface in the wide interlobular incisions, as is customary in horseshoe kidneys.

Two pelves were fused and joined the left ureter, and all pelves were ventral or ventro-medial in position. Hence it is clear that we are dealing with a bifurcated pelvis, or, judging from the arrangement of the papillæ, perhaps, more properly speaking, with a fused pelvis. The third pelvis, which was intact, still had 13 cm. of the right ureter attached to it. There are no evidences of obstruction.

A group of four radially disposed pyramids in the left extremity of the left lobe ended in one and two papillæ, which emptied into three calices of one arm of the pelvis. One of these calices receives the compound papillæ. The right extremity of the left lobe contains four pyramids, which empty into the other pelvis in common with two other larger pyramids in the left extremity of the median or isthmic lobe. Each of these pyramids has a *distinct* and individual papilla which empties into a separate calyx; but the four other pyramids end in two compound papillæ, each of which receives two pyramids which empty into a single calyx. Hence there are only three calices for the six papillæ and pyramids.

In the right extremity of the median lobe, and in the right lobe, there are nine pyramids of greatly varying size and disposition which open into as many calices, all of which communicate with the right ureter, which is somewhat larger than normal size. This third pelvis is also more nearly of the size and form of a normally-shaped pelvis, although the hilum which lies at the point of the ventral incision is somewhat distorted. The first pelvis arises in a slit in the left lobe, which is approximately parallel to the lateral convex border of that lobe. Hence the total number, or nineteen papillæ, is fully equivalent to or even in excess of the number normally present in two kidneys. Since the pyramids vary considerably in size, however, this numerical excess would be of no significance were it not accompanied by a similar excess in weight and also in size.

All the arteries which had not been cut in the autopsy arose from the *right* common iliac. Two smaller vessels entered the dorsal surface of the left lobe near its outer margin. One entered the median surface of the median lobe; and five, which arose from two trunks, entered at the hilum between the median and right lobes. An accessory artery, with three branches, also entered the dorsal surface of the free pole of the left lobe.

The veins which joined the *left* common iliac were arranged somewhat differently from the arteries. One emerged from the medial extremity of the pelvis of the left lobe; and another, much smaller, from the dorsal surface of the cranial extremity of this lobe at a point opposite the ventral incision between the left and median lobes. Three emerged at the opposite ends of the second pelvis, which was located between the left and median lobes; and six arose in the neighbourhood of the third pelvis, which was located between the right and median lobes.

The form, pelvic position, and gross appearance of the specimen, and the apparent fusion of the two chief hila, strongly suggest the "Kuchenniere" of Haller and Hyrtl; but the presence of a third or minor and independent pelvis in the left or smallest lobe, and the absence of actual fusion of the hila, makes such a designation nevertheless inaccurate. Since the smallest or third hilum lying in the left lobe is independent, and since the pyramids of the combined mass are arranged about three and not about one pelvis, the condition of triplicate kidneys which was suggested by the existence of three fairly distinct groups of vessels, and by the ventral lobulation, seems to be confirmed. Nevertheless, since only two ureters were present, and since the pelvis of the third lobe joined the larger one between the left and median lobes, it seems more likely that this specimen must be regarded as a transition form which has resulted in the usual way by fusion of the caudal poles of two Anlagen, one—the left—of which then became incompletely subdivided into two distinct portions. This conclusion also accords with the rarity of multiple kidneys and with Sappey's conclusion that none of the cases of triplicate and quadruplicate kidneys were probably such. Sappey (2) says, "Schulze, Laurent, Marchetti, au rapport de Haller, auraient observé quatre reins; Molenetti en aurait même vu cinq. Sans repousser ces derniers faits, je ferai remarquer qu'ils n'ont pas toute l'authenticité qu'on pourait désirer; ils ne doivent être admis qu' avec réserve." Nevertheless, Gosset (3) states that a case reported by Josso was probably such. Legueu and Papin also conclude that the term triplicate kidney is wholly unjustifiable, because it is simply a case where one kidney shows a tendency to duplication with more frequent partial duplicity of the ureter of that side. In the case here reported this tendency is splendidly illustrated on the left side, which had a bifurcated ureter; but the complete fusion of the caudal poles resulted in transforming the isthmus into a definite lobe, largely obscuring it. Were it not for this fact, and for the close approach of the cranial poles, this case is quite similar in form to Case I. as represented and reported by Legueu and Papin, to whose review, covering 300 cases, and to Strube's (4) excellent article, the reader is referred for a fuller discussion of the subject.

(1) Legueu and Papin, *Revue de Gynécologie*, t. xviii., 1912.
(2) Sappey, *Traité d'Anatomie*, 1873.
(3) Gosset, *Traité d'Anatomie humaine*, Poirier et Charpey.
(4) Strube, "Über congenitale Lage- und Bildungsanomalien der Nieren," *V.A.*, Bd. cxxxvii., 1894.

18. Recessus duodeno-posterior (Broesicke).

In their monograph on right-sided herniæ—herniæ mesenterico—parietalis dextra—Eisler and Fischer (1) state that only twenty-four such cases are found in the literature. According to Basset (2), who reported three cases of herniæ duodeno-posterior himself, only three cases belonging in this category had previously been reported. The largest of the hernial sacs in the series reported by Basset measured 18 × 14 cm., and had an opening admitting four fingers. All of these cases, as well as that reported by Merrigan (3), were true herniæ, however, and the occurrence of large peritoneal recesses wholly devoid of contents seems to be rare, for Waldeyer (4), in his well-known investigation on retro-peritoneal herniæ, called attention to the fact that although Treitz reported several cases of beginning retro-peritoneal herniæ, he did not speak of the occurrence of large empty duodeno-jejunal fossæ. Since the case to which attention is directed is not merely a fossa, but an extremely large empty recess, it is of special interest, for it seems to suggest that hernia is not necessarily associated with the formation of large so-called retro-peritoneal sacs.

The body was that of a white male past middle life, in which no other variations or anomalies were present. The opening leading to the recess, which lay directly dorsal to the ascending portion of the duodenum and the duodeno-jejunal flexure, measured 5 cm. cranio-caudally. Because of its position the walls of the portal were in contact, and the latter was undoubtedly guarded to a certain extent by the duodenum. The recess into which this opening led, widened out considerably both cranially and caudally as soon as the duodenum was passed. Its long axis was directed somewhat caudally, and extended to the ascending colon and the body-wall on the right. Cranially it extended to the liver, and caudally to the attachment of the root of the mesentery. It measured approximately 10 × 14 cm.

The mesentery of the transverse colon formed its ventral or anterior wall and the first and second portions of the duodenum lay dorsal to it. Since the right colic flexure lay but a few centimeters cranial to the superior border of the coxal bone, much of the right transverse and a portion of the ascending colon came into relation with the ventral wall of the sac. There was no common mesentery or other anomaly.

Although only a small portion of the colon was somewhat abnormally placed, and although it is not uncommon to find the right flexure as far caudal in cases of enteroptosis, yet the suppositions of Eisler and Fischer that right-sided herniæ are due to the atypical fusion of the ascending mesocolon with the dorsal body-wall would seem to be corroborated, to a certain extent at least. Since the recess was completely empty, however, it would be necessary to suppose that the loops of the small intestine which prevented this fusion in early embryonic life withdrew spontaneously after the recess had formed. Moreover, since it is unlikely that so large a recess could have formed and its walls remained separate so long, one would almost have to assume a later re-entrance of the intestine into the recess and a subsequent withdrawal. Waldeyer considered such an occurrence *possible* but *highly improbable*, for, as he points out, the tendency of peristalsis would be to force more of the intestine into the sac rather than to effect its removal. This reasoning is particularly applicable, it seems to me, to the case in question, for the recess was so large that it could easily have accommodated all of the small intestine. The ventral or anterior wall of the sac would undoubtedly have yielded easily to the pressure of the contained intestine, and formed a large pendulous sac. Moreover, the comparatively small size of the opening and its relation to the duodenum would have predisposed to strangulation, although it is undoubtedly true, as Treitz (5) suggested, that strangulation seldom occurs in cases of duodeno-jejunal herniæ, because they seldom contain more than a single loop of intestine, never any omentum, and especially because the portal of entry, which is non-muscular, is not subject to variation in size.

In spite of the large size of this recess and the accessibility of its portal, it does not seem likely to me that its formation can be ascribed to any of the factors enumerated by Treitz. Nor does it seem probable that it could have been associated by hernia, for the individual apparently had never suffered seriously from complications which one would expect to result from hernia into so large a recess. There were no abdominal scars, and death was due to an unrelated cause.

(1) Eisler and Fischer, *Die Hernia mesenterico-parietalis-dextra*, Leipzig, 1911.

(2) Bassett, *Über Hernien der Regio duodeno-jejunalis*, Inaug. Dissert., Berlin, 1908.

(3) Merrigan, "An Unusually Large Peritoneal Fossa," *Anat. Record*, vol. v., 1911.

(4) Waldeyer, *Hernia retroperitonealis nebst Bemerkungen zur Anatomie des Peritoneum, A.*, Bd. lx., 1874.

(5) Treitz, "Hernia retroperitonealis," *Ein Beitrag zur Geschichte innerer Hernien*, Prag, 1857.

(6) A number of other articles by Toldt, Waldeyer, Jonnesco, etc., and thesis by Poisson and Gobel were consulted, but for a large bibliography the reader is referred to the monograph of Eisler and Fischer.

19. The Effect of Disuse on Articular Cartilage.

The specimen, of which drawings are shown in figs. 22 and 23, is that of the distal extremity of the right femur, which was affected by a sarcoma. The extremity was obtained through the courtesy of Dr Harry B. Reynolds

Fig. 22.—Distal extremity of the femur, showing the cranially displaced medial condyle. Taken from the ventral surface. ½ natural size.

Fig. 23.—Distal extremity of the femur seen from the medio-dorsal aspect. ½ natural size.

of Palo Alto, by whom the amputation was done. The sarcoma, which had given rise to symptoms for about one year and a half, was limited entirely to the bone. The surrounding tendons and muscles were simply displaced and involved in the dense fibrous connective tissue surrounding the growth. The knee joint contained a slight excess of synovia, which was clear and opalescent. The capsule was thickened, but the synovial membrane looked quite normal, and the crucial ligaments were preserved. The whole distal extremity of the shaft of the femur, except the articular surfaces of the condyle and a thin layer of the lateral surface of the shaft, had been destroyed, and nothing but a meshwork of thin fragile bone extending around three-fourths of the perimeter supported the body-weight in this region. Although the neoplastic bone was only a few millimeters thick, there was no displacement of the lateral wall of the shaft or of the lateral condyle, the articular cartilage on which was normal in appearance save over a small ventral area. The medial condyle, on the contrary, had rotated dorsally and cranially so as to sustain considerable displacement. The inter-condyloid fossa was practically absent because of the encroachment of the tumor, and the ventro-lateral aspect of the articular surface of the medial condyle was forced out. As a result of bone absorption, the osseous articular surface of the condyle was as thin as paper, and the cartilage practically absent over the neoplastic area, on which most of the patella rested.

The displacement of the medial condyle, due largely to its rotation dorsally, was evidently a very gradual process, for the meshwork of bone which encased the tumor was carried cranially with the rotating condylar surface and presented the appearance of dough or tar into which an object is sinking. Although the osseous articular surface of both condyles was papyraceous, it was practically intact throughout, even in the area in which it lay parallel to and only a few millimeters away from the neoplastic bony network, which had been folded back upon itself.

The bony articular surface of the lateral condyle had been affected, but very slightly, in two places along its medial border by the sarcoma, and the cartilage over it seemed normal. The whole surface of the depressed medial condyle was covered by an uneven layer of smooth fibrous cartilage; and the medial meniscus, which had become adherent, was exceedingly atrophic. In fact, it had become so much thinner that it formed a continuous surface almost on the same level with the rest of the medial articular surface of the tibia. Similar fibrous transformation and atrophy had occurred on the medial condyle, which had been displaced so far cranially that it looked at first as though the condyle had been absorbed. The meniscus over the lateral condyle of the tibia, on the other hand, was well preserved and possessed normal mobility and almost normal thickness.

The changes in the cartilage on the condyles confirm in the main the experimental results obtained by Reyher (1), who found that the articular cartilages were preserved in their integrity at points of contact in the joints of dogs whose legs had been immobilised for one year. Reyher also found that atrophy and even complete disappearance of the cartilage occurred at points of no contact, just as is the case in the specimen here reported. From his experiments Reyher concluded that the nutrition of cartilage is dependent on friction and pressure, and that atrophy is not due to pressure alone. Menzel (2), whose conclusions were confirmed by Kuhlmann (3) to a certain extent, held a contrary view, however. Menzel, after immobilising the legs of rabbits for a period of approximately two months, found atrophy of the articular cartilage at the points of contact. Kuhlmann thinks that pressure atrophy is here associated with a simple atrophy, and that, in case of defective nutrition of a tissue, atrophy will take place fastest at points of pressure. Kuhlmann's findings corroborate Reyher in that he found the articular area of the bones denuded of cartilage at the points of contact. However, Kuhlmann thinks that his results agree with those of Reyher because some movement was still possible in the joints of the extremities of the dogs used by the latter, in spite of the fact that a plaster bandage was used for purposes of immobilisation.

The absence of articular cartilage and the slight roughening of the osseous articular surface of the patella can be referred to the fact that this area of the patella lay directly in contact with some of the neoplastic bone. Since, however, the articular cartilage, although thin, was preserved at the periphery of the patella, it is more than likely that both the pressure and friction which resulted from the limited movements still possible to the patient were above the threshold stimulus, *i.e.* above the minimum necessary to preserve the cartilage. But this was apparently not the case with the medial condyle and the opposing articular surface of the tibia. That the atrophy of the opposed medial articular cartilages was not the result of excessive pressure in this case is shown conclusively by the fact that the condyle is displaced dorsally and especially cranially. This could of course not be the case if the pressure exerted by the growing neoplasm had caused the displacement, for in that case the medial condyle would have been forced distally instead of proximally.

(1) Reyher, "Über die Veränderungen der Gelenke bei dauernder Ruhe," *Deutsche Zeitschr. f. Chir.*, Leipzig, 1878, Bd. iii.

(2) Menzel, "Über die Erkrankung der Gelenke bei dauernder Ruhe derselben," *Arch. f. klin. Chir.*, 1871, Bd. xii.

(3) Kuhlmann, *Über die Veränderungen in den Gelenken in Folge andauernder Ruhigstellung (im Anschluss an einem Fall von Gelenkneurose)*, Dissert., Kiel, 1898.

20. A Skeleton with Thirteen well-developed Ribs and Twenty-five Pre-sacral Vertebræ.

According to Hyrtl (1), "Eine wirkliche Vermehrung der Rippen durch Vermehrung der Brustwirbel, gehört unter die grössten anatomischen Seltenheiten." Moreover, Hyrtl evidently doubted such an occurrence, for, in discussing the vertebral column, he says, "Eine wirkliche, nicht auf Kosten der Hals—oder Lendenwirbel entstanden Vermehrung der Brustwirbel, gehört unter die grössten anatomischen Seltenheiten." Merkel (2), in discussing variations in the number of vertebræ, says, "Diese Zahlen sind ausserordentlich constant und es gehört eine Vermehrung oder Verminderung der Zahl der Hals—und Brustwirbeln zu den allergrössten Seltenheiten." Merkel, however, considers an increase in the number of lumbar and sacral vertebræ somewhat more common, but rightly emphasises the fact that it is necessary to have the whole vertebral column before one when reporting an increase in number in some region.

Le Double (3) also is of the opinion than an increase in the total number of pre-sacral vertebræ is very exceptional, for he says, "Il n'est pas douteux que les anomalies numériques non compensées des os du rachis thoracique sont infiniment plus exceptionnelles que les anomalies numériques compensées." In the table given by him on page 204, thirty-four cases of the occurrence of thirteen dorsal vertebræ in a series of 1352 spines studied by various anatomists are recorded, but the author himself found only one case in which there was a failure of compensation in a series of 200 vertebral columns examined.

In the skeleton to which attention is directed, the occurrence of a well-developed thirteenth rib was associated with the presence of twenty-five well-developed pre-sacral vertebræ. The case was that of an adult white male showing no other anomalies. The coccyx, which was very rudimentary, was composed of two portions, one of which was completely synostosed to the sacrum. Both portions were composed of a single mass, in which the individual constituents could not be distinguished. The sacrum was perfectly straight to the line of union of the fourth and fifth sacral vertebræ, where a gentle curvature began. This curvature rapidly increased, so that the first portion of the coccyx made an angle of approximately 115° with the rest of the sacrum. The second portion was composed of a small irregular mass which articulated loosely with the first portion.

Eight pairs of ribs articulated directly with the sternum, and the eleventh pair articulated with the seventeenth and eighteenth vertebræ. The nineteenth and twentieth vertebræ carried but one complete costal articular facet. The twentieth pre-sacral vertebra, *i.e.* the one bearing the last or supernumerary rib, had in general characteristics of a dorsal vertebra, but the inferior articular process is not turned outward, as is usual in the twelfth dorsal, but occupies almost exactly the same plane as those of the two preceding vertebræ (see fig. 24). The spinous process, which is broad and flat, has many of the characteristics of the spinous process of the lumbar vertebræ. The rest of the vertebræ show nothing worthy of special comment.

Since the average length of lumbar ribs is put at 2 cm. by Le Double, and the maximum at 8 cm., and since he states that lumbar ribs when

FIG. 24.—Thirteenth dorsal vertebra. ½ natural size.

present in a pair are usually asymmetrical, one would seem to be justified in concluding that the above specimens are thoracic and not lumbar ribs. Moreover, since the vertebra bearing the thirteenth pair of ribs has the characteristics of a dorsal vertebra, and since eight ribs articulated directly with the sternum, the above conclusion would seem to be substantiated very materially.

(1) HYRTL, *Topographische Anatomie*, 7. Aufl., Wien, 1882.
(2) MERKEL, *Handbuch der topog. Anat.*, Braunschweig, Bd. ii., 1899.
(3) LE DOUBLE, *Traité des variations de la colonne vertébrale de l'homme*, Paris, 1912.

21. A CASE OF HERNIA DIAPHRAGMATICA VERA CONGENITA, ACCOMPANIED BY 180° VOLVULUS OF THE STOMACH.

This rather remarkable instance, probably similar to that of Carruthers (1), of a large, true, congenital diaphragmatic hernia in a woman well advanced in years, would seem to deserve special mention in spite of the fact that it has been justly emphasised of late that diaphragmatic herniæ are not so uncommon as was supposed previous to the use of the X-ray. Moreover, it has also been stated that the presence of a congenital diaphragmatic hernia may give rise to no pronounced symptoms. Vogel (2), for example, stated that the presence of such an extremely large hernia spuria as reported by him may not give rise to any symptoms. To be sure, there may be no symptoms, but their absence does not necessarily imply perfectly normal functional conditions, for an individual who has never experienced the normal may be quite unconscious of the existence of the abnormal.

In another place (see *infra*, p. 95) the writer reports a case of hernia diaphragmatica spuria congenita in a lamb, which was essentially comparable with the case reported by Vogel in man. In this case the false hernia was undoubtedly responsible for death during labour of a full-term fœtus, which was otherwise of perfectly normal development. It is true that in case of the lamb the stomach was markedly enlarged and distended with viscid fluid, probably largely amniotic fluid, which completely prevented expansion of the left lung and sufficiently impeded that of the right to make post-natal life impossible. That respiratory and not cardiac difficulties must have been responsible for death in this lamb would also seem to be indicated by the fact that except for the slightly increased volume of the right lung with the first inspiration, which increase in volume was probably compensated for by the descent of the diaphragm and the expansion of the chest, there apparently was no interference with cardiac activity. Hence cardiac action was no more interfered with after or during than before birth, for it does not seem probable, even if possible, that the fœtal heart was seriously embarrassed by being forced against a rather large, incompressible and distended stomach by the maternal pressures exerted on the abdomen or chest of the lamb during labour. Moreover, the condition of the lung shows that labour was survived.

Why the case reported by Vogel should have lived to a comparatively advanced age, apparently without experiencing any symptoms, while the lamb referred to died during labour, it is of course impossible to say. However, it is quite certain that the human organism which survived the effects of such a serious defect for decades must have slowly accommodated itself to profoundly altered anatomical conditions. Moreover, that serious functional disturbances were undoubtedly present at birth, and perhaps also during early life, in Vogel's case, would seem to be suggested by the fact that so many of the cases of serious diaphragmatic defect succumb early in life or even soon after birth, and that others which do not survive labour are, no doubt, simply designated as still-born in entire ignorance of the existence of the anomaly and the real cause of death.

The body in which the following developmental anomaly was found was that of a female pauper fifty-three years old. The only thing that attracted attention to the cadaver was its fatness. The panniculus adiposus was from two to five centimeters thick, the breasts were voluminous, but the corpus mammæ atrophic and the papillæ mammæ also atrophic and depressed. The rather rounded thorax was asymmetrical because of a bulging of the third to sixth ribs at the right costo-chondral junctions. The caudal extremity of the xiphoid process was somewhat elevated. Because of the presence of the unusually thick panniculus adiposus and of a large fibroma uteri which completely filled the pelvis, it is unlikely that marked flattening of the abdomen was present during later life in spite of the displacement of the stomach.

When the abdomen was opened in the course of the dissection, the most noticeable things were the position of the great omentum and the transverse colon. The former, which was wrapped around the colon, extended obliquely across the abdominal cavity from the left hypochondrium to the right lateral abdominal region, where it was adherent. The cæcum, which alone was free and uncovered, overhung the pelvic brim.

The ascending colon was but 7·5 cm. long, and the right flexure situated 2 cm. cranial to the iliac crest. From here it extended diagonally to the seventh costo-chondral junction, where it passed into the thorax beneath a tendinous arch through a large defect in the musculature of the left half of the diaphragm. It reappeared as the descending colon, crossed the hilum of the spleen and reached the left abdominal wall opposite the tenth rib, beyond which its course was normal. Hence it is clear that there really was no transverse colon and no left flexure, but a short direct ascending, a long oblique ascending, and a long oblique and a short straight descending colon instead. Both portions of the loop of the colon contained in the hernial sac and the antral portion of the stomach were enveloped so completely by the omentum that they were invisible till the latter was removed.

The stomach, although actually in the abdominal cavity because of the existence of a hernial sac, was absent in its accustomed location, being represented in the region below the diaphragm—*i.e.* in the normal abdominal cavity—only by a slender tubular pyloric portion 3 cm. long, which lay immediately to the right and parallel to the oblique ascending portion of the transverse colon. The rest of the stomach was wholly cranial to the normal level of the diaphragm, but intraperitoneal. The spleen, although large, was practically normally located lying opposite the ninth and tenth ribs, and extending dorsal to the colon and the antral portion of the stomach and as far medially as the vertebral column. It was visible only at its lower medial border, being supported by an unusually large costocolic ligament (sustentaculum lienis) and veiled by the mesocolon medially. It lay directly caudal to the lateral pillar of the diaphragmatic portal.

The innervation of the diaphragm was normal; and the portal formed by the defect in the diaphragm, which measured 7·7 cm. transversely and 6·0 cm. sagittally, was bridged ventrally by a very definite smooth tendinous arch, from the borders of which the large peritoneal sac was invaginated cranially into the left pleural cavity. Upon removing part of the second to ninth ribs on the left side, the appearance shown in fig. 25 was presented and at once showed that the abnormality was undoubtedly congenital. The left lung, which was adherent nowhere, was composed of two lobes, but both were abnormal in shape and size. The upper lobe, which composed approximately nine-tenths of the total volume of the left lung, was prolonged into a long, thin, narrow tapering process 9 cm. long, which occupied the sulcus between the hernial and pericardial sacs and rested on the left dome of the diaphragm in the eighth intercostal space in the region of the mid-axillary line. The caudal extremity

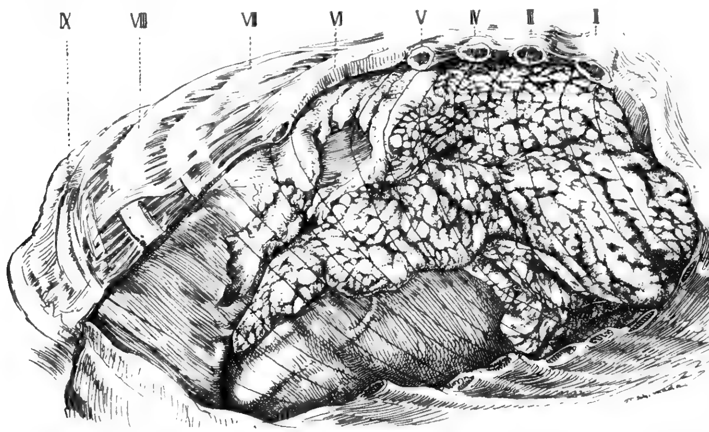


Fig. 25.—Left lateral view, showing the relation of the diaphragm, lung, pericardium, and hernial sac to each other.

of the lower lobe, which was very small and narrow measured 2·5 cm. at the tip and reached only as far as the fifth rib in the scapular line. It extended ventrally only as far as the axillary line and lay on the dome of the hernial sac. The latter, which was entirely filled, was formed by a layer of normal peritoneum and pleura and extended as far cranially as the third rib in the axillary line. It completely filled the portion of the right thoracic cavity, extending from this point to the diaphragm and from the lateral thoracic wall to the hilum of the right lung. It was but slightly constricted at its base, adherent nowhere to the contained or to the surrounding viscera, and composed only of pleura and peritoneum.

The heart, which was practically normal in position, as noted by other observers in cases of diaphragmatic herniæ, and the musculature of the right ventricle of which was but slightly hypertrophied, lay directly ventral to the hernial sac, the ventral wall of the latter and the pericardium being contiguous. The position and relative size of both are evident from an inspection of fig. 26, in which the lobes of the left lung are reflected cranially.

The highest point reached by the flattened and defective dome of the diaphragmatic musculature on the left is 2·5 cm. caudal to the caudal extremity of the corpus sterni; but the corresponding point on the right lies 4 cm. lateral to the antero-median line at the upper border of the fourth rib, or 4·5 cm. cranial to the above point. Since the highest point of the diaphragmatic attachment in the antero-median line is 2 cm. caudal

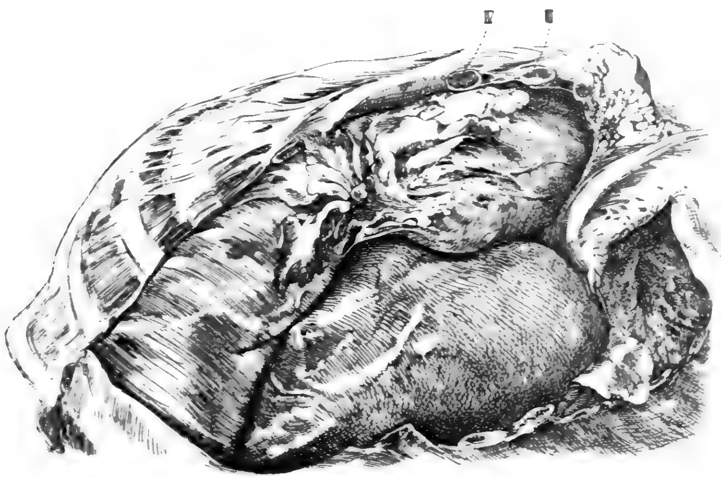


Fig. 26.—Same view as fig. 25, with lung and pericardial fat reflected.

to this point, the difference between the corresponding levels on the two sides is 6·5 cm.

Upon opening the hernial sac by a left lateral incision, the thick, voluminous great omentum was found completely to envelop the loop of the contained colon and formed a large portion of the contents. The stomach was not noticeable, in fact, until both the omentum and colon were reflected caudally and laterally. It was fastened to the aorta and dorsal wall of the thorax by fusion of the peritoneal reflection at the cardia and lesser curvature with the parietal pleura, and extended across the vertebral column to a point dorsal to the hilum of the right lung, the fundic portion of the stomach lying caudal and dorsal to the root of the latter. The stomach was small, cylindrical, almost vertical in position, and practically empty. The fundus and greater curvature, as well as the tubal pyloric portion, had rotated from left to right. The fundic portion was also folded over ventrally on the rest of the stomach somewhat, because it had exceeded it in rotation, having changed its position 180° from the normal. The rotation of the pyloric portion was only about 45°, and the cardia had not rotated at all. The dorsal wall of the fundus was prolonged into a sacculation which extended caudally toward the lateral wall of the diaphragmatic portal. A fold of the gastro-splenic omentum was attached to it, and it was evident that the sacculation resulted from traction by the spleen, which was held firmly in place by peritoneal reflections and by the arch of the diaphragmatic musculature beneath which it lay.

The œsophagus, which was only 18 cm. long, lay a trifle to the left of its normal position throughout its course, and turned almost directly laterally to the left opposite the sixth costo-vertebral junction. From here it extended slightly caudally to join the stomach opposite the sixth intercostal space dorsally.

From an examination of the anatomical conditions, it seems to me that the volvulus was acquired very gradually as a result of the marked increase in fatness during later years in life, although the great omentum which was wrapped around the loop of the colon and the stomach was so voluminous that it is probable that the deposition of fat in it must have compressed both the colon and stomach. Hence, as a result of prolonged increased pressure within the sac, the fundus would naturally be urged in the direction of least resistance, which was of course toward the right pleural cavity. Since this pressure must have been exerted over a period of years, it is highly probable that the extension of the serous hernial sac beneath the hilum of the right lung and of the pleural cupulæ—especially the right—high up into the neck, as shown in fig. 27, resulted in this way. It is also evident that the heart was subjected not only to periodic but also to an increasing pressure; and the clinical diagnosis of myocarditis at the time of death, and death itself, is easily accounted for. The post-natal production of such a high grade of volvulus would, to be sure, result very seriously under normal conditions, for it is usually rapidly fatal when acquired, even if there is but a partial rotation. However, in this case, the abnormal congenital position of the stomach apparently not only prevented the disastrous effect of volvulus on the vessels, but also obviated torsion at the pylorus and occlusion at the cardia as a result of the rotation. Moreover, it seems probable to me that the volvulus primarily resulted from the increased pressure within the hernial sac as a result of distension of the stomach by amniotic fluid during prenatal life; but, whatever its genesis, it must have had a very gradual evolution, or it would probably have been incompatible with life at any period. Were it not for the fact that the vagi and the spleen are normally located, one could assume a primary over-rotation of the stomach, but the relation of the fundus to the rest of the stomach would be difficult to explain on this basis.

From an examination of the literature on the subject of congenital diaphragmatic herniæ, it is not at all clear which cases were hernia and which were really primary congenital displacements of viscera which had never reached their normal location. It is evident, to be sure, that if the stomach is found out of its accustomed location it cannot be regarded as being herniated—not even falsely so—unless it can be shown that it once

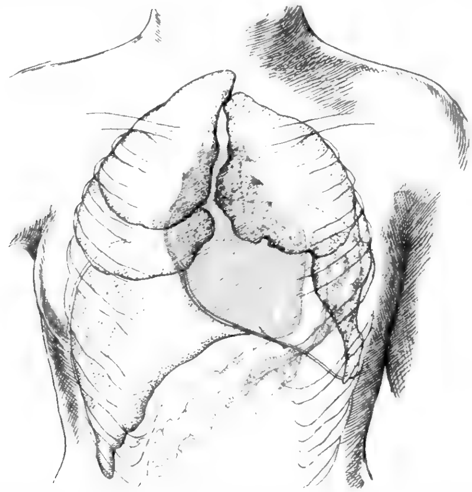


Fig. 27.—Outline sketch showing the relation of the hernial sac to the pericardium and lungs. The sac is shown as a discontinuous red line.

occupied the normal position and was displaced later. In the case under discussion the stomach had apparently never occupied its normal position. In considering the classification of herniæ of the diaphragm, it is hence necessary to distinguish clearly not only between traumatic and non-traumatic herniæ, to subdivide the non-traumatic herniæ reported up to the present as true and false (as has been customary), but also to exclude from the latter primary congenital abnormalities of position, such as the above, which have apparently been included among true herniæ because there was a hernial sac. However, they are plainly not such, and I cannot believe that the case here reported is unique. It is clear, it seems to me, that the so-called sac in this case did, of course, not result from a protrusion through the diaphragm, *i.e.* of a displacement cranially of the stomach, but from the migration caudally of the diaphragm over an abnormally anchored stomach, the spleen being carried caudally to its normal position by the lateral crescentic portion of the diaphragm.

(1) Carruthers, "Absence of Left Half of the Diaphragm in a Child ten days old," *Lancet*, 1879.

(2) Vogel, "Diaphragmatic Hernia, with Report of a Case," *Am. Jr. Med. Sci.*, vol. cxlv., 1913.

(3) Tuffier et Jeanne, "Le volvulus de l'éstomac," *Rev. de Gyn.*, t. xviii., 1912.

II. MAMMALIAN.

1. Congenital Hyperthyroidism in the Domestic Sheep (Ovis aries).

Some years since my attention was attracted to the extraordinary size of the thyroid occasionally seen in sheep fœtuses, by the large protrusion on the neck for which it was responsible, and by the extension of the head of the fœtus. This observation is apparently in entire accord with those made on human fœtuses and the human new born, for Ballantyne (1) states in this connexion that "Before birth the life of the fœtus is not threatened; but an abnormal presentation (forehead, face) may be produced, and so delay, and possibly infantile death during labour be brought about."

Schayer (2) states that Virchow estimated the occurrence of congenital struma as 1 to 2 per cent. for the city of Salzburg, and adds that Demme reported that $6\frac{1}{4}$ per cent. of all cases of hyperthyroidism observed in a children's hospital were congenital in origin. According to the writer's observations, congenital hyperthyroidism in the sheep probably is more common than this, in some localities at least. The mere presence of a prominence on the ventral surface of the neck was, to be sure, not taken as final evidence of thyroid hypertrophy, and hence the possibility that in some of these instances tumors or cysts of other origin were mistaken for goitre, as Ballantyne suggests for the human infant, is thereby excluded. These hypertrophied thyroids of fœtuses in the new born far exceed the size of the normal thyroids in adult sheep, and were not uncommonly accompanied by cyst formation. In a number of cases of hyperthyroidism in adult sheep, examined at the same time, the increase in weight of the gland was approximately tenfold, but in the fœtuses examined it was not uncommonly found to be twentyfold. In view of the extraordinary size which goitre can attain in man, these statements are of course not surprising except in so far as they call attention to, and emphasise the occurrence of, an extreme grade of hyperthyroidism in the prenatal life of the domestic sheep.

A concomitant increase in the size of the thymus or parathymus glands or the presence of anomalies was not observed, but a very striking thing was the extreme engorgement of the thyroid and jugular veins (see fig. 28), and the fact that the sternohyoid muscles were sometimes imbedded deeply in pressure sulci on the ventral surface of the cranial pole of the lobes of the hypertrophied thyroid glands, as shown in the accompanying illustrations.

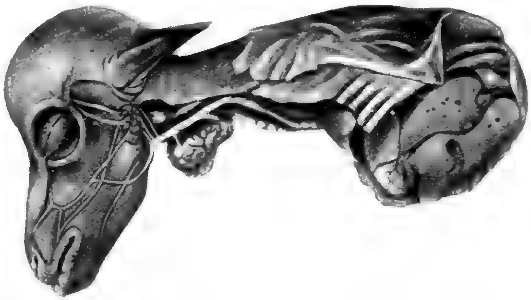


FIG. 28.—Congenital hyperthyroidism in the sheep. ⅓ natural size.

This congested condition of the blood-vessels is also mentioned by Schayer, who reported a case in an infant in which it was concluded that the spontaneous and rapid appearance and disappearance of the enlargement was largely a vascular phenomenon. In some cases the muscular impressions were so deep (see fig. 29) and the muscles so tense that the pressure from them would seem to have resulted eventually in division of the lobes

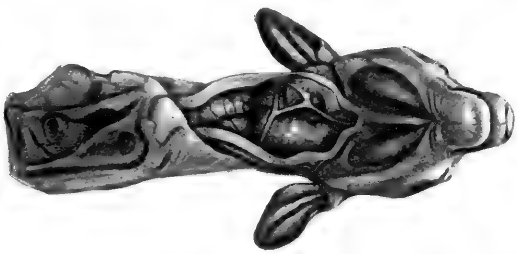


FIG. 29.—Congenital hyperthyroidism in the sheep. The left sterno-hyoid muscle cuts deeply into body of thyroid gland. ⅓ natural size.

unless hypertrophy had ceased. It is also evident that the tension on the muscles would probably have interfered with respiration, as is said to be the case in infants afflicted with congenital struma. No hypertrophy of the infrahyoid muscles, such as was described by Argaud, Billard, and Bataille (3), was noticed, however, although such a hypertrophy might have arisen after birth when these muscles would have been the main supports of the enlarged gland if hypertrophy had continued and not regressed, as is customary.

That cysts of the thyroid may appear extremely early in fœtal life in cases of congenital hyperthyroidism is shown by the fact that a cystic condition accompanied by hypertrophy of the thyroid was found in fœtuses only 9·8 cm. long (V.B.). In the latter case the cysts were 1·5 and 2·2 mm. in size respectively and lay directly beneath the lateral surface of the mid portions of both lobes. Upon microscopical examination the wall of the cyst was found to be composed of flattened epithelium, which enclosed slightly granular hyaline material containing some degenerating erythrocytes and an occasional remnant of parenchyma cells. It was also noticed that some alveoli were dilated and evidently in the early stages of cyst formation. Apart from the contents of these small cysts, nothing which looked like colloid formation was seen in this specimen. In normal specimens of similar age, on the other hand, colloid formation was general; but in the cases of hyperthyroidism parenchymatous hypertrophy was often so intense that the lumina of the alveoli, although very large, were completely obliterated. Only small amounts of colloid were left here and there, and the alveolar walls were very sinuous and folded. Indeed, not infrequently cellular proliferation was so intense that it was difficult to recognise the individual alveoli, simply because the whole alveolus was transformed into a solid epithelial mass. This is in entire accord with the comprehensive observations of Demme, who found 50 per cent of all cases of congenital struma to be a "struma hyperplastica."

In one case, that of a fœtus 30 cm. long, both lobes contained symmetrically placed oval cysts $8 \times 10 \times 12$ mm. which were located in the depths of the cranial pole. In a second case, a superficial spherical cyst approximately 15 mm. in size lay in the ventral surface of the right lobe, and another similarly placed, but only 5 mm. large, on the left lobe. Both of these were also located on the cranial pole of the gland. All these large cysts contained a viscous gelatinous fluid which suggested colloid. If these large cysts possessed a connective-tissue wall it must have been extremely thin, for none could be detected by gross examination alone. Although Bodenstein (4) states that the formation of cartilage is commoner in cystic goitres in infants, it was not found in any of the specimens in the sheep. Nor can it be concluded that the formation of cysts is a very rare occurrence, as Bodenstein states, and as Friedreich, Lebert, Spiegelberg and Hecker held for the human infant, or that they but rarely become of very great size.

Most of these cases of hyperthyroidism were seen in fœtuses 30–39 cm. long (V.B.), but the youngest fœtus measured only 9·8 cm. (V.B.) and was about six weeks old. It is probable, of course, that the condition is recognisable much earlier, but unfortunately no opportunity to continue these observations has been afforded since. It would be interesting and satisfying in this connexion to know whether these goitres in fœtal sheep disappear spontaneously after birth, as has been stated for infants, and whether any sexual or ancestral influences could be detected.

Since all, save two, of the fœtuses examined were entirely normal in appearance, this simple parenchymatous hypertrophy seems to be without other evident prenatal effects save those enumerated. In a few specimens, however, such an unusually large amount of subcutaneous fat was present that the skin was smooth and tense, the form extremely rounded and so plump that it seems possible that the formation of an unusually thick panniculus adiposus in these instances may be correlated with so-called congenital struma.

(1) Ballantyne, *Antenatal Pathology and Hygiene*, vol. i., Edin., 1902.

(2) Schayer, *Über Struma congenita*, Thesis, Berlin, 1896. (Contains a good bibliography.)

(3) Argaud, Billard, et Bataille, "Sur le rôle de pressure des muscles sterno-thyroidien et sur son hypertrophie au cours du goître," *Journ. de l'Anat.*, No. 5, Sept.-Oct., 1911.

(4) Bodenstein, *Ein Beitrag zur Kenntnis der Struma congenita*, Thesis, Kiel, 1910.

2. Triplicate Gall Bladders in the Cat (Felis domestica).

The multiple gall bladders shown in fig. 30 were found in a male cat about three years old. Upon examination the size and lobulation of the

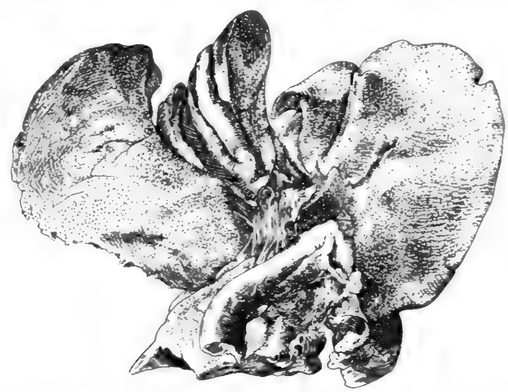


Fig. 30.—Triplicate gall bladders in the domestic cat. ½ natural size.

liver are practically normal, although all the lobes are somewhat more distinct and several small accessory fissures are present. The left lateral and especially the left median lobes are almost completely separated, and there is also the attempted formation of an accessory left intermediate lobe. The left median lobe is also completely separated from the right median by the suspensory ligament, which completely separates them. The three gall bladders lie imbedded in the right ventral surface of the cystic lobe; and the apices of the two lateral bladders, which project several millimeters beyond the caudal hepatic border, lie in deep notches in the liver substance. The apex of the third or intermediate gall bladder, which lies in contact with the other two, is capped with a small process of liver substance and has a duct in common with the left bladder. This common duct, which is wide, tortuous, and about 1 cm. long, joins that from the right lateral bladder, thus forming a very straight common cystic duct, which is joined by the various hepatic ducts to form the ductus choledochus. Just proximal to where the hepatic duct from the cranial and caudal divisions of the right lateral and that from the left and right lateral lobes join the common cystic duct, there is a decided ampulla, from the ventral surface of which a blunt conical diverticulum 5 mm. long and 4 mm. wide projects caudally. Because of its shape and position, and in view of the fact that there were three gall bladders in this specimen, this diverticulum can, I take it, be rightly regarded as an attempted formation of a fourth gall bladder.

3. The Formation of a large Subcutaneous Bursa in the Cervical Region in a Cat.

In a male cat about five years old, which had been kept as a household pet, an irregular area of skin on the ventral surface of the neck had been denuded of most of the long hair. This area, which was 2×3 cm. in size, was hyperæmic, but the epidermis was not abraded or infected. Since such an occurrence is not at all unusual, the matter received no further attention until a large subcutaneous bursa was found directly underneath. This bursa, which was largely unilateral, being located mainly to the right of the median line, extended approximately from the body of the mandible to the shoulder, measuring $4{\cdot}2 \times 3{\cdot}5$ cm. Hence it was considerably larger than the area of denudation above it. It contained a small quantity of viscous fluid and had a smooth, somewhat hyperæmic wall. The hyperæmia also extended for $\frac{1}{2}$–1 cm. into the surrounding subcutaneous tissue and into the overlying skin. Upon microscopical examination the smooth bursal wall, which was recognisable microscopically, was found to be composed of connective tissue, the inner layers of which were more closely packed, but there was no indication whatever of an endothelial lining. Hence these observations incidentally confirm the more recent conceptions as to the structure of synovial or bursal membranes.

The genesis of this unusual bursa must, I believe, be attributed to the irritation by scratching. Cats and dogs of this locality are severely infested with fleas [Pulex felis—(cenocephalus canis)], even if kept under the most favourable conditions. The cutaneous irritation produced by these parasites is a particularly intense one on the ventral region of the neck just caudal to the mandible. Hence the animals often scratch these areas vigorously and repeatedly until most or even all of the hair is removed and the skin becomes erythematous and scaly. This repeated superficial irritation must have been accompanied by traction on the subcutaneous areolar tissue, with consequent stretching and loosening of its fibres, but unfortunately no detailed evidence on the genesis of this bursa was obtained. Hence it would be unwise to indulge in speculation regarding the details of the process.

4. A Case of Pseudo-hermaphroditism (?) in a Goat (see fig. 31).

In this animal, which had the external appearance, and to some extent also the habits, of a female, the seat of the vulva was marked by a prominent raphe, which ended ventrally in a symmetrical conical swelling a little over

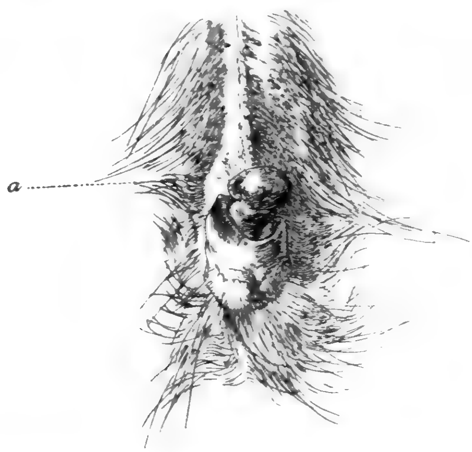


Fig. 31.—Pseudo-hermaphroditism (?) in a goat (see fig. 26). Natural size.
a, Eminence due to dilation of the urethra.

1–1½ cm. long, 1–1¼ cm. wide, and 1 cm. thick. The enlarged extremity which formed the glans penis was attached to a much paler, thinner, and a more cylindrical protruding stalk ½ cm. in diameter, which was surrounded and hooded to a certain extent by a prominent, extremely hyperæmic, hairless cuff of modified skin, which ended ventrally in a still more prominent portion about $1\frac{1}{2}$ cm. long, from the ventral surface of which numerous long hairs arose in the form of a tuft. The dorsal surface was formed by modified skin, and covered by very short hairs only.

The scrotum, which was normally located, was asymmetrical and so poorly developed as to be scarcely noticeable. Two somewhat undeveloped testicles were present.

Instead of passing cranially toward the umbilicus along the ventral surface of the abdomen, the penis was doubled back upon itself somewhat sinuously, as shown in fig. 32. The most cranial portion of the reduplication was 6·5 cm. ventral to the anus, and the reversal in direction was complete. The urethra, which was plicated longitudinally and of very small calibre, lay ventral to the penis and ended in a small papilla with a prominent ventral lip, which was completely hidden because of its position

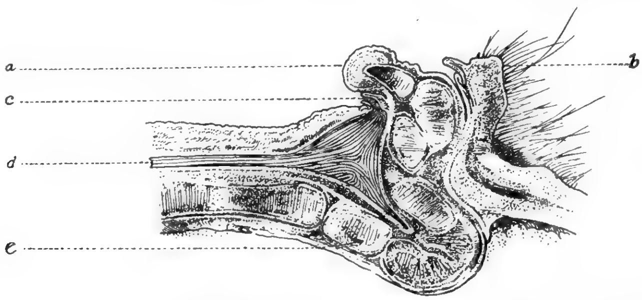


Fig. 32 —Median sagittal section of penis and urethra. Natural size.
a, Glans penis ; *b*, prepuce ; *c*, urethral orifice ; *d*, urethra ; *e*, cavernous body of penis.

between the glans and the conical elevation formed by the dilated portion of the urethra. The dorsally directed glans, which resembled that of a monkey quite closely, was exposed freely; and the urethra lay almost exactly in a median plane several millimeters beneath the raphe, and was separated from the glans only by a small fold of the frænum. Although there was no corpus cavernosum urethra, the latter followed the ventral surface of the penis throughout its extent, for it passed up into the acutely flexed portion or elbow of the penis, as shown in fig. 32.

5. Absence of the Left Half of the Diaphragm in a New-born Lamb and its Effect on the Development and Position of the Thoracic Viscera.

Although it is of no special significance in the interpretation of diaphragmatic defects, the following case would seem to deserve discussion since Gössnitz (1), who gave an excellent digest of the literature on the subject, states that only ninty-nine cases of diaphragmatic herniæ in mammals other than man have been reported, and that only fourteen of these were congenital.

Upon opening the abdomen of this lamb, which had survived birth but a few moments, the most striking thing was the absence of the larger portion of the intestine. As a result of this absence the abdominal cavity seemed empty. Upon examination it was found that the greater portion of the left half of the diaphragm was absent. The left crus was present, however, and the œsophageal opening, although displaced somewhat to the right, was

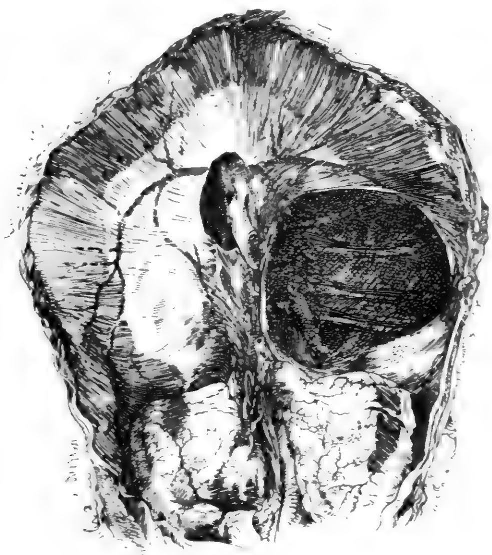


Fig. 33.—Defect in diaphragm of a new-born lamb. ½ natural size.

practically normal. The free border of the central tendon formed an arch which was directly continuous with the left crus and formed a prominent fold, which was attached to the lateral surface of the vertebral column. Ventrally the central tendon was continued in a narrow crescentic slip of muscle which was about 1–1½ cm. wide, and was attached directly lateral to the mid-line. In the margin of the dorsal border of this fold the left branch of the inferior phrenic vein was contained, and formed an arch which ended laterally at the tip of the eleventh rib in the region of the mid-axillary line.

The defect in the diaphragm (see fig. 33), which corresponds to the maximum defect reported by Gössnitz, formed an oval opening 5×6 cm. large through which over half of the small intestine, the cæcum, and a portion of the large intestine, practically all of the distended rumen, the spleen, and part of the pancreas had passed into the left pleural cavity. The stomach, which composed the larger portion of the mass was greatly distended and lay directly upon the left lung with its left extremity. The spleen, which was small, was rotated counter-clockwise, displaced cranially, and occupied a position to the right of the vertebral column between the œsophagus ventrally and the aorta dorsally. The base of the heart was practically undisturbed, but the apex was deflected to the right about 1–1$\frac{1}{5}$ cm. The mediastina were intact, but markedly displaced to the right, caudal to the heart, carrying the œsophagus and aorta with them. In the region of the twelfth vertebra the aorta lay in a median plane directly ventral to the spinal column, and beginning here and going cranially it formed a gentle curve to the right until it had passed completely to the right of the vertebral column in the region of the seventh dorsal vertebra, from where it gradually curved to the left again to reach the base of the heart.

In the region of the eighth to the tenth dorsal vertebra, where the aorta and œsophagus were separated 2·3 cm. dorso-ventrally, the mediastina were deflected markedly to the right, forming a long oval fossa, the caudal portion of which contained the spleen.

The left lung, which was totally collapsed, was only about half normal size and the lobulation was imperfect. The pleura and pericardium were everywhere continuous through the openings in the diaphragm; and the left phrenic nerve, although also deflected to the right in its course caudal to the heart, was apparently unaffected. The right lung, which was somewhat under-developed, had been only partially inflated by attempted respiration.

This defect in the diaphragm is apparently due to failure of the pleuro-peritoneal membrane to form on the left side, thus allowing the stomach, spleen, and other abdominal viscera to pass into the embryonic pleural cavity and preventing the full development of the left lung. Since the liver was normal and fully developed, failure of the left pleuro-peritoneal membrane to form might seem to be called in question, however, for Mall (2) states that "the liver grows into the pleuro-peritoneal membrane while it is being separated from the septum transversum on its ventral side." Perhaps it may be assumed that only a portion of the pleuro-peritoneal membrane formed, and the same may be true of the normally innervated ventral musculature of the diaphragm which failed to extend dorsally. Or it is not unlikely that the liver, which normally invades the pleuro-peritoneal membrane, may be able to continue in its development quite independently of it.

The presence of an apparently normal left phrenic nerve excludes the possibility of a defective innervation of the early musculature, and hence it is evident that the absence of the pleuro-peritoneal membrane probably prevented the musculature which invaded the septum transversum from extending dorsally and laterally, although it may have been prevented from so extending by the presence of the abdominal viscera in the pleuro-peritoneal hiatus. Since the liver was normal, and since none of the displaced viscera—the cardiac end of the stomach, the spleen, intestines, and pancreas—bore any evidence of constriction, it would seem, however, that the diaphragmatic musculature failed to extend dorsally independent of the pleuro-peritoneal membrane although it is present ventrally and has a normal innervation. Hence it seems probable to me that the pleuro-peritoneal membrane acts as an indispensable guide for the ingrowing musculature of the permanent diaphragm. Furthermore, it is possible that the presence of the stomach, or its usually rapid growth cranially, made possible by a slower development of the lung or for other reasons, could prevent the formation of the pleuro-peritoneal membrane and hence make it possible for the musculature to extend into the latter. For, according to Wölfel (3), " Bald shiebt die Leber, die in den ventralen Schenkel des Urnierenbandes hineinwächst, diesen und sich selbst zwischen Lunge und Panzen ein und zwingt den letzteren, sich weiter dorsal aufzurichten, indem sie ihn zugleich mit den Urnierenband den weg in die Pleurahöhlen verlegte." But it is evident that this separation may not be effected if the stomach has encroached too far upon the lung to permit the liver to separate the two viscera by extension into a pleuro-peritoneal membrane which has failed to form, or if degeneration of the pleuro-peritoneal membrane has occurred after separation from it of the liver. Furthermore, since Mall's statement regarding the late closure of the "opening behind the pleural and peritoneal cavities" on the left side in man also holds for sheep, according to Wölfel, the occurrence of this defect on the left may be due to the fact that the stomach, which passed into the gap, prevented the completion or even the formation of the pleuro-peritoneal membrane and the later extension dorsally of the diaphragmatic musculature.

(1) Gössnitz, *Sechs Fälle von linkseitigen Zwerchfelles und Defekt*, Thesis, Jena, 1903. (Gives an extensive bibliography.)

(2) Keibel and Mall, *Human Embryology*, vol. i., Phil., 1910.

(3) Wölfel, *Beiträge zur Entwickelung des Zwerchfelles und Magen bei Wiederkäuern*, Thesis, Giessen, 1907.

6. Aberrant Adrenals in the Great Omentum of the Cat.

In the course of an investigation upon accessory spleens and hemal nodes, small reddish nodules one to three millimeters in size, which, upon microscopical examination, were found to be adrenals, were usually mistaken for accessory spleens. Since not all accessory spleens found were examined microscopically, it is possible that an examination of all specimens would probably have revealed more adrenals. Since both adrenals found were taken from the omentum of the same animal, the

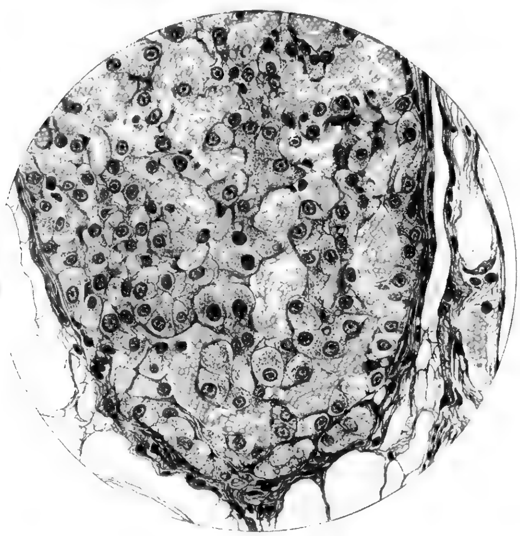


Fig. 34.—Aberrant adrenal from omentum of cat. ×505. Zeiss 3-E.

ratio of their occurrence would stand as one in sixty-nine cats. This included cats of all ages and in somewhat varying conditions of health. In one of these specimens of aberrant adrenals the parenchyma is arranged somewhat characteristically, but in the other this is not the case, as fig. 34 shows. Moreover, some portions of this specimen are extremely vascular and the cells vary considerably in size.

7. Cysts of the Parathymus of the Sheep.

The occurrence of cysts in the parathymus glands of the sheep was observed by Schaper (1), and was also called attention to by Meyer (2). The unusual size and the presence of a group of these cysts, occasionally seen in fœtal sheep, is quite remarkable. Fig. 35 represents a section of the parathymus from a sheep fœtus 26 centimeters long. In this specimen only the largest of the cysts contained some material of a colloidal nature, but since the occurrence of colloid is not at all rare in developing parathymus glands, it does not seem unlikely that cyst formation is directly attributable to an accumulation of colloid. Although no very large number of parathyroids from adult sheep were examined, yet it seems strange that not a single cystic specimen was found among them, and it is surprising

FIG. 35.—Cystic parathymus from sheep fœtus, 26 cm. Camera lucida. ×97.

that the production of colloid and cyst formation are present during the marked growth of embryonic life.

(1) SCHAPER, "Über die sogenannten Epithelkörper (Glandulæ parathyroideæ) in der seitlichen Nachbarschaft der Schilddrüse und der Umgebung der Arteria carotis der Säuger und des Menschen," *Archiv f. mikr. Anat.*, Bd. xlvi., 1895.

(2) MEYER, "The Occurrence of Intra-thoracic Parathyroid Glands," *Anat. Record*, vol. iii., 1909. *Proc. Ass. of Am. Anat.*, pp. 272–274.

8. Cystic Thyroids in very young Sheep Fœtuses.

The youngest fœtus in which the thyroids were found to be markedly cystic was only 9·7 cm. long. As the rough sketch in fig. 36 shows, these cysts were relatively very large and contained much colloid. From an examination of these thyroid glands it would, I believe, be impossible to say whether this condition would be likely to persist or not, and the probability seems to be that the process does not progress, for in not a single case of the older fœtuses examined were any cysts found of even approximately the same relative size.

FIG. 36.—Cystic thyroid gland from a sheep fœtus, 9·8 cm. long. Actual size of section $1\frac{3}{4} \times 4\frac{3}{4}$ mm.

9. AN EXCEPTIONALLY SYMMETRICAL HORSESHOE KIDNEY LYING DORSAL TO THE VENA CAVA IN THE CAT.

The specimen shown in the accompanying illustration was received through the courtesy of Mr John Edwin Paulson, one of our students. It is interesting particularly because of its (1) regularity in form and almost perfect symmetry, (2) because of the absence of any intermediate portion which might justly be termed an isthmus, and (3) because it lies dorsal to the vena cava. A further point of interest might be the fact that it was observed in the cat, for none of the veterinary journals accessible to me mention such an anomaly. Nevertheless one would, to be sure, expect it to occur.

The fused renal mass is located at approximately the usual level, but lies directly ventral to the vertebral column, its mid-point lying a little to the right of the median line. The superior right free pole lies several millimeters farther cranially than the left. The dorsal surface is even and flat, and there is no indication of lobulation anywhere. Since the line of fusion of the inferior poles is displaced a few millimeters to the right, the two halves are almost exactly equal in size and also symmetrical. Their total volume is, however, apparently somewhat smaller than the combined volume of normal kidneys, but there are no signs of gross pathological lesions.

The vena cava, which lies ventral to the kidney, crosses it a trifle to the left of the median line. Both renal veins are so short that the kidney can be regarded as being sessile on the vena cava. A single renal artery, which arises from the aorta about half a centimeter cranial to the kidney, runs ventro-caudally, entering the incisure between the free cranial poles and bifurcating near the ventral surface to form two very short right and left renal arteries. The unpaired renal artery also gives rise to an unpaired ovarian artery, which lies ventral to the kidney and bifurcates opposite the cranial border of the fused inferior poles, forming the respective ovarian

FIG. 37.—Horseshoe kidney in the cat.

arteries. There are, however, two ovarian veins. The left joins the vena cava just caudal to the kidney, and the right just opposite the free left pole directly opposite the left adrenal vein. Both adrenals, which are only about two-thirds normal size, are directed ventro-dorsally and lie against the cranial surface of the free left pole. There are two independent ureters, which lie ventrally, as is customary, and pursue practically a normal course.

In a recent contribution and review of the literature on horseshoe kidneys in man, Legueu and Papin (1) mention the fact that the dorsal surface of the fused kidneys is always grooved by the vena cava and aorta, but they do not mention the possibility of the vena cava lying ventrally, and none of their many illustrations show it in this position.

(1) LEGUEU et PAPIN, "Le rein en fer cheval," *Rev. de Gyn.*, t. xviii., 1912.

THREE EXAMPLES OF A RIGHT AORTIC ARCH. By DOUGLAS G. REID, M.B., Ch.B. Edin., B.A. Trin. Coll. Camb., *Demonstrator of Anatomy in the University of Cambridge.*

CASES in which there is persistence of the fourth right aortic arch are, of course, very well known.

Nevertheless, in the cases here recorded, which occurred in adults, presented no fibrous remnants of a left aortic arch, and were not associated with transposition of the viscera or any marked cardiac anomalies, there are certain points which appear worthy of note.

Unfortunately, a number of structures had been cut before I saw the specimens.

In Cases II. and III. (see figs. 2, 3) the aortic arch, as it passes backwards on the right side of the trachea, lies just above the right bronchus.

In Case I., however, it is placed at a considerable distance above the bronchus (see fig. 1). In this specimen the highest point of the arch lies 1 cm. below the upper border of the body of the first dorsal vertebra.

The aorta ascends through the superior aperture of the thorax into the root of the neck, and must have given rise to marked suprasternal pulsation.

But in Case I., as in Case III., and as in most cases of right aortic arch (Allen Thomson and Turner), the left subclavian artery arises posteriorly, and the left common carotid is the first branch of the arch (see figs. 1, 3).

In Case I. it arises in front and to the right of the trachea, is still anterior to this at the level of the presternal notch, and must also have given rise to marked pulsation in this situation.

It is noteworthy, therefore, that suprasternal pulsation, even when most marked, may not always indicate the presence of an aneurism, and other physical signs may help to show this.

However, it seems worth while revising the causes to which attention has now been drawn, apart from aneurism, of suprasternal pulsation.

(1) An aortic arch which ascends to the level of the presternal notch.

This may or may not be due to the persistence of a more primitive position.

Poirier states that "il n'est pas rare chez les sujets âgés de voir la crosse

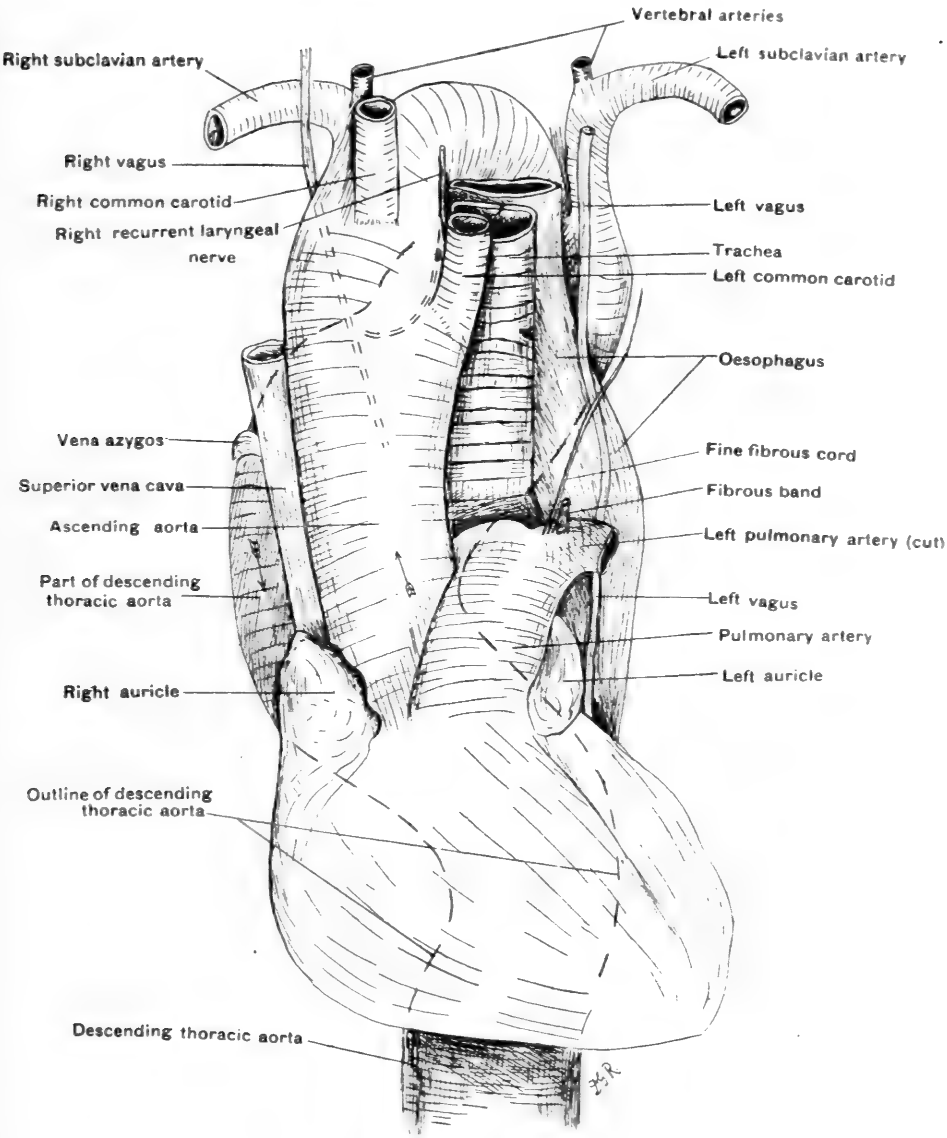

Vertebral arteries
Right subclavian artery
Left subclavian artery
Right vagus
Right common carotid
Right recurrent laryngeal nerve
Left vagus
Trachea
Left common carotid
Oesophagus
Vena azygos
Fine fibrous cord
Superior vena cava
Fibrous band
Ascending aorta
Left pulmonary artery (cut)
Part of descending thoracic aorta
Left vagus
Pulmonary artery
Right auricle
Left auricle
Outline of descending thoracic aorta
Descending thoracic aorta

FIG. 1.—Case I.

de l'aorta battre dans la dépression sus-sternale—en raison du développement du grand sinus."

(2) Abnormally situated branches of the aortic arch.

(*a*) A right (or left) innominate artery[1] "may divide higher than usual, and may then incline abnormally to the left, mounting in front of the trachea above the sternum" (Morris's *Anatomy*).

(*b*) The right subclavian, when its place of origin is to the left of the middle line (Hutchison and Rainy, *Clinical Methods*).

(*c*) The left common carotid in certain cases of right aortic arch, as I have indicated.

(3) The thyroidea ima, whose pulsations one sometimes sees as well as feels.

In Case I. the pulmonary artery, 2 inches long, lies in its usual situation, and divides, as normally, a little below, in front of and to the left of the bifurcation of the trachea, and in front of the root of the left bronchus (a relation never mentioned in the books).

The serous pericardium had been removed, and one could not determine the height to which it had ascended.[2]

In Case III., as in the case described by Allen Thomson (*Glasgow Medical Journal*, vol. xi., April 1863, p. 1), in which both aortic arches apparently had remained patent throughout until a relatively late period of intra-uterine life, and in which there was a left innominate artery, the posterior part of the arch and the upper part of the descending aorta presented a dilated portion. This is placed behind the œsophagus, and corresponds to the pouch-like trunk in Turner's ordinary case of right aortic arch.[3]

It sends forward a projection which lies to the left of the trachea, gives origin to the left subclavian artery, and terminates in a truncated extremity to which, at the root of the subclavian (see fig. 3), the ligamentum arteriosum, round which the left recurrent laryngeal nerve hooks, is attached.

Therefore in this specimen the trachea and œsophagus are almost completely encircled by the aorta.

Allen Thomson and Turner first pointed out that this dilatation which lies

[1] In old people this artery (Poirier) terminates "plus haut, au niveau du bord supérieur de l'extrémité sternale de la clavicule."

Annandale demonstrated that the innominate artery may be compressed by a finger introduced behind the upper border of the sternum.

[2] Normally the serous sac of pericardium, as Poirier points out, ascends to the back of the root of the innominate artery, and therefore into the superior mediastinum. The text-books overlook this important point. The student, when asked the contents of the superior mediastinum, always omits the serous pericardium and the azygos vein (whose arch reaches "à la hauteur de la 4^e^ ou de la 3^e^ vertèbre dorsale" (Poirier).

[3] *British and Foreign Medical Review*, 1862, vol. xxx.

behind the œsophagus is to be regarded, not as secondary, but as representing a persistent left aortic root (*i.e.* a portion of the left dorsal aorta caudad to the dorsal extremity of the fourth left aortic arch).

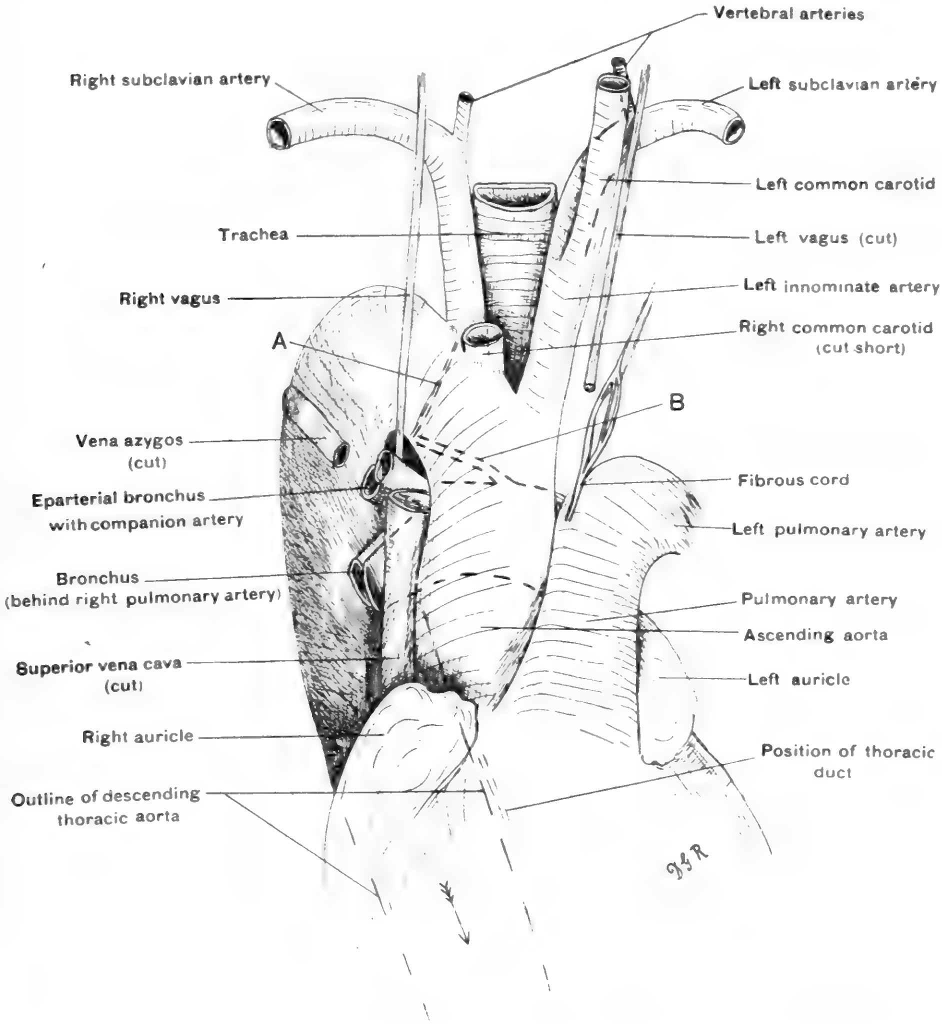


FIG. 2.—Case II.

In Case I. the aortic arch itself curves quite distinctly inwards behind the œsophagus. Its posterior part, and the commencement of the descending aorta (which lies behind the œsophagus) are also somewhat dilated, but there is no distinct projection as in Case III., and the subclavian artery arises more directly from the arch. The aorta extends distinctly beyond the left margin of the œsophagus, and produces a deep groove on the medial surface of the left lung above the hilum.

Apparently in association with the unusual height to which the aortic arch ascends, the upper aortic intercostal arteries are much less oblique

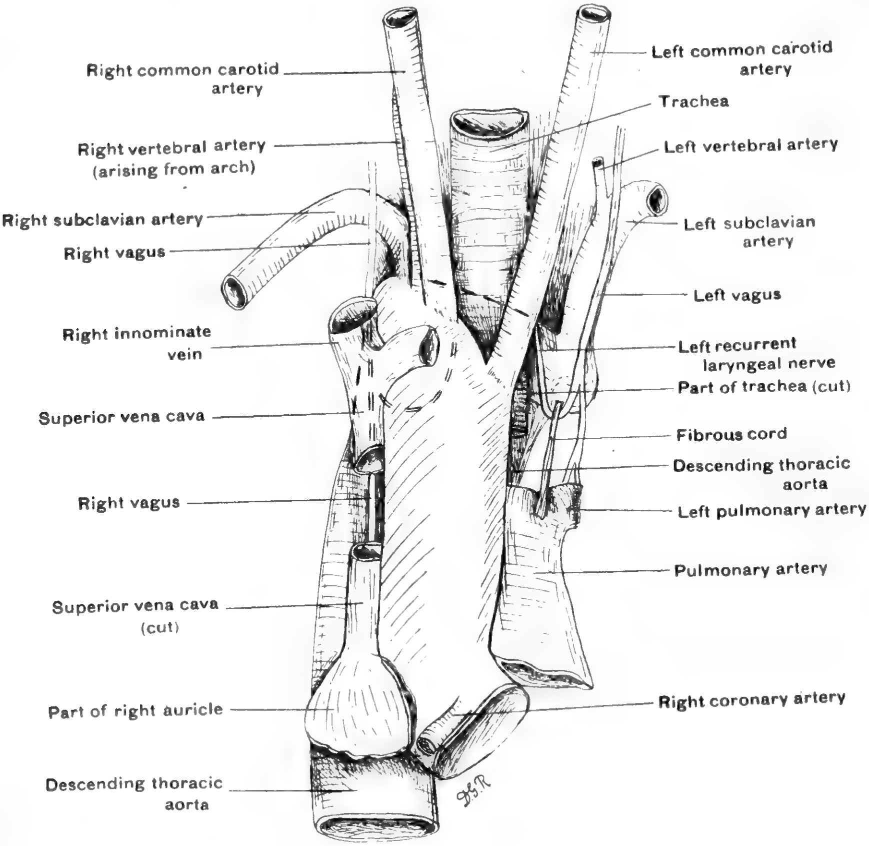


Fig. 3.—Case III.

than is usually the case. The descending thoracic aorta (the abdominal aorta had been removed) is remarkably sinuous.[1]

Above, it lies to the left of the middle line, but, taking a curved course, it comes to lie entirely to the right of the middle line and produces a deep

[1] Another case of right aortic arch with persistence of the left aortic root, as in this case, and sinuosity of the descending aorta, is recorded by Annan (*Journal of Anatomy and Physiology*, vol. xliv. p. 241). As in this case, there was no scoliosis. The presence or absence of atheroma is not noted. Atheroma was present in my specimen.

depression behind the hilum of the right lung. Below this level it regains a position to the left of the middle line, into which it comes near the aortic hiatus of the diaphragm.

In Case II., where there is a left innominate artery (partial persistence of the fourth left aortic arch) and no trace of the left aortic root, the descending aorta as it passes downwards inclines gradually to the left and forwards to reach the middle line close to the hiatus.

Little regard has been taken of the relations of the thoracic duct in cases of a fourth right aortic arch, and even Garnier and Villemin, in a recent and detailed description of a right aortic arch in a fœtus,[1] omit to mention the duct.

Allen Thomson, however, states that in his case it lay on the right side of the descending thoracic aorta, between it and the azygos vein, and joined the angle of union of the right jugular and subclavian veins.

But in Case II. the duct, except near the aortic hiatus of the diaphragm, where it lies behind the aorta, is placed on the left side of the descending aorta in front of the left intercostal arteries. Above, it passes towards the right jugular-subclavian confluence, but unfortunately its upper end had been cut by the dissectors.

In Case III. there is no duct to be found.

In Case II. a portion remains which lies in front of the left intercostal arteries, behind the parts of the aorta which lie to the left of the middle line, but to the left of the intervening portion opposite its concavity (see fig. 1). "In human embryos the observations on the thoracic duct are still scanty."

In Case III. the fibrous cord (ligamentum arteriosum) which passes from the pulmonary artery to the aortic root, and round which the left recurrent laryngeal nerve hooks, has already been mentioned.

In Case II. there are two fibrous cords. One (see fig. 2, B), a stout band, is attached to the right pulmonary artery 15 mm. from its origin, and passes to the right and upwards to a point on the inferior aspect of the aortic arch. The right recurrent laryngeal nerve (fig. 2, A) takes origin opposite this point, and comes into contact with the right extremity of the band.

The other arises from the pulmonary trunk, and divides into a number of distinct cords. In Case I., in addition to a stout band, a fine cord is present; and both are attached to the pulmonary artery close to one another.

It was unfortunate that only the parts shown in the figures had been left by the dissectors.

[1] *Bibliographie Anatomique*, vol. xix. p. 277.

A consideration of the points of attachment of these fibrous remnants of the sixth (pulmonary) arches would indicate that in Case II. a distinct portion of the right pulmonary artery was formed by the sixth right aortic arch, as is normally the case according to Bremer.[1]

The arrangement in Case I. may indicate that the pulmonary arches have fused (a fusion is described by Bremer) up to the points of origin of the pulmonary arteries, and, in view of the very plastic nature of the embryonic arteries, a variation such as this is not surprising.

In Case II. it would appear that the left sixth arch had remained patent until a relatively late period of intra-uterine life.

In cases of right aortic arch with persistence of the left aortic root (fig. 1) the presence of a fibrous remnant representing the right pulmonary arch has hitherto escaped observation.

It would appear from the presence of two distinct cords in Case I. that both pulmonary arches had remained pervious until a relatively late period, although the left may be the one which usually remains patent until birth.

I am not aware that the presence of the fibrous remnants of both sixth aortic arches has hitherto been recorded.

The relations of the other parts are accurately represented in the figures.

It will be seen that the vena azygos major (vena azygos) does not present its usual direct relation to the trachea, the aortic arch, of course, intervening. The right vagus nerve is also separated from the trachea by the aorta. In cases like III. and I. the recurrent laryngeal nerves come into close relation with the trachea at practically the same level.

In Case II. the vena azygos lies in contact with the posterior aspect of the descending aorta, and takes a course exactly parallel to it. But in Case I. this vein, like the thoracic duct, is not curved in conformity with the aorta.

Although the question as to what influence the atheroma in Case I. had in producing the sinuosity is to be kept in mind, the occurrence of sinuosity in two cases in which there was a left aortic root along with the right aortic arch suggests that the condition may be of developmental origin.

[1] Rathke held that in mammals both pulmonary arteries arose primitively from the sixth left aortic arch.

Bremer's recent papers (see the *Anat. Record*, 1909, vol. iii., No. 6, p. 334) indicate that in man the pulmonary arteries arise, one from the right and the other from the left sixth arch, which, however, never (?) forms a definite part of the left pulmonary artery.

His had already stated that primitively a pulmonary artery arises from each sixth arch, but that later both spring from the sixth left arch.

Turner, from the consideration of a case described by Breschet, also specially pointed out (in 1862) that in man the pulmonary arteries might arise one from each sixth arch.

In such cases, on the other hand, the presence or absence of correlated variations of neighbouring structures is noteworthy. Thus there was no corresponding sinuosity of the thoracic duct, although the duct, of course, is related closely to the aorta during development.

In cases of right aortic arch, that relation of the thoracic duct to which I have drawn attention, viz. its presence on the left side of the descending thoracic aorta, also appears worthy of special notice, and suggests that primitively there is a more symmetrical arrangement of the lymphatic channels than is at present known to exist.

MEASUREMENTS ON A HUMAN EMBRYO 30 MM. LONG. By

Frank E. Blaisdell, sen. (*From the Division of Anatomy of the Department of Medicine of Stanford University.*)

The present observations are based on an imperfect human embryo obtained without data. They constitute an inquiry into the relative size of organs and the degree of development attained in this embryo, measuring 30 mm. from vertex to breech after fixation in alcohol.

So far, embryological measurements have been confined to external measurements, and it does not seem improbable that a series of careful measurements on the chief internal organs may form a far better criterion for estimating the age of embryos. It is to be hoped that a group of embryos of approximately similar external size may be subjected to corresponding measurements, with the idea of securing such a basis and of throwing some light on the rate of development in the various viscera, in the same and in different embryos.

Condition of the Embryo.

The posterior parietal and anterior cervical regions, portions of the abdomen and lower extremities, were lacerated. The injury to the head had involved the lateral wall of the occipital portion of the right cerebral hemisphere. All of the other parts of the body were perfect and in excellent condition. The embryo, which is apparently normal, is No. 9 of the collection.

Method of Preparation.

The embryo was fixed in alcohol, embedded in paraffin, and cut serially for class work. The head was cut sagittally and the body transversely. One-half of the head, as cut, constitutes a sagittal series of one hundred and ninety-five sections (Series 9). From the transverse series of the neck and thorax twenty-five sections were selected from different levels, and these constitute Series 9a of the collection. The sections were cut 16 micra in thickness. Both series were stained with Mallory's connective-tissue stain.

Measurements and Age of the Embryo.

The damaged condition made it necessary more or less to approximate the length of the lower extremities. According to Mall's method of estimating the standing height, the measurements for Embryo No. 9 are as follows:—A vertex-breech length of 30 mm., a hip-knee (*hk*) length of 3·0 mm., and a knee-heel (*kh*) length of 6·0 mm., with a standing height of 39·0 mm. The head of No. 9 is somewhat large in proportion to the body, the upper extremities are flexed, and the forearm and hand lie transversely across the thorax; the arms are placed somewhat vertically in relation to the antero-lateral thoracic wall, with a well-marked bend at the elbows. The fingers are all free. The eyelids are completely closed and adherent. It is evident that the embryo is older than its size indicates. Unfortunately, the lack of a menstrual history prevents any discussion of the question from that standpoint, and recourse must therefore be had to a comparison with embryos of a known age and development. Probably 32 mm. vertex-breech measurement is nearer the truth, and the age about seventy days.

The measurements made from a median sagittal section of the head of No. 9 are as follows:—The diameter on a plane cutting a point between the occipital cartilage and atlas to the anterior nasal spine is 10·0 mm. The greatest cephalic diameter, which lies parallel to this line, measures 12·5 mm., while a line drawn at right angles to the first gives the height of the head as 11·0 mm. The height, as measured from the occipital cartilage at the anterior margin of the foramen magnum to the vertex, is 12·5 mm. The transverse diameter through the shoulders just cephalad to the margin of the cartilaginous manubrium and close to the articulationes humeri was 10·0 mm., and the sagittal diameter in the same plane 6·5 mm. The transverse diameter of the thorax, on a plane through base of the heart, 9·5 mm.; and the sagittal diameter in the same plane, 8·0 mm. The transverse diameter of the thorax on a plane through the mammary anlagen was 9·5 mm., and the sagittal diameter in the same plane 7·5 mm. The length of the forearm and hand, measured from a point over the cartilaginous olecranon to the tips of the fingers, 7·0 mm.

All micrometrical determinations have been made with a Zeiss ocular micrometer.

Derivatives of the Epiblast.

Epidermis.—Embryo No. 9 exhibits considerable variation in the thickness of the epidermis. In the region of the scalp the epidermis is two-layered, and one or both layers are absent in places, showing that they are easily detached. The peridermal cells are fusiform, and here and there two cells deep. The cells of the stratum germinativum, which have nuclei somewhat centrally placed, are short and cuboidal, varying more or less in form from mutual pressure. In the lateral pectoral region, and especially lateral to the mammary region, the epidermis is distinctly two-layered, with larger cells than those on the scalp. Over the dorsal and anterior thoracic regions the stratum intermedium is present. Here the peridermal cells are fusiform in places and seem thicker, but there is so much denudation that it is hazardous to make a positive statement. Over the brachium the basal cells are rather more columnar than cuboidal. This is especially true medially where they are distinctly columnar, with nuclei apically situated. Over the face, mammary region, forearm, and hand, the stratum

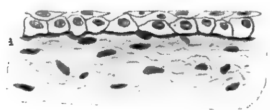


FIG. 1A.—Integument of the right side, lateral to the mammary region. Nuclei in the undifferentiated corium very sparse. Outlined with the aid of the camera lucida. B. & L., oc. 1½ in.; obj. ⅙ in. Reduced ½.

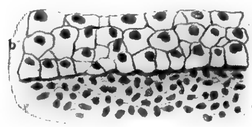


FIG. 1B.—Integument of the right mammary region, slightly lateral to the mammary anlagen. Outlined with the aid of the camera lucida. B. & L., oc. 1½ in.; obj. ⅙ in. Reduced ½.

Note.—A Zeiss microscope has been used, except when otherwise stated. Tube length of 15, and the drawing surface raised 30 mm. above that of the table.

intermedium is well developed. The cells of the superficial stratum are larger, thicker, with straighter sides and larger oval nuclei. It is difficult, however, to judge the proper focal plane, for the cells are transparent and the picture changes with the focal plane. Hence an endeavour has been made to judge and consider only the cell layers where the line of sectioning has fallen perpendicular to the surface. Commencing just above the supraciliary region, the epidermis becomes three and four cells thick, especially in the region of the mouth. On the lips the cells of the stratum germinativum gradually become high columnar, the nuclei are more elongated, and closely placed to each other so as to form a regular, heavily stained nuclear line, all these characteristics becoming more prominent as the buccal walls are approached. The same structural characteristics are present in the basal layers or stratum germinativum between the adherent palpebræ, as well as on the volar surface of the hands, where the nuclei are very deeply stained.

Derivatives of the Epidermis.

Hair germs are present in the supraciliary region, upper and lower lips, but not elsewhere on the head. The incomplete series of sections of the neck and thorax contain none in those regions.

Fig. 2 shows the degree of development reached by the hair germs. A very few may possibly possess a slight kiln-like arrangement of the cells, but since they are heavily stained the exact details are obscured. Several of the hair germs have an aggregation of heavily stained nuclei in the corium in close proximity to them. These aggregations represent differentiating papillæ. Section 49, from which the camera lucida tracing was made (fig. 2), shows the basal cells of the epidermis in the supraciliary region to be of the high columnar type. Such a pronounced columnar

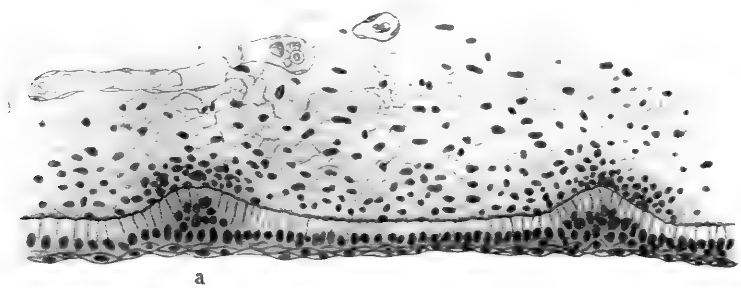


Fig. 2.—Sagittal section of two hair germs in the right supraciliary region. At (*a*) the line of sectioning is through the side of a germ. Drawn with the aid of the camera lucida. Series 9A, section 49. B. & L., oc. 1 in.; obj. $\frac{1}{6}$ in. Reduced $\frac{1}{2}$.

form may be due partly to an obliquity of sectioning, although other sections do not show evidence of this. At (*a*), fig. 2, a germ is cut through the side and the nuclei of the stratum germinativum immediately adjoining are shown as assuming a straight course. It has not been possible to count all the hair germs in the supraciliary region, but as many as forty-three have been counted and numerous others in earlier stages of development are present.

Mammary Anlagen.—The mammary anlagen are more or less oval in outline. The right gland consists of two closely approximated divisions. The maximum diameter of these divisions measured transversely is 166·5 micra, and the depth to which they penetrate the mesoblast, as measured from the epidermal surface, is 216·4+ micra. The thickness of the overlying epidermis is 24·2+ micra. The formation of a connective-tissue sheath is indicated by the condensation of the surrounding mesenchyma and the crowded state of the nuclei. Fig. 1 shows the abundance of the latter, as contrasted with their sparseness in the undifferentiated corium lateral to the mammary region.

A differentiated corium and tela subcutanea are not yet discernible. The connective-tissue reticulum is made up of fine delicate fibrillæ, and the deep surface of the developing glands with their enveloping sheaths rest upon a stratum of wavy parallel fibrillæ, that are more condensed and heavily stained. The latter is the developing pectoral fascia. The mesenchymal tissue in the vicinity of the glands has a much greater depth than at some distance from it.

Lacrimal Apparatus.—The lacrimal apparatus consists of solid epithelial cords.

The lacrimal canal cords end abruptly against the deep surface of the conjunctival epithelium, and are therefore not in continuity with it. In

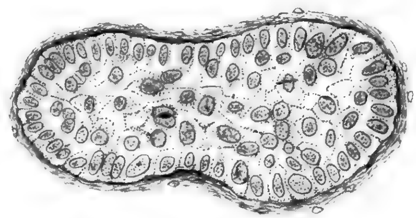


Fig. 3.—Section through the point of junction of the lacrimal cords with the nasolacrimal cord. Camera lucida drawing. Oc. 3; obj. E. Reduced $\frac{1}{2}$.

all sections of the series a distinct and rather heavily stained line marks the basal line of the conjunctival epithelium. Both lacrimal cords are largest where they are in juxtaposition to the conjunctival epithelium, their diameter being 68·1+ micra. From that point each gradually diminishes to 45·4+ micra opposite the medial border of the lacus lacrimalis, again to increase in size as their junction with the nasolacrimal cord is approached, the diameter of the superior cord being 48·4+ micra, and that of the inferior 53·0+ micra. The average diameter of the nasolacrimal cord is about 61·0+ micra. That portion of the cord which corresponds to the position of the lacrimal sac has a diameter of 60·6+ micra, which increases to 75·7+ micra; thence the diameter decreases to 42·4+ micra as the cord enters the nasolacrimal canal, to increase again to about 54·5+ micra as the nasal epithelium is approached.

The central cells of the lacrimal and nasolacrimal cords have stained less strongly than the peripheral cells, but there is no distinct evidence of their degeneration to form a lumen. Fig. 3 is a camera lucida drawing of a section through the point of junction of the lacrimal cords with the nasolacrimal cord. In the cords the nuclei of the basal cells are slightly more elongated than elsewhere, and placed more closely and regularly, so as to form a more or less regular line. The nuclei of the intermediate and centrally placed cells are more oval. The basal part of the peripheral and more or less columnar cells shows as a narrow, clear, and unstained line. The regular row of elongated nuclei of the basal cells shows most plainly in the thickened distal extremities of the lacrimal cords just where they approach the conjunctival epithelium.

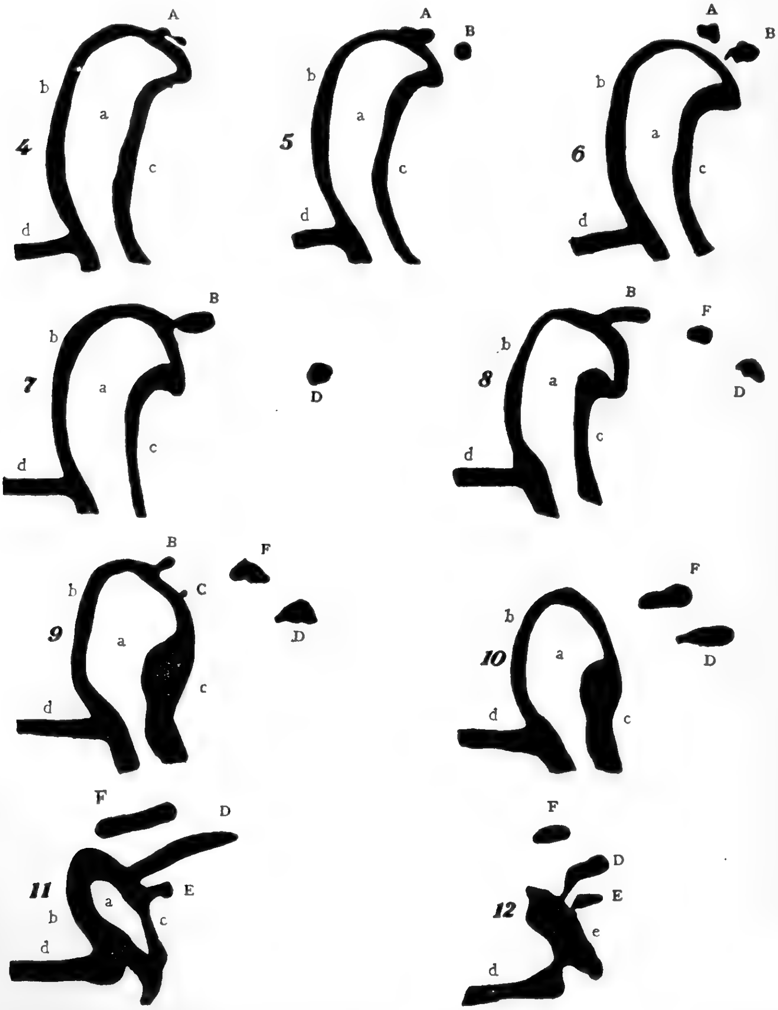
The mesenchymal tissue immediately surrounding the cords has undergone considerable condensation and differentiation to form a sheath. This sheath is less evident in the palpebral mesoblast, where there is a general condensation with a marked increase in the number of nuclei.

The nasolacrimal cord passes downward between the centre of ossification for the superior maxilla and the lateral wall of the cartilaginous nasal capsule. At the superior extremity of the developing lacrimal groove, the centre of ossification of the lacrimal bone is in contact with the nasal capsule. The nasolacrimal cord is surrounded by a thin sheath of condensed mesenchyma, and the accompanying blood-vessels are sufficiently abundant in the mesoblast occupying the pathway of the nasolacrimal canal.

The conjunctival sac in sagittal section appears as an arcuate space between the palpebræ and the bulbus oculi. The greatest distance between the superior and the inferior fornices is 1.6+ mm., the measurement having been made in a straight line between the two points named. At the internal angle of the sac, the rudimentary semilunar fold, which has a mesoblastic core, projects inwards to the distance of about 52 micra. The cells of the palpebral and bulbar conjunctival epithelium possess spherical nuclei, which lie about three deep. However, the outlines of the cells are not evident, and the basal layer does not form a regular row. The basal layer of columnar cells so evident in the inter-palpebral epithelium passes quickly into low columnar, then cuboidal, and becomes lost as a distinct layer after attaining the conjunctival surface of the palpebræ. At many points and in different sections the epithelium appears to be from four to six layers deep, but this thickness is undoubtedly due in part to an obliquity of sectioning.

Lacrimal Glands.—The anlagen of the ducts of the right lacrimal gland are six in number. The epithelial cords have grown dorsad and somewhat laterad into the mesoblast, from the superior and lateral angle of the conjunctival sac. The longer cords are slightly tortuous, and the longest one has penetrated the surrounding mesenchyma to a distance of 482·8+ micra from the surface of the conjunctival epithelium (fig. 8, D, and

13). The longest cords are lateral in position, and exhibit the most irregularity and curve medialward (cords D and F, figs. 7, 8, 9, 10, 11, 12).



Figs. 4–12.—Diagrammatic camera lucida drawings of serial sections, showing the anlagen of the ducts of the glandula lacrimalis dextra. The order given is medial to lateral.

a, saccus conjunctivalis ; *b*, epithelium tunicæ palpebrarum ; *c*, epithelium tunicæ bulbi ; *d*, epithelium interpalpebrale ; *e*, epithelium fornicis lateralis.

Cord F is not shown to join the conjunctival epithelium, and this fact strongly suggests the loss of a section at that point. The smallest cords are more medial as a rule. Cord B, figs. 8 and 13, has a diameter of 48·4+ micra. In the cords that have been cut longitudinally, the central cells are clearer and sparser than those at the periphery. Cord F, fig. 12 (section 128), shows a well-marked line bounding the apical surfaces of the medial layer of the peripheral cells, which are at least two layers deep. The central part of this cord has a homogeneous and hyaline appearance, with an apparent coagulum which has stained more or less deeply. The conjunctival epithelium is compact and in continuity at the point of junction with the cords.

The surrounding mesenchymal tissue is condensed and crowded with nuclei, but there is no evidence of a distinct differentiating sheath. As

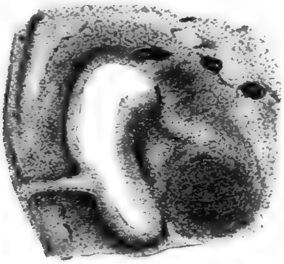


FIG. 13.—Sagittal section through the anlagen of three cords of cells of the right lacrimal gland.

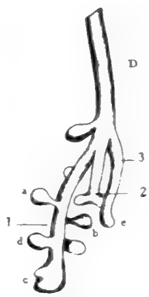


FIG. 14.—Drawing of a reconstruction of the developing parotid gland. Reduced ½.

D, ductus parotideus ; 1, 2, 3, primary rami ; *a*, *b*, *c*, *d*, *e*, secondary divisions or buds.

usual, a heavily stained line marks the basal attachment of the cells to the mesoblast. Most of the cords have shrunken away from the surrounding mesoblast, leaving a clear and unstained space between the two, which is crossed by fine fibres connected with the base of the epithelial cells. Nerves and capillary blood-vessels are present among the anlagen, which fig. 13 shows in greater detail. A nerve is in close proximity to cord D (*vide* fig. 8).

Crystalline Lens.—In sagittal section, and as it appears in the series of sections, the lens is regularly oval in outline. Its antero-posterior diameter is 731·2+ micra, and its vertical diameter 877·5 micra. At the anterior pole the epithelium is about one-fortieth of the antero-posterior diameter of the lens, or 18·1+ micra.

Parotid Gland.—The parotid gland has been reconstructed (fig. 14) after the methods of Schaffer and Born. It is less developed than the submaxillary glands, for they have well-developed connective-tissue sheaths surrounding the ducts and acini, and as a whole stand out distinctly among the other and less conspicuous structures (fig. 16).

The parotid gland arises from the buccal epithelium. In embryo No. 9 the epithelial cord can be followed laterad to the masseter, around which it curves, being in close relation with it. Just after leaving the lateral border of the muscle a division into what may be termed its three primary rami takes place, and these in turn possess buds which represent secondary divisions. Ramus 1 (fig. 14), which is the oldest, or perhaps more correctly a direct continuation of the main cord, lies exceedingly close to the carotid artery at its distal extremity; but it does not come in contact with it, nor with any of its larger branches. The veins occupy a similar relation, and the adult relationship has not yet become apparent. The course and relations of the cylindrical cord and its divisions may best be indicated by considering it in four portions as follows:—

1*st*. It is straight for a very short distance as it passes laterad from the buccal epithelium and beneath the external maxillary artery.

2*nd*. Then follows a very slightly tortuous portion as it passes through the buccal mesenchyma to the medial margin of the masseter.

3*rd*. It then arches across, passing external to the masseter to its lateral margin.

4*th*. The final portion enters the region between the masseter and the ramus of the mandible medially and the external auditory meatus laterally. In this portion division and budding occur, producing the various rudimentary ducts and acini. The mesenchyma, which immediately surrounds the duct, has become condensed, and later forms the connective-tissue elements of the duct and sheath. This differentiation is most evident at the proximal end of the duct and gradually less so to the point of ramification; for the fourth portion is surrounded by undifferentiated mesenchymal tissue. To be sure, changes are going on in the mesoblast, but none are recognisably concerned in the development of the sheath of the gland.

Where the duct leaves the buccal epithelium it has a diameter of 69·6+ micra, with a lumen 23·1+ micra. Fig. 15 represents a transverse section of the duct where it approaches the masseter; although the section is very slightly oblique, it gives a correct picture of the relative proportions of the walls to the lumen. The lumen is closed in the superficial portion of the buccal epithelium, for it can be traced only partly through it. Just before the primary divisions the duct has a diameter of 45·4+ micra, and the lumen, although less sharply defined, because more or less filled with broken-down cells, can nevertheless be traced into the rami as far as the buds. The epithelial cells, forming the walls of the duct and its divisions, are irregular in outline and possess large nuclei. Fig. 15 shows that the basal cells are not arranged in a regular layer, and do not exhibit any evident differentiation. Their bases are marked by a heavily stained line. Since the epithelial rami have shrunken away from the surrounding mesoblast to a greater or less extent, a clear unstained interval separates the two. This space is crossed by very fine strands, some of which are incomplete and project from the mesoblastic surface or from the bases of the peripheral epithelial cells. Ramus 1 (fig. 14) has a diameter of about 45·4+ micra at base, and a distinct lumen 9·0 micra in diameter. Ramus 2, which also has a distinct lumen, has a diameter of 45·4+ micra. Ramus 3, which is probably the youngest of the three, has a diameter of 48·4+ micra at the base, the only point where it possesses a lumen. Bud *a*, which has

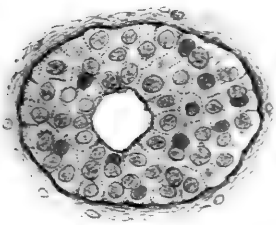


FIG. 15.—Transverse section of the ductus parotideus. Oc. 3; obj. E. Reduced ½.

FIG. 16.—Section of the submaxillary gland. Oc. 3; obj. A. Reduced ½.

no lumen, has a diameter of about 62·1+ × 81·8+ micra at the middle, and 34·8+ micra at the base. Bud *b* has a very narrow base. Bud *c*, which is 68·1+ micra in diameter at the base, is large, terminal, and knot-like, and apparently was beginning to develop two smaller outgrowths from its medial surface. Its greatest diameter is 106·0+ micra. Bud *d* has a much greater diameter at the base than bud (*a*), and a lumen has also apparently begun to appear.

In sections 47 to 51 a solid cord of cells, that ends blindly and has no connection with the parotid duct, is present. From its position near the medial border of the masseter, it is to be considered the branch observed by Chievitz. M'Murrich states that the significance of this structure is at present uncertain (*Human Embryology*, vol. ii., 1912, p. 348).

Submaxillary Duct.—At a short distance from the frenulum linguæ, in the floor of the embryonic mouth, the submaxillary duct has a diameter of 56·8+ micra. It has a distinct lumen 23·3+ micra in cross-section, with walls about 16·6+ micra thick. The outlines of the cells are not evident and the nuclei are about three deep. In the four sections studied there is some variation in the relative proportions of the walls and lumen of the duct. One section shows the lumen a mere fissure with the walls practically in contact, suggesting that this condition may be accidental. With the high moist power it can be seen that the basal cells have separated from the contiguous mesenchyma, and that very fine strands pass between the two.

Derivatives of the Neural Epiblast.

Ophthalmic Cup.—The two layers of the ophthalmic cup are not in contact, but are separated by a considerable distance; the pigment layer is closely approximated to the undifferentiated chorioid as far forward as the anterior margin of the cup. The retinal layer, which becomes gradually thinner from the position of the developing ora serrata to the margin of the cup, is irregular where the ciliary processes develop later. At the periphery of the lens the retinal layer has a diameter of about 49·9+ micra, and is about four or five cells thick. The pigment of the external layer does not extend beyond the angle of the margin. This layer has a width of about 23·3+ micra. The optical part of the retinal layer at the fundus of the cup is 116·5+ micra thick where the line of sectioning is perpendicular to the surface. The pigment layer at the same place has a thickness of 12·1+ micra. The margin of the ophthalmic cup, as observed in the sections, lies at the periphery of the lens, at about the junction of its anterior and middle thirds. The length of the ciliary and iridal portions of the ophthalmic cup, as measured in a straight line from the ora serrata to the anterior margin, is about 406·2+ micra.

Optic Nerve.—The optic nerve, the vertical diameter of which is 357·5 micra, is solid and shows no evidence of its previous hollow state.

Cerebral Hemisphere.—The greatest length of a hemisphere, measured from the frontal to the occipital pole, is 9·0 mm. The thickness of the hemisphere varies according to the degree of growth and differentiation in different regions. Measurements made on the larger medial sections, where the plane of sectioning is quite perpendicular to the surface, gives the following results:—

Superiorly and at the frontal pole the thickness of the wall varies from 260 to 178·7+ micra, and similarly at the occipital pole the thickness varies from 138·1+ to 105·6+ micra. That part of the anterior olfactory lobe, from which the bulbus and tractus olfactorius are developed, appears as an evagination directed vertically downward, the apex of which is in relation with the membranous lamina cribrosa. The fila olfactoria can be seen entering at the dorsal part of the apex. The evagination, which is 1267·5 micra long, was measured from a line cutting the base at its junction with the hemisphere. The length of the cavity is 1·0+ mm. The walls and cavity have (section No. 2, Series IX. A) the following dimensions in micra :—

	Anterior wall.	Cavity.	Posterior wall.
At base . . .	162·5	81·2+	373·7+
At middle . . .	243·7+	130·0	292·5
At apex . . .	357·5	130·0	146·2+

Ganglia of the Dorsal Roots.—The dorsal ganglia vary more or less in size and shape. In the lower cervical and thoracic regions they are situated in the intervertebral foramina.

Spinal Cord.—The twenty-five transverse sections, which constitute Series IX. A of the lower cervical and thoracic regions were selected from different levels. Four sections have been selected as best representing the degree of development in the cord. At the level of the foramen magnum it has a sagittal diameter of 1·8+ mm. (Series IX. A, section 5.)

Fig. 17, section 33, represents a section made transversely on a plane through the lower cervical region, cutting the trachea just below the larynx; the lateral lobes of the thyroid gland, and the upper part of the articulationes humeri. It is through the cervical enlargement, and shows that the myelon is nearly oval in section at that point. The surface line of the funiculi cuneati, as studied on a horizontal plane, is arcuate, and continues the line of the lateral funiculi, the latter being less arcuate in outline. On each side of the posterior median septum the funiculi graciles are very prominent, and consequently these funiculi form two ridges that are continued downward as far as the lower thoracic region at least, and there disappear. In section 33 the funiculi graciles are slightly divergent, and the re-entrant surfaces between them form an acute angle—the posterior median fissure. The surface line of the ventral funiculi is less arcuate than the dorsal, and a slight angle is evident ventro-laterally. The surface is slightly sunken just ventral to the posterior roots (fig. 17, *a*), and is most pronounced in the cervical and superior thoracic portions of the cord. The anterior median fissure is broad and rounded at the bottom. A commissura anterior is present. The central canal is large and pointed ovate in shape.

The posterior and anterior grey columns are large and have broad connexions on each side. Across the median plane a posterior grey commissure is more or less distinct dorsal to the degenerating ependymal cells. The posterior grey columns are noticeably larger than the anterior.

The measurements of the cord are as follows (fig. 17):—

Cord—	
Sagittal diameter	1446·2+ micra.
Transverse „	1251·2+ „
Central Canal—	
Sagittal diameter	503·7+ „
Transverse „	211·2+ „
Vertebral Canal—	
Sagittal diameter	1787·5 micra.
Transverse „	1727·5 „

Fig. 18, section 48, represents a section made transversely on a plane through the base of the neck just above the cartilaginous manubrium, below the thyroid gland and articulationes humeri and through the upper part of the thymus gland. At this level the cord is less oval and somewhat pentagonal in outline. The angle at the junction of the dorsal and lateral surfaces is more marked. The sides are less arcuate, more parallel, and arch into the surface of the ventral funiculi. The surface of the funiculi cuneati is straighter and somewhat oblique, giving an ogival effect to the outline. The prominence of the funiculi graciles is about the same as at a little higher level, but the re-entrant surface between them is less acutely angled. The surface just ventral to the dorsal roots is the same as at a higher level.

The measurements are (fig. 18):—

Cord—	
Sagittal diameter	1300·0 micra.
Transverse „	1202·5 „
Central Canal—	
Sagittal diameter	471·2+ „
Transverse „	195·0+ „
Vertebral Canal—	
Sagittal diameter	1706·2+ „
Transverse „	1576·2+ „

Fig. 19, section 35, represents a section made on a plane through the atrio-ventricular orifices of the heart. At this level the cord is still more pentagonal in section. The lateral surfaces are straighter ventro-dorsally and the surface lines but slightly arcuately re-entrant. They are marked both dorso-laterally and ventro-laterally by somewhat evident angles from the surface of the cuneate and ventral funiculi respectively. The surfaces of the ventral funiculi are arcuate, and the anterior median fissure is more acutely angular at the bottom. The dorsal funiculi are shaped about the same as at the higher level at the base of the neck, but the funiculi graciles

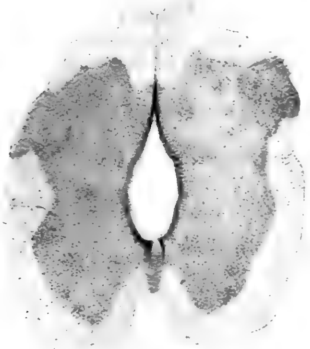


Fig. 17.

Fig. 18.

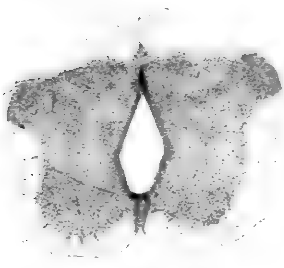


Fig. 19.

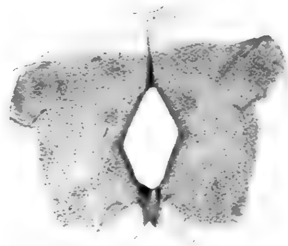


Fig. 20.

Transverse sections of the medulla spinalis, as observed under low power. × 70. Reduced to ½.

are less prominent; the re-entrant surface between them is correspondingly shallower and broader. The central canal is more rhomboidal in cross-section than at the level previously described. The sunken surface ventral to the dorsal roots is not noticeable, and there is still greater disparity between the grey columns.

The measurements are (fig. 19):—

Cord—

Sagittal diameter	1015·6 + micra.
Transverse „	1121·2 + „

Central Canal—

Sagittal diameter	406·2 micra.
Transverse "	195·0 "

Vertebral Canal—

Sagittal diameter	1348·7 "
Transverse "	1592·5 "

Fig. 20 was drawn from section 31, which was on a horizontal plane through the liver and diaphragm, at the caudal extremity of the sternum. At this level the myelon is less pentagonal and more quadrate in section. The surface lines of the lateral funiculi are straighter and more parallel; the dorso-lateral and ventro-lateral angles are marked, the latter more rounded. The surface of each ventral funiculus is arcuate from side to side, and the anterior fissure shallower and less acutely angled at the bottom. The surfaces of the funiculi cuneati are straighter on each side, and the dorsal outline less ogival. The funiculi graciles are less prominent and the intervening surface scarcely re-entrant. The central canal is rhomboidal.

The measurements are (fig. 20):—

Cord—

Sagittal diameter	991·2 micra.
Transverse "	1137·5 "

Central Canal—

Sagittal diameter	406·2 + "
Transverse "	219·3 + "

Vertebral Canal—

Sagittal diameter	1332·5 "
Transverse "	1462·5 "

For the sake of accuracy it should be stated that the sections are not cut on a perfectly horizontal plane, but slightly diagonally. However, this obliquity is scarcely enough seriously to affect the diameters.

The lumen of the central canal has undergone considerable obliteration between the dorsal zones. The canal is also evenly curved from side to side across the floor-plate. If any angles have existed they have become obliterated, and this is a probable explanation of the deeply stained ependymal cells observed each side of a centrally located clearer area in the floor-plate.

Derivatives of the Mesoblast.

The cartilaginous skeleton is well developed and centres of ossification for the following bones have appeared:—

Clavicle.—The cartilaginous outline is already involved in ossification.

Mandible and Maxilla.—The most conspicuous centre is that for the lower border and front of the alveolar process. None of the sections show that the distal end of Meckel's cartilage is involved in the process of ossification, and there are two other small centres which have not been clearly identified. One of these may be the centre for the coronoid process. The other consists of two punctiform areas lying between and below the proximal end of Meckel's cartilage and the tympanum. A well-developed centre is present for the maxilla.

Nasal Bone.—A distinct centre lies over the cartilaginous nasal capsule.

Lacrimal Bone.—A thin delicate centre lies over the side of the nasal capsule.

Malar Bone.—Two centres are apparently present.

Frontal Bone.—Ossification is well under way in the orbital plate and lower portion of the vertical part.

There is no evidence of centres in the parietal and temporal membranes or cartilages.

The twenty-five sections constituting the selected series of transverse sections, Series IX. A, give negative results for centres of ossification in the lower cervical and thoracic regions.

Ocular Bulb.—The sclera is well defined from the surrounding orbital connective tissue. The chorioid-sclera has a thickness of 83·2+ micra posteriorly, at a point where it is sharply defined by being in contact with a rectus muscle. The fibrils of the sclera, as viewed in sagittal section, run parallel to each other, and are more or less undulating. The meshes which are elongately fusiform vary in width and size. The nuclei are elongate and have their long axes parallel to the fibrils, with which they are in close contact. In the equatorial region, at the places of muscular insertions, and in the ciliary zone as well, they become much more abundant, and a large number of them are shorter, thicker, and more oval. A moderately large vessel, probably a vena vorticosa, is occasionally present in cross-section in the sclera. No muscular tissue has yet differentiated in the ciliary body.

Cornea.—The corneal tissue is more condensed, and structurally resembles the sclera, into which it passes imperceptibly. The meshes between the fibrils are narrower. The thickness of the substantia propria corneæ is 63·6+ micra at the periphery, and 31·8+ micra at the middle. The corneal epithelium is two or three layers thick. The cells of the basal layer appear cuboidal, and the nuclei are relatively large, round, or slightly oval. The superficial cells are flattened and appear more or less fusiform in section. The epithelium has a thickness of 15·1+ micra. The sclera passes quite gradually, although somewhat abruptly, into the surrounding orbital connective tissue. Its fibrils become farther apart, finally less parallel, with shorter and more irregular meshes.

The distance between the internal surface of the cornea and the anterior surface of the lens is about 33·9+ micra. This space is filled at the periphery with mesoblast, which disappears in the tissue of the sclera opposite the lenticular zone of the ophthalmic cup. Except for a very attenuated layer extending over the lens, and that constituting the corneal endothelium, which is 3·9+ micra thick, the mesoblast is absent centrally, leaving a space, the cavity of the aqueous humor.

The basal cells of the corneal epithelium rest upon a rather deeply stained and fine line, that marks the anterior limit of the substantia propria corneæ, but such a line is not evident at the posterior limit.

Chorioid.—The chorioid, which is not clearly differentiated from the sclera, can only be recognised by the few capillary vessels lying immediately adjacent to the pigment layer of the ophthalmic cup. These capillaries are less evident in the fundus, and are most distinct in the region of the ciliary body.

Posterior Chamber.—The internal layer of the ophthalmic cup is not in contact with the external or pigment layer, and the diameter of the vitreous chamber has not been measured. The greatest internal diameters of the eye are as follows:—the vertical diameter between the internal surfaces of the chorioid-sclera is 1·8 mm; the antero-posterior diameter, measured as nearly as possible in the optic axis, is approximately 2·0 mm. The measurement was made between the internal surface of the chorioid-sclera posteriorly and the internal surface of the corneal endothelium anteriorly.

Muscles.—The voluntary muscles are well developed, and those that are in longitudinal section show distinct striations. Much of the muscular tissue is stained either very slightly or very heavily, hence the striations could not be studied in all.

Arm.—The diameters of the cartilaginous shaft of the humerus in the middle third are 650·0 × 645·0 micra, while the transverse diameter through the epicondyles is 1·4+ mm.

Forearm.—The cartilaginous radius has a length of 3·8+ mm. The diameter of the head is 0·5 mm.

Thoracic Aorta.—The thoracic aorta is of uniform size and quite cylindrical in section. It is in close relation with the ventral surface of the cartilaginous centra of the thoracic vertebræ, being on an average about 211·2+ micra ventral to the same. The total diameter is 406·2+ micra. The lumen measures 211·2+ micra, and the walls have a thickness of 86·5+ micra.

Contents of the Carotid Sheath.—The common carotid has a diameter of 178·7+ micra, with a lumen of 76·5+ micra, and a wall of about 96·5+

micra thick. The internal jugular vein, which varies in size, measures 422·5 × 739·3 + micra, and is distended with blood. The vagus nerve, although epiblastic, may be mentioned as having a diameter of about 133·2 × 233·1 micra.

Heart.—In one of the transverse sections the heart is cut longitudinally and through the atrio-ventricular orifices. At the apex a broad and well-marked sulcus longitudinalis is present. One cusp of the tricuspid valve has a thickness of 45·4 + micra, but the others are thicker and evidently have been sectioned obliquely. The left ventricular wall has the following thickness in micra:—near the base, 227·5; at middle, 276·2 +; at apex, 178·7 +. Similarly for the right ventricular wall:—near the base, 260·0; at middle, 162·5; at the apex near the sulcus longitudinalis, 97·5. The septum at the middle has a thickness of 487·5 micra, being thinner near the base and apex. The above measurements do not include the trabeculæ carneæ.

Derivatives of the Mesoblast and Hypoblast.

Œsophagus.—Three tunics are recognisable in the œsophagus—an epithelial, a muscular, and an intervening connective-tissue layer. The peri-œsophageal connective-tissue tunic is slightly denser in the neck than in the mediastinum; in the latter region it is delicate, loose, and stains very lightly. The œsophagus is largest at its commencement, and gradually diminishes in diameter from above downward, to a point slightly above the bifurcation of the trachea (fig. 21, C to J), where it becomes smaller, more cylindrical, and nearly uniform in diameter and size, and continues so to the œsophageal opening in the diaphragm, the diameters being 422·5 × 455·0 micra. Just below the termination of the pharynx the œsophagus has a diameter of ¾ mm. (fig. 21, C). It is contiguous to the trachea throughout the entire length of the latter, except for a short distance opposite the lower end of the larynx and the beginning of the trachea (fig. 21, C and D). The interval of separation is about 166·5 micra wide. Fig. 21, A and B, two sections through the lower extremity of the pharynx.

The epithelium has a mean thickness of 37·3 micra. The cells of the basal layer have become distinctly columnar and are clear and unstained at their bases. The other layers of the mucosa have not differentiated from the subepithelial mesenchyma, which forms a well-marked tunic varying in thickness as a result of longitudinal folds which extend through the whole length of the œsophagus, below a point just above the bifurcation of the trachea (fig. 21, J to X). Above this point the lumen is more open (fig. 21, C to I) and the form of the œsophagus is transversely oval for a short distance, as a result of sagittal flattening (fig. 21, H and I).

Rugæ are present above a point opposite the bifurcation of the trachea. Since they are more irregular in development the lumen is more irregular in outline. The subepithelial mesenchyma, which has a mean thickness of about 81·0+ micra, is thinnest between rugæ. Opposite them the thick-

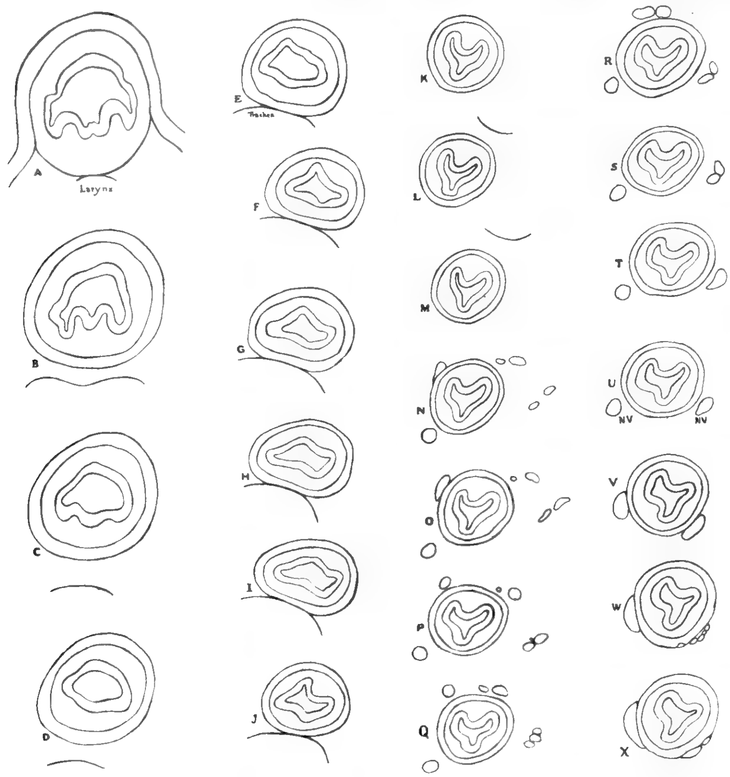


Fig. 21.—Outlines of transverse sections of the œsophagus and pharynx, at different levels, serially arranged. × 70. (Zeiss oc. 3 ; B. & L., obj. 1 in.) Reduced to ⅓.

A, through the termination of the pharynx ; B, through the transitional point ; C and D, œsophagus slightly separated from the larynx ; E to J, œsophagus contiguous to the trachea ; K, immediately below the bifurcation of the trachea ; K to M, œsophagus in relation to the aorta, beyond which point the latter is too distant to be shown in the figures ; N to X, œsophagus in relation with the nervi vagi (above N the latter is too distant to be shown) ; X, a short distance above the hiatus œsophageus.

ness is much greater, being 66·6+ and 141·7+ micra. The tunica muscularis has an average thickness of about 37·8+ micra, but is a little thicker opposite the larynx.

The lumen varies in shape in different parts of the œsophagus, and the epithelial walls are in contact nowhere. It is larger and more broadly open in the first part, where it is irregular and not affected by distinct rugæ. In the lower part of the pharynx and the beginning of the œsophagus where it is connected to the larynx by condensed mesenchymal tissue, two distinct and well-marked parallel prominences, which project into the lumen, are present in the ventral wall (fig. 21, A and B). At the beginning of the œsophagus the lumen has a transverse diameter of about 357·5 micra (fig. 21, C); and as the œsophagus becomes more distinctly cylindrical in the region of the tracheal bifurcation, the three longitudinal rugæ become distinct. The largest is the dorsal and more or less slightly sinistral in position. The other two, which are ventro-lateral in position, are subequal, and scarcely one-half as prominent as the dorsal ruga. Consequently the lumen is tri-radiate in form as seen in transverse section; narrowest below the tracheal bifurcation, and becomes slightly larger as the diaphragm is approached.

The relation of the œsophagus to the trachea and aorta already indicates the adult condition. In determining their relative positions, a line was drawn on the camera lucida outlines of the sections, to represent the median sagittal plane passing through the anterior median fissure and the posterior median septum of the spinal cord, and the chorda dorsalis. In some sections, especially those of the upper thorax, this line cut the sternal cartilage at the middle, but lower down where some asymmetry exists it passed sinistrad to the sternum. The right side of the thorax appears slightly more prominent than the left. At the termination of the pharynx the œsophagus is directly dorsal to the larynx; lower it becomes gradually and slightly more sinistral, while still lower it appears to be in the median plane, with the trachea distinctly more dextral down to its point of division. At its beginning the thoracic aorta is sinistral to the median plane, and the œsophagus median on a plane ventral to it. That is, a frontal plane passing between the two would touch the ventral wall of the aorta and the dorsal wall of the œsophagus, which are about 0·06 mm. distant from each other. At a lower level the aorta becomes slightly more medial; the œsophagus more ventral, or rather ventro-dextral and distant. As the diaphragm is approached both are sinistral in position as regards the median plane, the œsophagus being distinctly ventral to the aorta. A short distance above the œsophageal opening in the diaphragm the œsophagus is 0·5 mm. distant from the aorta. At its commencement it lies about 341·2+ micra ventral to the vertebral column; below the tracheal bifurcation it is about 520·0 micra distant, and but a short distance above the diaphragmatic opening it is 1·1+ mm. ventral to the same.

Trachea.—Immediately caudal to the larynx the trachea is oval in section and the sagittal diameter is greater than the transverse. The oval shape may in part be due to an obliquity of sectioning, although a short distance farther caudad it becomes cylindrical. A short distance cephalad to the bifurcation it is slightly transversely oval. Cartilaginous rings are present. It has a uniform shape between the points above mentioned. In its cylindrical portion the diameters are 633·7 + × 601·2 + micra; with a lumen of 438·7 + × 373·7 + micra, and an epithelium 22·7 + micra thick. In the transversely oval portion, just above the bifurcation the transverse diameter is 650·0 micra, and the sagittal diameter is 438·7 + micra.

Bronchi.—In sections 12 and 13, Series IX. A, the right bronchus is transversely and the left bronchus longitudinally cut. In the right bronchus, cartilages are present. The diameters are 487·5 × 325·0 micra, and that of the lumen about 268·1 + × 228·5 micra. The thickest part of the wall with the cartilage is 156·5 + micra.

In the left bronchus the cartilages disappear before the hilum of the lung. The sagittal diameter is 292·5 micra, and the thickest part of the wall with cartilage is about 111·5 + micra.

Thyroid Gland.—The greatest diameters of a lateral lobe are 568·7 + × 487·5 micra. The largest parathyroid, which is quite cylindrical in section, measures 186·4 + × 133·2 micra in diameter.

Thymus.—Both lobes taken together have a transverse diameter of 1·0 + mm., and a sagittal one of 487·5 micra. They gradually taper as they ascend into the neck to a short distance above the cartilaginous manubrium, where the apices appear equal and cylindrical in section.

List of Measurements.

Vertex to breech	30 mm.
Hip to knee	3·0 „
Knee to heel	6·0 „
Estimated standing height	39·0 „

Head.—Median sagittal section of head—

(*a*) Diameter on a plane cutting a point between the occipital cartilage and atlas, through the anterior nasal spine	10·0 mm.
(*b*) Greatest sagittal diameter	12·5 „
(*c*) Height of the head. Obtained by drawing a line at right angles to that from which (*a*) was made.	11·0 „
(*d*) Height as measured from the occipital cartilage at the anterior margin of the foramen magnum to the vertex	12·5 „

Thorax—	
Transverse diameter through the shoulders just cephalad to the margin of the cartilaginous manubrium and close to the articulationes humeri	10·0 mm.
Sagittal diameter in the same plane	6·5 "
Transverse diameter on a plane through the base of the heart	9·5 "
Sagittal diameter in the same plane	8·0 "
Transverse diameter on a plane through the mammary anlagen	9·5 "
Sagittal diameter in the same plane	7·5 "
Forearm and hand—	
Length from a point over the cartilaginous olecranon to the tips of the fingers	7·0 "
Mammary anlagen—	
Maximum transverse diameter of the right anlage	166·5 micra
Depth to which they penetrate the mesoblast, from the surface	216·4+ "
Thickness of epidermis over the anlage	24·2+ "
Lacrimal apparatus—	
The lacrimal cords, which are largest where they are in juxtaposition to the conjunctival epithelium, measure	68·1+ "
From that point each gradually diminishes to	45·4+ "
opposite the medial border of the lacus lacrimalis, to again increase in size as their junction with the nasolacrimal cord is approached, the diameter of the superior cord being	48·4+ "
And that of the inferior cord	53·0+ "
The average diameter of the nasolacrimal cord is about	61·0+ "
That portion which corresponds to the position of the lacrimal sac, has a diameter of	60·6+ "
It increases to	75·7+ "
And decreases to	42·4+ "
as the cord enters the nasolacrimal canal, and increases again to about	54·5+ "
as the nasal epithelium is approached.	
The greatest distance between the superior and inferior fornices of the conjunctival sac is	1·6+ mm.

The rudimentary semilunar fold projects into the sac to the distance of approximately . . . . . 52·0 micra

The longest developing duct of the lacrimal gland has penetrated the surrounding mesenchyma to the distance of . . . . 482·8+ „
from the surface of the conjunctival epithelium.

Cord B (fig. 14) has a diameter of . . . . . 48·4+ „

Crystalline lens—

The lens has an antero-posterior diameter of . . . 731·2+ „
and a vertical one of . . . . 877·5+ „

At the anterior pole of the lens the epithelium is about 18·1+ „
in thickness, being approximately one-fortieth of the total antero-posterior diameter.

Ophthalmic cup—

The retinal layer at the periphery of the lens has a diameter of about . . . . . 49·9+ micra
and the external or pigment layer is about . 23·3+ „ thick

The optical part of the retinal layer at the fundus is about . . . . 116·5+ „ „
and the pigment layer . . . . . . 12·1+ „

The length of the ciliary and iridal portions as measured in a straight line from the ora serrata to the anterior margin of the cup is about . . . . 406·2+ „

Optic nerve—

The vertical diameter of the nerve is . . . . . 375·5 micra

Cerebral hemisphere—

The greatest length, as measured from the frontal to the occipital pole, is . . . . 9·0 mm.

Superiorly and at the frontal pole the thickness of the wall varies from . . . . . . 260·0 to 178·7+ micra
but at the occipital pole it varies from 138·1+ to 105·6+ „

Rhinencephalic evagination—

Measured from a line cutting the base at its junction with the hemisphere at the surface has a length of 1267·5 „

The total length of its cavity as measured from a point on a line with the inner surface of the wall of the hemisphere is . . . . 1 0+ mm.

The walls and cavity have the following dimensions in micra :—

	Anterior wall.	Cavity.	Posterior wall.
At base . . .	162·5	81·2+	373·7+
At middle . .	243·7+	130·0	292 5
At apex . .	357·5	130·0	146·2+

Spinal cord.—Measurement of cross sections in micra :—

Plane of section.	Object cut.	Sagittal.	Transverse.
At level of foramen magnum .	Cord	1·8+ mm.	
Fig. 17.—Lower cervical region just caudad to the larynx:	Cord	1446·2+	1251·2+
	Central canal	503·7+	211·2+
	Vertebral canal	1787·5	1527·5
Fig. 18.—Just cephalad to the manubrium sterni	Cord	1300·0	1202·5
	Central canal	471·2+	195·0
	Vertebral canal	1706·2+	1576·2+
Fig. 19.—Through the atrio-ventricular orifices	Cord	1015·6+	1121·2+
	Central canal	406·2	195·0
	Vertebral canal	1348·7	1592·5
Fig. 20.—Through caudal extremity of the sternum	Cord	991·2	1137·5
	Central canal	406·2+	219·3+
	Vertebral canal	1332·5	1462·5

Parotid gland—

At the point where it leaves the buccal epithelium the parotid duct has a diameter of	69·6+	micra,	
with a lumen of	23·1+	„	
Just before the primary divisions it has a diameter of	45·5+	„	
Ramus 1 (fig. 14) has a diameter of about .	45·4+	„	
with a lumen.	9·0	„	
Ramus 2 has a diameter of	45·4+	„	
Ramus 3 „ „	48·4+	„	at the base
Bud *a* has a diameter of about .	62·1+×81·8+	„	
at the middle, and	34·8+	„	„
Bud *b* has a very narrow base. Bud *c* which is large has a diameter of about .	68·1+	„	„
and a greatest diameter of	106·0+	„	

Submaxillary duct—

The duct at some distance from the frenulum linguæ has a diameter of	56·8+	micra	
with a lumen of	23·3+	„	
The walls are about	16·6+	„	thick

Ocular bulb—

The chorioid-sclera has a thickness of . . . . . posteriorly at a point where it is sharply defined through contact with a rectus muscle.	83·2+ micra

Cornea—

The thickness of the substantia propria corneæ is .	63·6+ „
at the periphery, and	31·8+ „
at the middle.	
The corneal epithelium has a thickness of	15·1+ „
The corneal endothelium	3·9+ „
and the distance between the internal surface of the cornea and the interior surface of the lens is about	33·9+ „

Posterior chamber—

The greatest vertical diameter between the internal surfaces of the chorioid-sclera is	1·8+ mm.
The antero-posterior diameter, measured as nearly as possible in the optic axis, is approximately . .	2·0 „
It is made between the internal surface of the corneal endothelium anteriorly and the internal surface of the chorioid-sclera posteriorly.	

Arm—

The diameters of the cartilaginous shaft of the humerus in the middle third are	650·0 × 645 micra
And the transverse diameter through the epicondyles is	1·4+ mm.

Forearm—

The cartilaginous radius has a length of	3·8+ mm.
The diameter of the radial head is	0·5 „

Thoracic aorta—

The average distance ventral to the cartilaginous centra of the thoracic vertebræ is	211·2+ micra
The total diameter is about	406·2+ „
The lumen measures	211·2+ „
And the walls have a thickness of	86·5+ „

Contents of the carotid sheath—

The common carotid artery has a diameter of . .	178·7+ „
with a lumen	76·5+ „
and walls with a uniform thickness of about .	96·5+ „

The internal jugular vein, which varies in size and is distended with blood, measures	422·5 × 739·3 + micra
The vagus nerve is about	133·2 × 233·1 ,,

Heart—

A cusp of the tricuspid valve has a thickness of	45·4 +	,,
The ventricular walls have the following thickness in micra:		
Left wall near base	227·5	
at middle	276·2 +	
at apex	178·7 +	
Right wall near base	260·0	
at middle	162·5	
at apex near the sulcus longitudinalis	97·5	
The interventricular septum at the middle has a thickness of	487·5	micra

but is thinner near the base and apex. The above measurements do not include the trabeculæ carneæ.

Œsophagus—

A nearly uniform size is maintained between a point opposite the bifurcation of the trachea and a short distance above its passage through the diaphragm.

The diameters at this point are	422·5 × 455·0	,,
and just below the termination of the pharynx it measures	$\frac{3}{4}$	mm.
The maximum distance of separation from the trachea, at a point opposite the lower end of the larynx, is	166·5	micra
The tunica presents the following variations in thickness:—		
Epithelium, maximum thickness	43·9	,,
minimum thickness	30·3	,,
mean thickness	37·3	,,
The muscularis has an average thickness of about	37·8 +	,,
The sub-epithelial mesenchyma has a minimum thickness between the rugæ of	34·8 +	,,
A maximum thickness at the largest ruga of	141·7 +	,,
at the smallest	66·6 +	,,
with a mean thickness of	81·0 +	,,
The transverse diameter of the lumen of the œsophagus at the beginning is	357·5	,,
and below the bifurcation of the trachea about	199·8	,,

The distance of separation from the thoracic aorta at the beginning of the descending portion is . . . 95·4+ micra
and a short distance above the œsophageal opening in the diaphragm it is . . . . 0·5 mm.

The distance of the œsophagus from the vertebral column at the beginning is . . . . . . 341·2+ micra
below the tracheal bifurcation, about . . . . 520·0 „
and a short distance above the opening in the diaphragm it is . . . . 1·1+ mm.

Trachea—

In its cylindrical portion the diameters of the trachea are . . . . 633·7+ × 601·2+ micra
and the lumen measures . . . . 438·7+ × 373·7+ „
The thickness of the epithelium is . . . . . 22·7+ „
Above its bifurcation the diameters are as follows:—
Sagittal . . . . 438·7+ „
Transverse . . . . 650·0 „

Bronchi—

The right bronchus measures . . . . . 487·5 × 325·0 „
the lumen . . . . 268·1+ × 228·5 „
and the wall with cartilage about . . . 156·5+ „
The sagittal diameter of the left bronchus is . . . 292·5 „
and the wall including the cartilage is about 111·5+ micra thick

Thyroid gland—

The greatest diameters of a lateral lobe are . 568·7+ × 487·5 micra
And the largest parathyroid measures . . 186·4+ × 133·2 „

Thymus—

The transverse diameter through both lobes is . . . 1·0+ mm.
and the sagittal diameter of a lobe is . . . . 487·5 micra

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A CONGENITAL ABNORMALITY OF THE HEART AND BLOOD-VESSELS.

By W. E. Carnegie Dickson, M.D., B.Sc., F.R.C.P.E., *Pathologist, Royal Hospital for Sick Children, Edinburgh*; and John Fraser, M.D., M.Ch., F.R.C.S.E., *Assistant Surgeon, Royal Hospital for Sick Children, Edinburgh.*

An interesting specimen of congenital errors in the development of the heart and blood-vessels has come under our observation; the uniqueness of the condition seems to warrant its publication.

Clinical History.

The specimen was obtained from a male child four months old. The baby was admitted to hospital on account of persistent vomiting, which in certain respects resembled the vomiting of congenital stenosis of the pylorus. Examination, more especially by means of bismuth meals and X-rays, showed that, while there was no stenosis of the pylorus, there was a dilatation of the first portion of the duodenum. The child failed to respond to medicinal treatment, and a posterior gastro-enterostomy was performed. Some hours after operation the child collapsed and died.

In view of the cardio-vascular abnormalities which were discovered post-mortem, it is interesting to note the observations which were made upon the heart during life. The organ was found to be distinctly enlarged, the apex beat was in the sixth interspace and a finger-breadth outside the nipple line. The right border of the heart was $1\frac{1}{4}$ inches from the middle line, and the left border extended a full inch beyond the nipple line. Auscultation revealed a systolic bruit, heard most clearly in the pulmonary area; there was also some accentuation of the second sound.

Description of Specimens.

Examination of the heart showed:—

(1) The right auricle and left auricle were healthy.

(2) The ventricular portion of the heart was uniformly enlarged and hypertrophic.

(3) There was an incomplete interventricular septem.

(4) From the base of the ventricles a single large vessel was given

off (the aorta): its origin was guarded by three complete semilunar valves, and into it both ventricular cavities opened.

(5) The right pulmonary artery originated from the aorta half an inch from the commencement of the latter: the pulmonary vessel passed directly to the right lung.

(6) The left and the right common carotids originated directly from the aorta.

(7) The right and left subclavian vessels passed directly from the

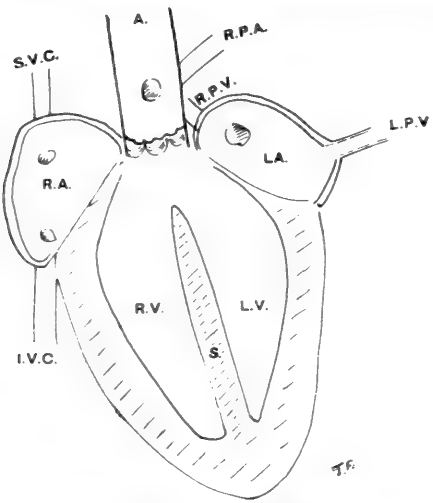

FIG. 1.—Section of heart (diagrammatic).

A., aorta; S.V.C., superior vena cava; I.V.C., inferior vena cava; R.A., right auricle; L.A., left auricle; R.V., right ventricle; L.V., left ventricle; S., interventricular septum; R.P.A., right pulmonary artery; R.P.V., right pulmonary vein; L.P.V., left pulmonary vein.

aorta, springing from just beyond the arch and passing outwards to the upper extremities behind the apices of the lungs.

(8) The left pulmonary artery originated from the descending aorta and passed outwards to the lung behind the œsophagus.

Speaking embryologically, it would appear that the development became disturbed during the third week. The points in abnormal anatomy are in keeping with—

A.—A persistence of the right and a disappearance of a considerable portion of the left aortic arch.

B.—A representation of a portion of the left aortic arch by the left subclavian artery.

C.—A non-division of the primary aortic stem.

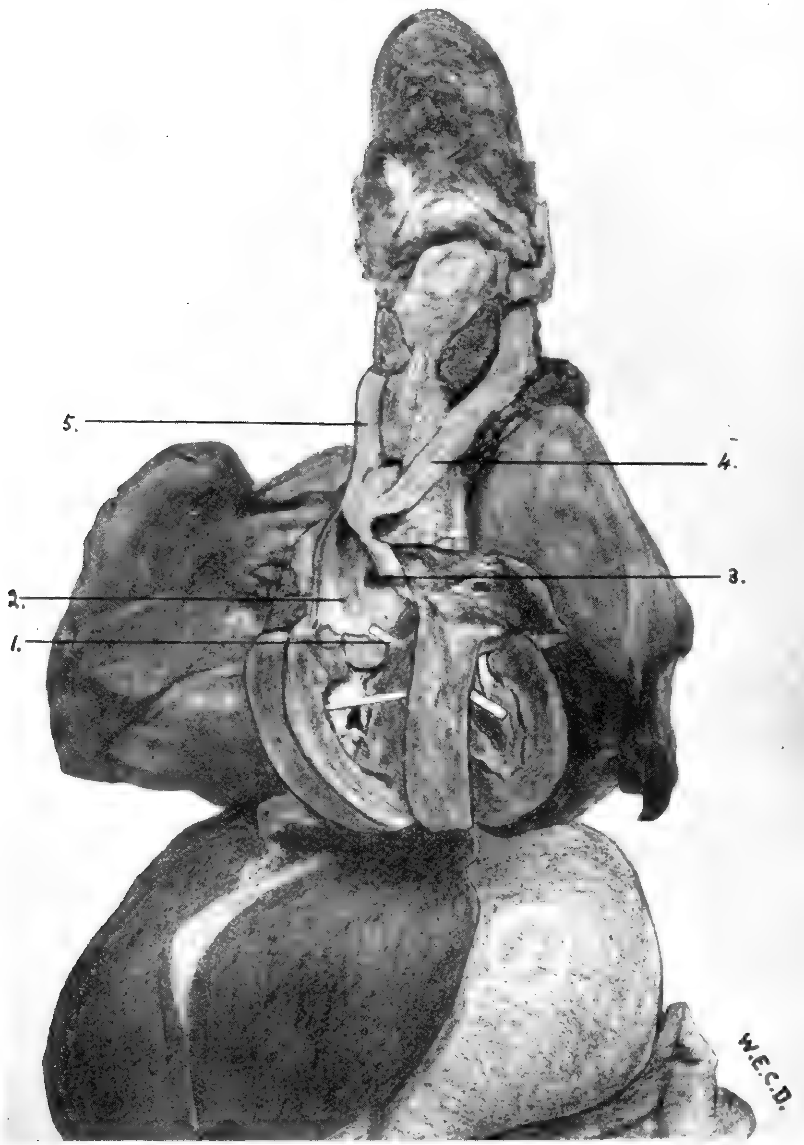

FIG. 2.—Heart and blood-vessels, anterior view.

1, upper end of the incomplete interventricular septum ; 2, the aorta ; 3, the origin of the right pulmonary artery ; 4, the left common carotid artery ; 5, the right common carotid artery.

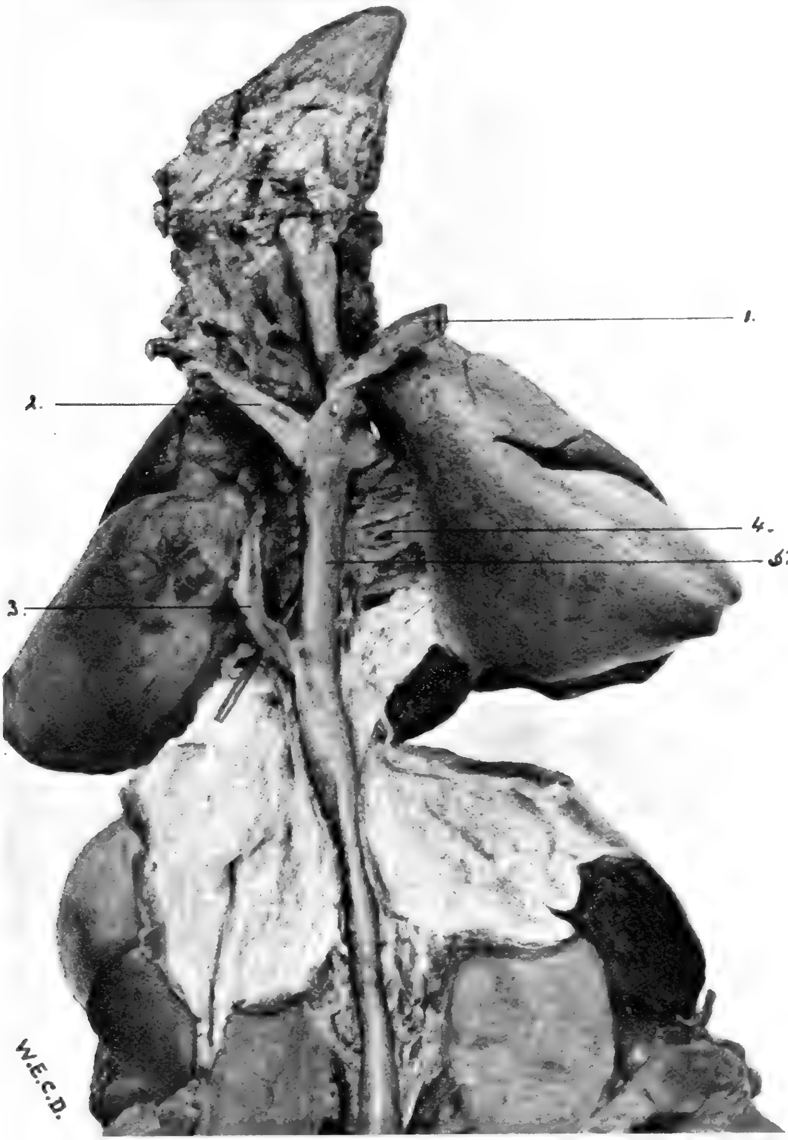

FIG. 3.—Thoracic aorta, posterior view.

1, the right subclavian artery; 2, the left subclavian artery; 3, the left pulmonary artery: 4, the pulmonary veins; 5, the thoracic aorta.

D.—A non-development of the infundibular or bulbous portion of the right ventricle, with which probably the non-development of the pulmonary stem is associated.

It is difficult to offer any explanation of the origin of the left pulmonary artery.

We are indebted to Dr John Thomson, physician to the Children's Hospital, for permission to examine the specimen and to record the facts regarding it.

Dr Thomson brought the specimen to the notice of Professor Keith, Curator of the Royal College of Surgeons' Museum, London. Professor Keith threw much valuable light upon the developmental explanation of the abnormality, and to him we are also indebted.

THE COURSE OF THE PHRENIC NERVE IN THE EMBRYO.

By M. Amin, *Assistant Professor of Anatomy, School of Medicine, Cairo.*

The phrenic nerve is a valuable structure in the embryo, for several reasons. Its fibres reach their termination—and hence the whole course of the nerve can be traced—at an earlier date than do the fibres of any other spinal nerve; and from the relation which the nerve presents to the pleura and pericardium, as well as to the diaphragm, it is of great service in tracing the development of these different portions of the cœlom, as well as the early stages of the development of the diaphragm.

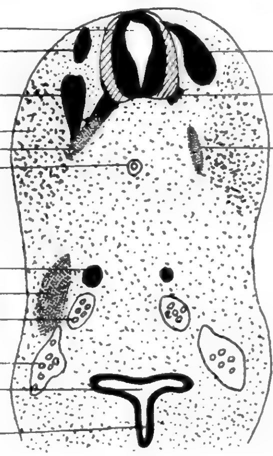

Fig. 1.

The nerve cannot apparently be traced in embryos of less than 5 mm. maximum length, and in the following account a description is given, with figures, of the origin, course, and termination of the nerve as it was found in a 6-mm. embryo.

Description of the Right Phrenic Nerve.

Beginning with a transverse section at the level of the fourth cervical ganglion (fig. 1), the nerve was found arising from the anterior roots of the fourth cervical nerve as the latter takes origin from the spinal cord.

Placed lateral to each nerve (on the right and left sides of the embryo) is the remains of a somite.

As the nerve is traced downwards, it passes ventrally, and comes to lie behind the anterior cardinal vein; and at a still lower level it establishes a communication with the fifth cervical nerve, and comes to lie in a cup-shaped invagination at the junction of the anterior cardinal vein with the primitive subclavian vein from the limb bud (fig. 2).

The relationship at this level is that the nerve is mesial to the subclavian vein, for that vessel lies more in a dorso-ventral axis than in the

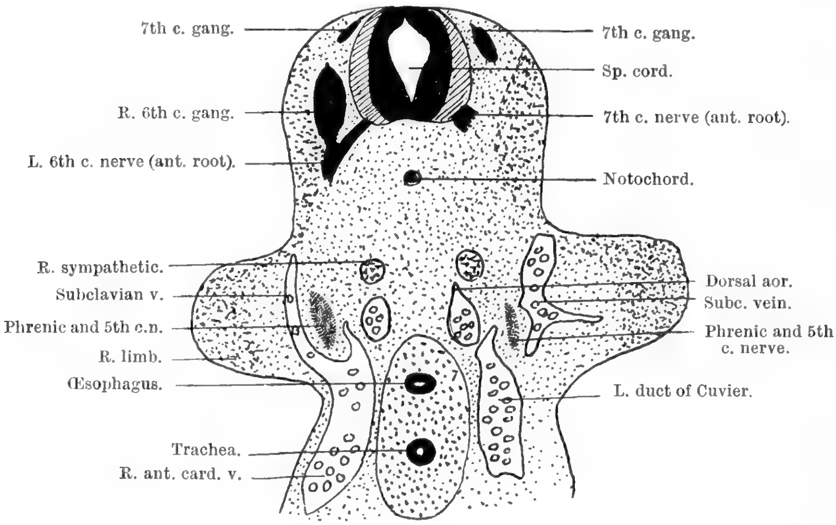

Fig. 2.

coronal plane. In sections beyond this level, the nerve retains a similar position, and then comes to lie lateral to the duct of Cuvier (fig. 3).

Further on, the nerve comes into relation with the early divisions of the cœlomic cavity, and lies between the antero-lateral recess laterally and the pleuro-pericardial passage medially (fig. 4).

The position of the nerve at this level is important, as the nerve is now coming to lie in the upper part of the arch connecting the anterior and posterior pulmonary ridges; but at this stage the nerve lies lateral to the lung bud, and posterior to the pericardial sac.

From the figure, evidence is afforded of the very extensive changes which occur at a later stage in connexion with the development of the lungs. In order to attain the adult relationships, the lung buds must at a later stage grow laterally, behind the phrenic nerve, and finally send their

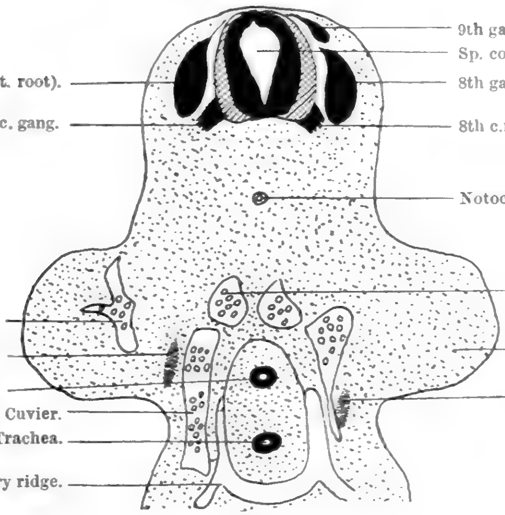
9th gang.
Sp. cord.
7th c. nerve (ant. root).
8th gang.
7th c. gang.
8th c.n. (ant. root).
Notochord.
R. dorsal aor.
Subcl. vein.
Phrenic.
L. upper limb.
Œsophagus.
Phrenic.
R. duct of Cuvier.
Trachea.
Ant. pulmonary ridge.

FIG. 3.

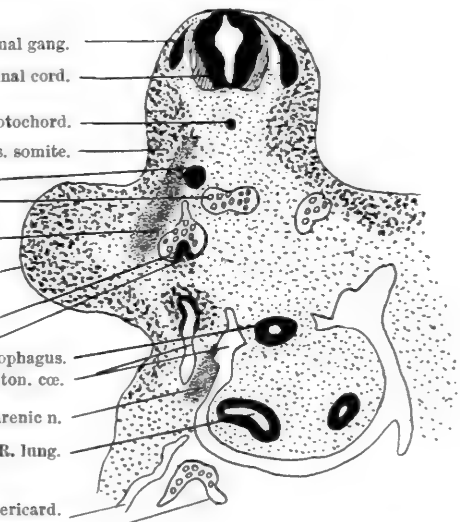
8th spinal gang.
Spinal cord.
Notochord.
Mes. somite.
Sympathetic.
Dorsal aor.
Brach. plex.
7th and 8th ant. c.n.
Fore limb.
Post. card. v.
Pronephros.
Œsophagus.
Periton. cœ.
Phrenic n.
R. lung.
Pericard.
R. horn of s.v.
Auricle.

FIG. 4.

anterior parts forwards, with the investing pleura, and so entirely alter the relationship present at this stage of embryonic life.

In sections below this level the nerve is found to terminate among the cells of the ventral aspect of the septum transversum, with the pericardium anterior and mesial and the anterior pulmonary ridge posterior to it (fig. 5).

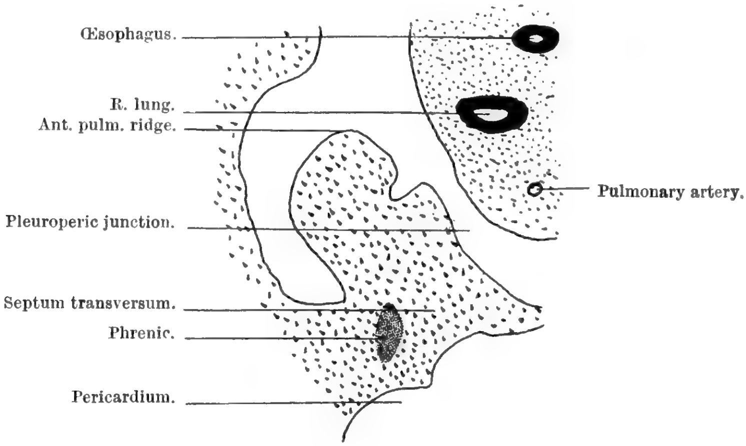

Fig. 5.

The figures illustrating the course of the nerve are obtained from projection drawings of sections at the various levels.

Lastly, I have to express my great thanks to Professor David Waterston of King's College, who kindly helped me much in working out this nerve, which I did in his laboratory at the King's College, London.

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NOTE ON TWO CASES OF WELL-MARKED SUPRASTERNAL BONES. By A. Francis Dixon, *Trinity College, Dublin.*

During the last few years I have examined a large number of subjects for the presence of suprasternal bones, and as detailed illustrations of them have, as far as I am aware, not been published, it seems worth while to reproduce X-ray pictures of two cases in which they were well developed.

These pictures were kindly made for me by my friend Dr W. G. Harvey, University Demonstrator in Röntgen Photography in Trinity College. They illustrate very beautifully the form, position, structure, and relationships of the ossicles.

Fig. A represents the condition found in a young adult man. The suprasternal bones are conical in form, well developed, and almost symmetrically disposed. The wide base of each articulates by a diarthrodial joint with a special facet on the superior border of the manubrium sterni close to the medial edge of the clavicular notch. At their bases the ossicles almost meet in the median plane, but superiorly their apices are separated by a distinct V-shaped interval. The capsular ligaments which unite the ossicles to the manubrium sterni are loose enough to permit considerable movement at the articulations.

Fig. B is taken from an adult woman. The suprasternal bones are somewhat pea-shaped, and are placed close against the median plane. As in the first specimen, they are connected with the superior border of the manubrium sterni by diarthrodial joints; and further, a diarthrodial joint is present in the median plane where the right and left ossicles are in contact with one another. In both cases it will be noticed that the architecture of the suprasternal bones resembles that of the sternum.

Each suprasternal ossicle is tied down to the sternum by a well-defined fibrous capsule which is specially thickened on its anterior aspect to form a rounded cord-like ligament. The anterior surfaces of the ossicles are connected by a fibrous band, the upper margin of which is continuous with

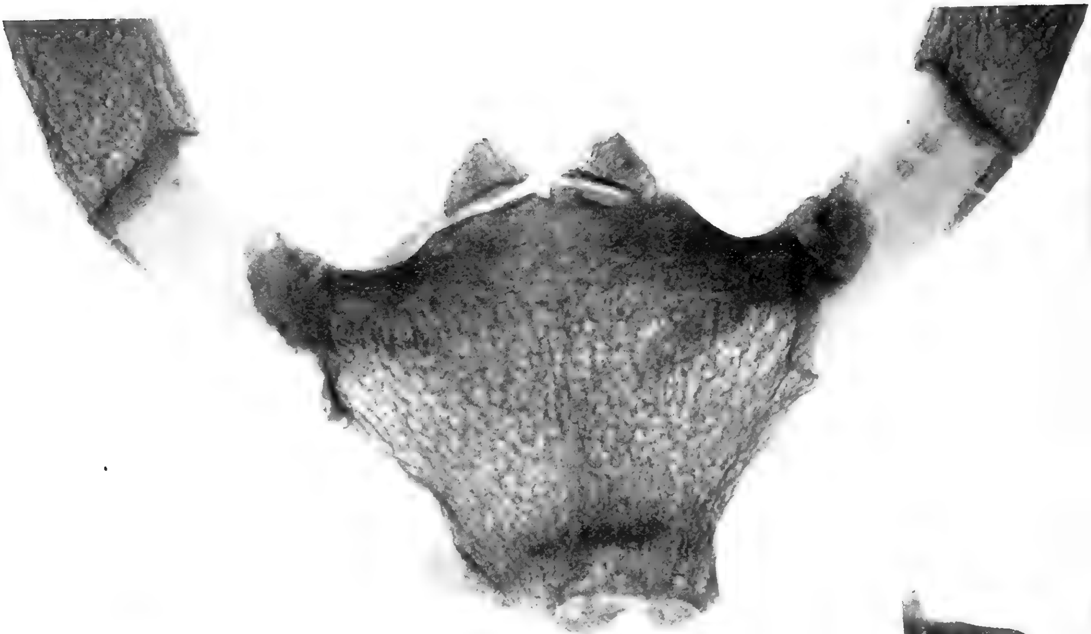

Fig. A.

Fig. B.

the interclavicular ligament. Laterally each is connected to the clavicle by a fibrous cord the lower and lateral edge of which is continuous with the sterno-clavicular ligament.[1]

It should be mentioned that the suprasternal bones are not directly connected with the fibro-cartilaginous articular disc, and that the joints which they form with the sternum are distinct, and isolated from the sterno-clavicular articulations.

In each case the X-ray pictures show that the suprasternal bones are

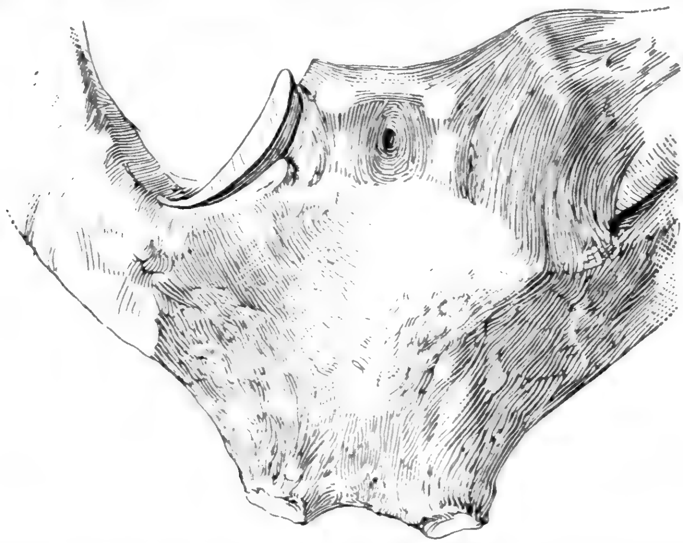

Fig. C.—Suprasternal bones and the ligaments connected with them. From an adult female subject; same specimen as fig. B. Drawn by Mr J. T. Murray.

much larger than a dissection of them and of their ligaments would lead us to believe. The greater part of the surface of each ossicle is covered by the strong cord-like ligaments which pass to the manubrium sterni, the clavicle, and to the ossicle of the opposite side. (Compare figs. B and C.)

Note.—The X-ray figures were exhibited at the Exhibition of the International Medical Congress in London, summer 1913.

[1] Somewhat similar ligaments have been figured by Thomas Carwardine, *Jour. of Anat. and Phys.*, vol. xxvii., 1893, p. 232.

THE DEVELOPMENT OF THE LOBUS QUADRATUS OF THE LIVER, WITH SPECIAL REFERENCE TO AN UNUSUAL ANOMALY OF THIS LOBE IN THE ADULT. By Professor PETER THOMPSON, *Birmingham*.

IN view of the interest associated with the modifications which the lobes and the fissures of the human liver have undergone during the process of evolution, any specimen which would appear to throw light on the problem deserves the closest examination. In the past much of our knowledge has been derived from a study of the anatomy of the organ in the fœtus, in man's nearest allies—the anthropoid apes, and in other more generalised forms. In recent years, too, much has been done to trace the phylogenetic and ontogenetic development of the lobes and fissures of the liver in human and other embryos, and in the well-known publications of A. Thomson (1), Mall (2), Ruge (3), Rex (4), Bradley (5), de Burlet (6), and others, not only has the development of the lobes and fissures received attention, but also the arrangement of the vascular system within the organ during its early stages of growth, and in the adult.

Apart from de Burlet's publication I have not, however, been able to find any special reference to the development of the lobus quadratus in the human liver, or to its influence on the fossæ on either side of it. It is to these points more particularly that I wish to direct attention, since it is generally held that the lobus quadratus is merely a quadrilateral area of the visceral surface of the liver, bounded by certain fossæ, and of no comparative morphological interest. It was the apparent absence of this lobe in a specimen obtained from the practical anatomy rooms in this University that suggested an investigation as to when and how it appeared in the normal human liver. As a matter of fact, a small tubercle was present in this liver, which, after comparison with the models of the liver from early embryos, was clearly the representative of the lobus quadratus. It will be convenient if this specimen be briefly described before proceeding with the account of the models which have been made to explain the anomaly.

The specimen was obtained from a male subject, aged 60 years, the cause of death being certified as bronchitis. On the visceral surface of the organ (fig. 1), the division into right and left lobes is indicated ventrally by a deep cleft occupied by the gall-bladder. The lobus Spigelii and the processus caudatus are well marked and distinct, and it is noteworthy that the former is larger than usual and has a form closely resembling that found in a 11·25 mm. embryo. Of the fissures four are clearly defined: (1) the right lateral, (2) the fissure limiting ventrally the processus pyramidalis, (3) the fissure partly limiting the processus caudatus, and (4) a deep depression—the fossa for the ductus venosus. On pulling the gall-bladder—the fundus and body of which were entirely surrounded by peritoneum and quite free—downwards and backwards from the fossa (fig. 2),

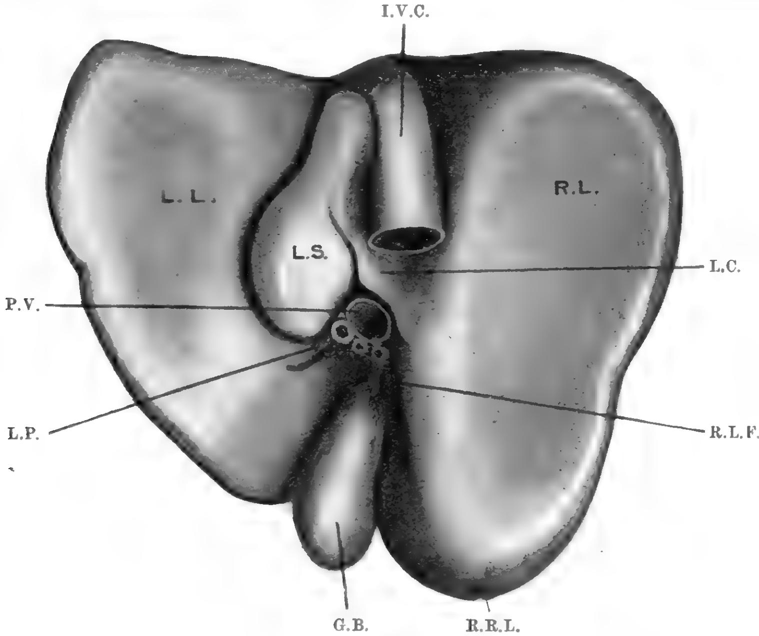

FIG. 1.—Visceral aspect of adult liver with rudimentary lobus quadratus.

three structures stand out clearly: the round ligament, a small rounded tubercle which, as already stated, represents the lobus quadratus, and a connecting ridge of tissue, partly hepatic and partly fibrous, joining the tubercle to the under surface of the left lobe. The significance of this connecting ridge will become evident after an examination of the model of the liver from a 11·25 mm. embryo. In fig. 3 a view of the liver from the front is shown, with the relations to one another of gall-bladder, ligamentum teres, rudimentary quadrate lobe, and an area designated the "uncovered area." This uncovered area is a portion of the right lobe, which would, one imagines, have been subjacent to the lobus quadratus, had the latter been of the normal size.

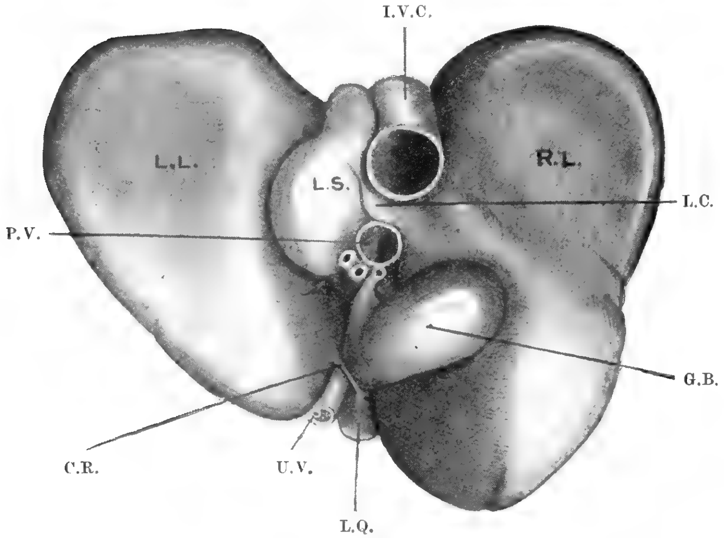

FIG. 2.—The same, with gall-bladder pulled away to show the ligamentum teres and rudimentary quadrate lobe.

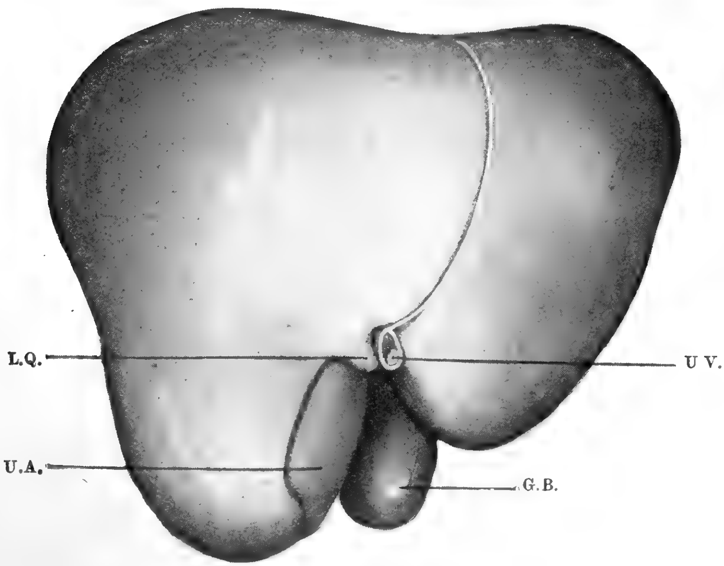

FIG. 3.—The same, seen from the front.

In the generalised mammalian liver we recognise six lobes (Flower) (7), R. central, L. central, R. lateral, L. lateral, L. Spigelii, and L. caudatus, the line of the ligamentum teres being taken in this case as the median plane. The right central lobe lies between the median plane and the right lateral fissure, and the gall-bladder is placed usually somewhere near the middle of the lobe on the visceral surface. It can therefore be said to be composed of two parts: (1) between the fossa for the gall-bladder and the right lateral fissure, and (2) between the fossa for the gall-bladder and the median plane. On referring to fig. 1 it will be seen that in the specimen just described the first part is present and appears quite normal, whilst the second part (fig. 2) is rudimentary and appears as the small rounded tubercle previously referred to.[1] If this interpretation be correct, then it would appear that one portion of the right central lobe, the median (L. quadratus), exhibits an interesting malformation, and it is one of the objects of this paper to show that it is, in fact, in a condition of arrested development. The condition, permanent in this specimen, is transitory in embryos in the fifth week. Moreover, it somewhat resembles the arrangement of parts in the adult pig, in which the quadrate lobule is a relatively small process, and the rest of the right lateral lobe is of large size.

Anomalies in the lobulation of the liver are by no means uncommon, and variations in the size and form of the lobus quadratus have been described by several observers. In Rolleston's (8) first case, in which the right lobe was small and the left lobe large, the lobus quadratus was three times the size of the remainder of the under surface of the right lobe. In a second specimen the gall-bladder was placed below the lobus quadratus instead of being on its right side, whilst in a third case described by him the lobus was rudimentary, being represented by a small strip of liver tissue only. In a case described by Barclay-Smith (9) the gall-bladder was abnormally placed and the lobus quadratus appeared in its usual position, whilst Hochstetter (10) has described and figured two cases of abnormally placed gall-bladder with absence of the lobus quadratus. Ruge's admirable papers (3) are well known, and in them will be found an enormous number of observations referring to abnormalities of the lobes and fissures of the human liver. In one of them he has dealt specially with the abnormal folds, fissures, and accessory lobules found in connexion with the lobus pre-portalis (L. quadratus), but there does not appear to be any case at all resembling the one described above.

It will be convenient to describe next the three wax models of the

[1] That the fossa (or fissure) separating these two parts in fig. 2 is the fossa vesicæ felleæ is shown by the attachment of the neck of the gall-bladder by a mesentery to its floor.

human liver figured in the text, of which the following details may be noted:—

Specimen I. Greatest length of embryo 7 mm. Sections 10 μ. Magnification of model 50 times.

„ II. Greatest length of embryo 11·25 mm. Sections 10 μ. Magnification of model 37·5 times.

„ III. Greatest length of embryo 16 mm. Sections 10 μ. Magnification of model 50 times.

In recent years several models have been made and illustrations published to show the form of the liver in the human embryo. Of these mention should be made particularly of the reconstructions by Bromann (11), Mall (2), and H. M. de Burlet (6). In his monograph on *The Bursa Omentalis*, published in 1904, Bromann shows figures of models of the liver of four human embryos measuring 3 mm., 5 mm., 8 mm., and 11·7 mm. respectively. Mall, in his paper on the *Structural Unit of the Liver* (1906), gives a detailed account of the early development of the liver, and shows illustrations of models of the organ from embryos 24 mm. long, 17½ mm. long, and a second one 24 mm. long. The growth of the quadrate lobe, however, is not specially traced in either of these publications, attention being directed to other matters. The material for de Burlet's paper on "Die äusseren Formverhältnisse der Leber beim menschlichen Embryo" (1910) comprises five specimens, of the following lengths respectively (1) 4·75 mm.; (2) 10 mm.; (3) 18 mm.; (4) 23 mm.; and (5) 32 mm. It will thus be seen that the models figured in the present paper fall into the intervals between the first three of the last-named series, and as the subsequent description will show, it is in embryos about 33 days old, *i.e.* 11·25 mm. long, that the interval on the visceral surface between the gall-bladder and the vena umbilicalis becomes occupied by a mass of liver cells, forming a small rounded tubercle, the forerunner of the lobus quadratus.

Specimen I.

Upon the ventral aspect (fig. 4) is an extensive area, where the liver and septum transversum are united, corresponding to the interval between the two layers of the ligamentum falciforme, which are continuous below round the vena umbilicalis. To the right is the mass of tissue (mesenchyme) in which lies the gall-bladder. This tissue is continuous on the one side with the omentum minus (fig. 5), and on the other with the ligamentum falciforme, the whole forming the so-called ventral mesentery.[1]

[1] In this connexion it is interesting to note that, as Professor A. Keith kindly pointed out to me, the gall-bladder in the cassowary (*Casuarius bennetti*) is situated in the omentum minus.

The right lobe is larger than the left, and the quadrate lobe is not present. From the upper border a large vein emerges, the ductus venosus Arantii,

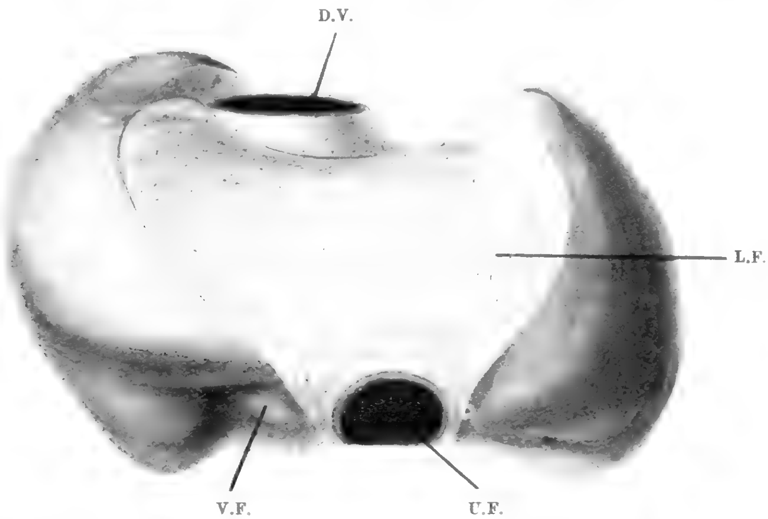

FIG. 4.—Specimen I., 7 mm. Model of liver seen from the ventral aspect. ×50.

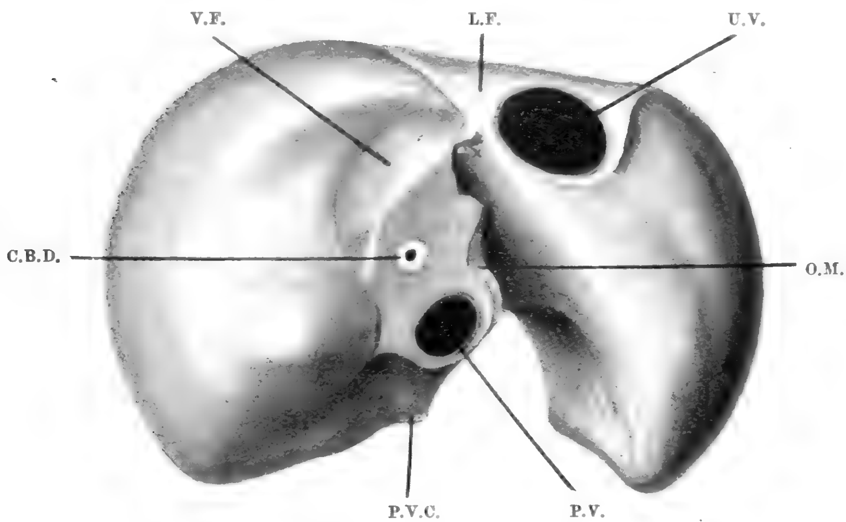

FIG. 5.—Same model as in fig. 4, seen from the caudal aspect. ×50.

which passes through the septum transversum to open into the right auricle. In fig. 5, which shows the model from the caudal aspect, some of these points are brought out more clearly, and between the gall-bladder and the vena umbilicalis (marked with X) is seen the point where the quadrate lobe begins to differentiate. Dorsally (fig. 6) is the attachment of the omentum minus, with an area corresponding to the future lobus Spigelii on its right, and on the right of this again the plica venæ cavæ (*Nebengekröse*). Between these two mesenteries the pouch of peritoneum which foreshadows the bursa omentalis is formed as a diverticulum. The part between the liver and the alimentary tube is the recessus hepato-entericus, and the blind cranial end, which is prolonged so as to lie between

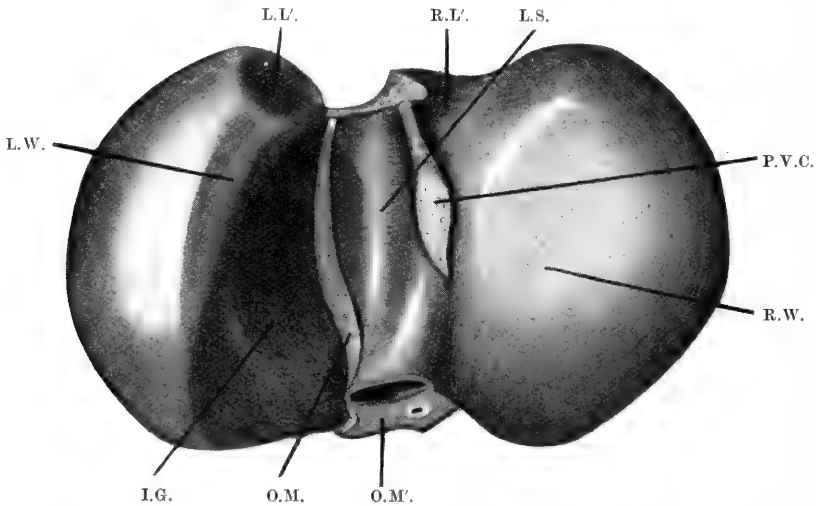

Fig. 6.—The same model as figs. 4 and 5, seen from the visceral surface. × 50.

the right lung bud and the alimentary tube, is the recessus pneumato-entericus. As the portion of the alimentary canal, with which this latter part of the recess is related, is the right side of the future œsophagus, it is sometimes termed the peri- or para-œsophageal cœlom. At the caudal end of the *Nebengekröse* is the foramen epiploicum. Here the general peritoneal cavity comes into communication with the recessus hepato-entericus by a long narrow passage across the back of the liver. The various areas of contact with neighbouring organs are sufficiently indicated in the figure.

Specimen II.

The main features to be observed in fig. 7, which shows the model from the ventral aspect, are (1) the appearance of a small tubercle between the gall-bladder and the vena umbilicalis, the beginning of the lobus quadratus; (2) the consequent pushing of the vena umbilicalis somewhat to the left; and (3) the prolongation of the caudal part of the right lobe into the abdominal cavity as an irregular process which comes into relation with the intestine. The irregular character of this extension is better seen in Specimen III. Mall (2) has drawn attention to a similar disposition in his models, and remarks "that in its growth the liver may atrophy in one portion and expand in another, the aberrant bile-ducts marking those portions of the liver which have been shifted. They are present in those

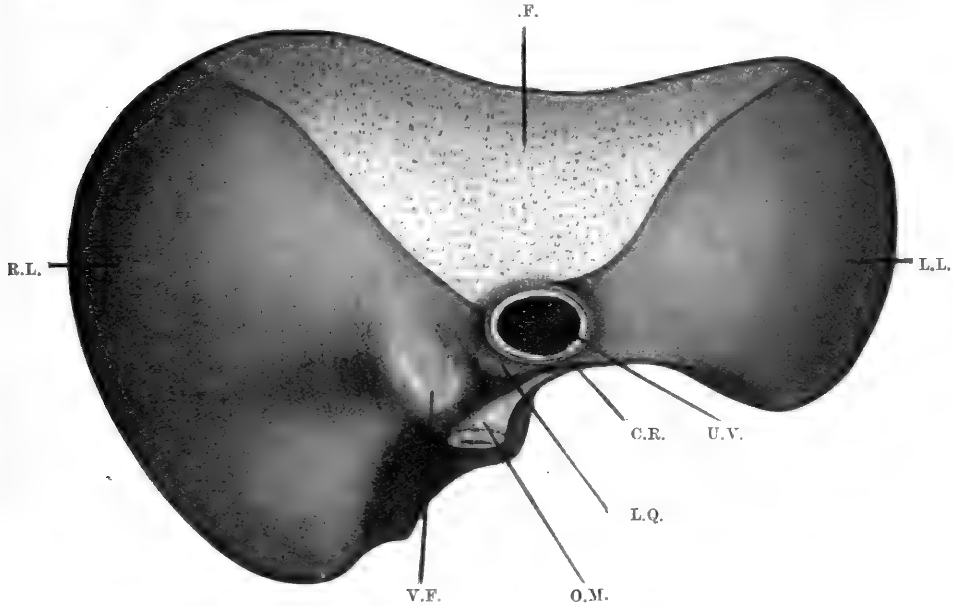

FIG. 7.—Specimen II., 11·25 mm. Model of liver, seen from the ventral aspect. × 37·5.

portions of the liver which had to make way for encroaching organs. Not only must large masses of the liver disappear entirely, but also smaller areas throughout the liver, especially along the trunk of the main vessels, as the liver is growing from its centre towards its periphery."

Although the incisura umbilicalis with the ligamentum falciforme and the fossa sagittalis sinistra are taken as the line of division between the right and left lobes of the liver in the adult, this is not borne out by the developmental history of the organ, or by injection experiments through the portal vein, as Rex's beautiful illustrations show. Nevertheless it is a highly convenient mode of description, and because of this its retention is justified. Cantlie (12) demonstrated in 1897 that a line drawn from the fundus of the gall-bladder to the exit of the hepatic veins divides the liver into equal portions, the right and left lobes, and illustrated his contention by an interesting pathological specimen in which disease had destroyed the true right lobe, leaving the left lobe intact and greatly hypertrophied, and by other evidence. The embryological data supplied by my models support this view. It has been shown in Specimen I. that the line of attachment of the so-called ventral mesentery appears as a continuous attachment both on the ventral and dorsal aspects of the liver, and that the gall-bladder is placed in mesenchyme which is continuous with the

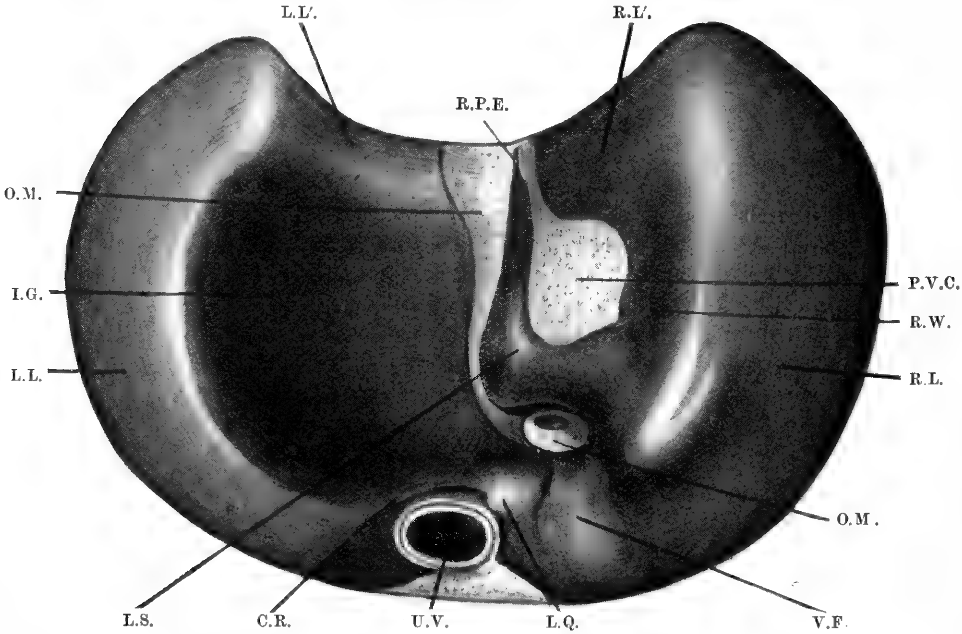

Fig. 8.—Same model as fig. 7, seen from the visceral surface. ×37·5.

omentum minus. The omentum minus is thin until we come to the portal fissure, where it forms a relatively thick mass. Together with the gall-bladder it can be regarded as the true median plane of the liver on the dorsal and caudal aspects. From the mesenchyme enveloping the gall-bladder a fold (fig. 5) runs cranially, as already stated, and joins the ligamentum falciforme, thus continuing the median plane on to the ventral surface. From this point the median plane can be indicated only in an arbitrary way, since, over a large area of the ventral surface, liver and septum transversum are fused together. However, if a line be drawn (fig. 4) from the fold just mentioned to the left border of the ductus venosus, it joins the cranial end of the omentum minus. The area which is marked X in fig. 5

is to the left of the fold, and is clearly a part of the left lobule. This is the preportal area, and indicates the place where the lobus quadratus will begin to develop.

On the dorsal surface (fig. 8) the attachment of the omentum minus is a conspicuous landmark. Further to the right is the plica venæ cava, and the foramen epiploicum in relation to its free caudal end. Between these two mesenteries is the bursa omentalis and the lobus Spigelii. The bursa omentalis at this stage is still called the recessus hepato-entericus, and its blind cranial end the recessus pneumato-entericus. The latter is becoming smaller in this specimen preparatory to being pinched off to form a closed sac, the bursa infracardiaca (see fig. 10), which lies, when present, in the adult just above the diaphragm, between the lung and the right side of the œsophagus. In a specimen of left diaphragmatic hernia in an adult recently examined here in the post-mortem room, this bursa was readily found on the right side, and measured 1½ inches in length.[1] The quadrate lobule is well seen growing ventrally between the vena umbilicalis and the gall-bladder, and connected by a prominent ridge across the vein dorsally to another prominent ridge which forms the lateral boundary of the impressio gastrica on the left lobe. In fig. 2 the corresponding ridge has been noted. Its connexions and its relation to the ligamentum teres make it comparable with the ridge just described.

Specimen III.

Fig. 9 is a view of the liver from the ventral aspect. For a short distance, passing obliquely upwards and to the right from the vena umbilicalis, the two layers of the ligamentum falciforme have come together, or, in other words, the separation of the liver from the septum transversum is here practically completed. The fundus of the gall-bladder still reaches the ventral edge of the liver, and, owing to the development of the lobus quadratus on the left and the squarish mass of liver substance which is elevated between two deep impressions for the small intestine on the right, it now appears to be sunk in a cleft—the beginning of the deep cystic fissure,—which is such a striking feature of the liver of the fœtus towards the middle of the third month. In Specimens I. and II. it will have been noted that the gall-bladder with its investing mesenchyme, whilst being embedded in the under surface of the liver, presents one side, relatively extensive, which is superficial, and it is only as we approach the seventh week that a further sinking in becomes apparent. In reality it is the growth of liver substance on either side of it which in part, at any rate,

[1] The bursa is also well developed in the chacma baboon, and lies between the azygos lobe of the lung and the œsophagus.

produces the appearance of being placed in a cleft. In Mall's embryo 24 mm. (No. 10), *i.e.* about the end of the eighth week, the model of the liver shows the gall-bladder in a deep fossa, and the fundus some distance away from the ventral border.

In his well-known paper on the fissures of the human liver, Professor A. Thomson (1) draws special attention to the disposition of the gall-bladder in the fœtus at the end of the second month. At this period the gall-bladder lies in a well-marked fissure, and the fundus reaches a point about midway between the porta and the ventral border. Further, in 41

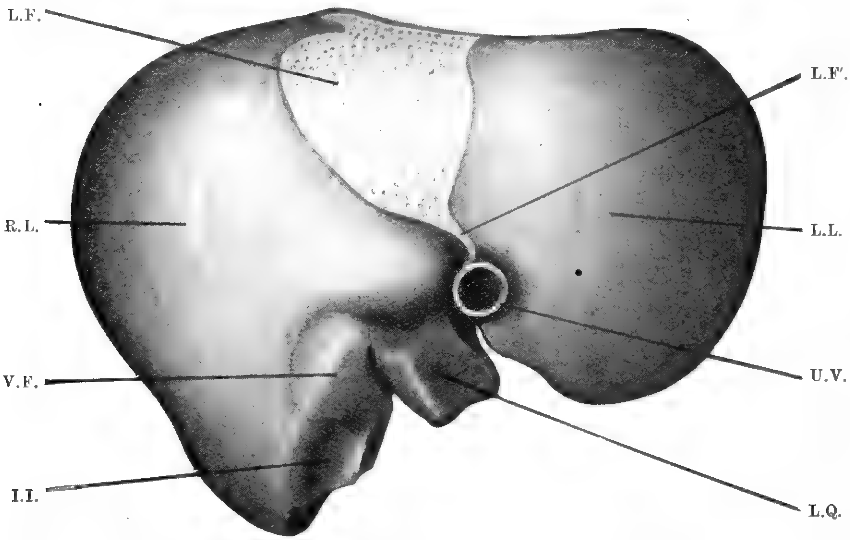

FIG. 9.—Specimen III., 16 mm. Model of liver, seen from the ventral aspect. × 25.

per cent. of all the cases examined, fœtal and adult, a fissure, continuous with the former, extended in front of the fundus as far as the ventral edge of the liver. This corresponds, in fact, with the fissure which Ruge (2) later on designated the fissura precystica. A. Thomson came to the conclusion, and rightly so, as my models show, that the gall-bladder developed in a fissure which extends forwards to the ventral border of the liver. He, however, came to regard the precystic fissure as preceding the appearance of the gall-bladder. From a study of my models it will be evident that up to the end of the sixth week the gall-bladder occupies the whole extent of the fissure. In older specimens it would appear that, owing to the liver and gall-bladder growing at different rates, the gall-bladder soon comes to occupy the position as shown in Mall's models (eighth week), and in the earliest specimen figured by A. Thomson. If this view is correct, then the fissura precystica would represent the most ventral portion of the early cystic depression.

The lobus quadratus is in Specimen III. a well-developed lobule placed between the gall-bladder and the vena umbilicalis, and projecting ventrally for some distance. Uneven on the ventral surface, smooth and concave on the visceral surface, where it is moulded over the pyloric portion of the stomach, it is attached to the liver above and on its right; elsewhere it is free. A groove running from the gall-bladder on the right to the vena umbilicalis on the left limits it above (fig. 9). On its right edge is a small tubercle, whilst to the left it is flattened. De Burlet in his Object III. finds the tubercle on the left margin, not on the right, and names it the lobulus parumbilicalis. In each case it is probably an area of liver substance growing along a line of least resistance. In the specimen now described it would be, if a name were given to it, a lobulus paravesicalis.

A Thomson found that a small lobule, connected with the lobus quadratus on the visceral surface and adjacent to the fissura umbilicalis, was a common feature in the fœtal livers which he examined. He also met with it in anthropoids, and frequently in the adult human liver. Apparently it corresponds with the lobulus parumbilicalis which de Burlet found in his Object III. Ruge has suggested that some of these small outgrowths in adults are produced mechanically, and are in some way to be associated, causally, with the respiratory movements of the diaphragm. He has also described as a lobulus parumbilicalis a small outgrowth on the *left* lobe adjacent to the fissura umbilicalis A good example of this type is to be seen in the Museum of the Royal College of Surgeons, London.

There is no trace apparently of the right lateral fissure in Specimen III., but the possibility of it coinciding with the fossa of the gall-bladder must be remembered. If the fissure were present, as it is in de Burlet's Object II. (though it is absent in Object III.), then there seems no doubt that this process (fig. 10, L.Q.) would represent the lobus quadratus. When, however, the fissure is absent, the interpretation is more difficult. In such a case it may be regarded as representing a large part, and exceptionally the whole of the right central lobe. The abnormal adult specimen described above demonstrates, if the interpretation there given is right, that the right central lobe can and does develop as two moieties —right and left of the gall-bladder fossa. The right moiety is in fact a part of the right lobe, and has shared in the general growth and expansion of this lobe; on the other hand, the left moiety—lobus quadratus—seems to have some independence, and may be a small process as in the liver of the adult pig, and in the abnormal specimen described above, or its growth may be precocious as in Specimen III., in the average normal human adult, and in many other mammals. In other words, as C. Bradley (5) has pointed out, the "lobus quadratus" appears to be of little importance in some animals, whilst in others it is evidently of much more moment. What may be the reason of this difference it is difficult to say. But as the lobe receives special vessels from the recessus umbilicalis, it seems reasonable to suppose that the size and number of the vessels will have

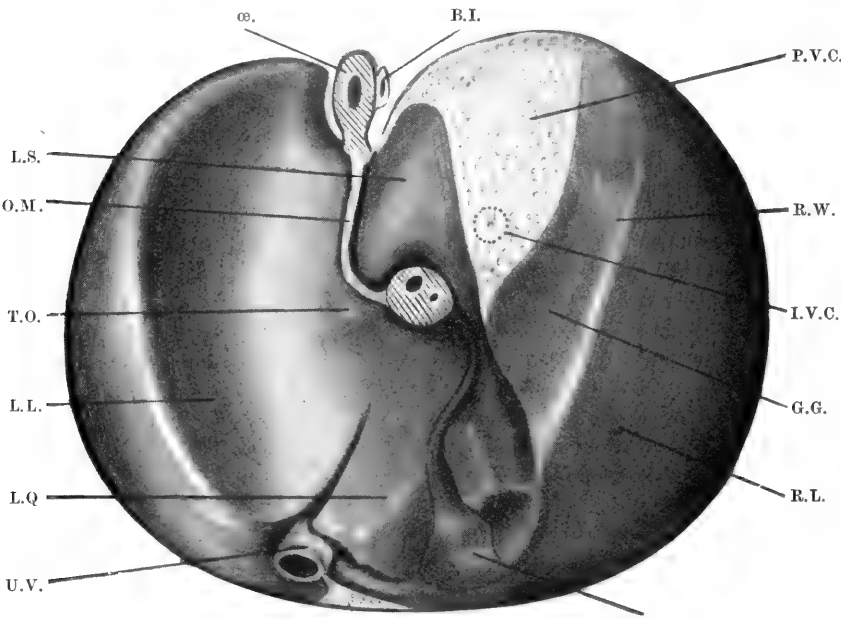

Fig. 10.—Same model as fig. 9, seen from the visceral surface. × 25.

some influence in determining the extent of its development. In this connexion I may quote the observation of Rex (4) in full:—"Ich möchte das Astwerk des R. umbilicalis in ein rechtseitiges und ein linksseitiges Scheiden. Das rechtseitige Astwerk versorgt jenem Abschnitt des mittleren Lappens welcher links von der Fossa cystica zu liegen kommt. Dieser Abschnitt entspricht dem 'Lobus' quadratus der ungelappten Organe." What Rex observed in the adult human organ, F. P. Mall has confirmed in the embryo. At the end of the fifth week vessels radiate from the recessus umbilicalis "into the middle and left lobules of the liver," *i.e.* just at the time when the quadratus lobule makes its appearance.

On the visceral surface (fig. 10) the extent of the preportal area can be well seen, and a comparison made between it and the corresponding area in Specimen II. (fig. 8). On the right is the gall-bladder, and on the left the umbilical fissure. The latter, whilst extending to the ventral edge of the liver, stops short some distance in front of the porta, owing to the presence of a bridge of liver substance uniting the quadrate to the rest of the left lobe. In Specimens I. and II. the vena umbilicalis lies in a tunnel of liver substance, whilst in Specimen III. it is lying in a deep groove or fossa. The groove is incompletely covered over by the growth of two lips, one being the left lateral border of the quadrate, the other being a part of the left lobule. In Mall's three models, and in three of de Burlet's, *i.e.* in six cases, an open fissure occurred once only. Is the canal in which the vein runs in these cases an extension of the primary tunnel, or has it been formed secondarily by union of the lips over the fissure? Further, is the fissure present in my Specimen III. the result of a breaking down of the floor of a tunnel, or has it been formed by the growth of the lobus quadratus, as this grows from the region of the portal in a ventral direction? It is impossible to answer these questions finally from a study of my small series of models. All I can do is to state what I find in the specimens. The bridge over the fissura umbilicalis near to the porta is apparently primary, and on comparison with fig. 8 it will be seen that it is placed at the original point of junction of lobus quadratus with the left lobule, or, in other words, it indicates the area of the left lobule from which the lobus sprung. On microscopical examination there is no sign of an intervening raphé. The latter might be expected if the bridge had been formed by fusion of two lips. With regard to the fissura umbilicalis itself, it is not possible to speak so definitely. On examining the opposed lips of the fissure, there is a small area over which there is no peritoneum—where, indeed, it looks as if the tissue had recently broken down. This is near the bridge; elsewhere the peritoneum is a definite feature along the lips. One is thus precluded from stating that the fissure is primary in its whole course. On the other hand, it may be that the lips can unite for limited distances and then break down again. Obviously a large series of models about this period are necessary before any definite pronouncement can be made. However, should further investigation show that the open fissura umbilicalis at or about this stage—*i.e.* from five to six weeks—is a "primary" fissure, meaning, by that term, a fissure formed as the lobus quadratus extends ventrally with its left margin free from the beginning, then there would seem good ground for regarding the lobus in man as something more than merely a quadrilateral area. Having these and other distinctive characters, the term "lobus," as applied to it in the consolidated organ such as occurs in man, would then appear to be justified.

Other features to be noted on the visceral surface of Specimen III. are the extensive area free from peritoneum, the plica venæ cavæ, with the orifice for the vena cava shown diagrammatically as it leaves the liver to enter into relation with veins on the posterior body wall. The lobus Spigelli is assuming more the form found in the adult, with a wide notch between the processus papillaris and the processus caudatus. The bursa omentalis extends dorsally behind the lobus Spigelii as far as the cranial limit of this lobe, where the blind end presents an uneven termination. Here are two minor recesses (seen also in Specimen II.), and from the dorsal one of the two the bursa infracardiaca has been pinched off to form the closed sac lying on the right side of the œsophagus, represented much strengthened in the figure, as the wall was too thin to model.

Therefore, although the lobus quadratus is not bounded by "true" fissures, yet, as these models show, it appears as a distinct process which develops into a definite hepatic area. This process grows as an extension of the left lobule, and at a different time and in a different way than the part of the right central lobe between the gall-bladder and the right lateral fissure. It may remain small or develop into a considerable area.

Finally, it may be noted that the pancreas obtained from the subject in which the abnormal liver was found also presented an interesting anomaly. The dorsal and ventral masses of the pancreas had failed to unite in the usual way; the duct of the dorsal pancreas was the main duct, and opened on a normal papilla minor, and the duct of the ventral pancreas opened, in common with the ductus choledochus, on the papilla major. No anastomosis between the two ducts could be traced.

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EXPLANATION OF FIGURES.

B.I.	bursa infracardiaca.
C.B.D.	ductus choledochus.
C.R.	connecting ridge from lobus quadratus to left lobe.
D.V.	ductus venosus Arantii.
G.B.	gall-bladder.
G.G.	area of contact, genital gland.
I.G.	impressio gastrica.
I.I.	impressio intestinalis.
I.V.C.	inferior vena cava.
L.C.	processus caudatus.
L.F.	area of fusion between septum transversum and liver.
L.F′.	ligamentum falciforme.
L.L.	left lobe of liver.
L.L′.	area of contact, left lung.
L.P.	processus pyramidalis.
L Q.	lobus quadratus.
L.S.	lobus Spigelii.
L.W.	area of contact with Wolffian body.
O.M.	omentum minus.
œ.	œsophagus.
O.M′.	thick mass of mesenchyme continuous with omentum minus.
P.V.	vena porta.
P.V.C.	plica venæ cavæ.
R.L.F.	right lateral fissure.
R.L.	right lobe of liver.
R.L′.	area of contact, right lung.
R.P.E.	recessus pneumato-entericus.
R.R.L.	marginal rest of right lateral fissure.
R.W.	area of contact, right Wolffian body.
T.O.	tuber omentale.
U.A.	uncovered area of right lobe.
U.V.	vena umbilicalis sinistra.
V.F.	mesenchyme surrounding gall-bladder.

THE CHARACTERS OF THE ENGLISH THIGH-BONE. By F. G. PARSONS, *Professor of Anatomy in the University of London.*

THIS piece of work was undertaken in order to obtain, if possible, a standard of comparison for the various thigh-bones which we are so constantly digging up throughout the British Isles.

"How do these compare with a typical English femur?" we are often asked, and we have to say that nobody knows what a typical English femur is like any more than he knows what a typical English skull is like.

The bones in our dissecting-rooms are usually sawn into pieces, and even were they kept whole they would be of doubtful value, since they are almost always those of very aged people.

The femurs from which we teach, and those which our students buy, come from anywhere in Southern and Eastern Europe, so that, in order to get a type of an English femur, I have resorted to the great mass of bones beneath the church at Rothwell in Northants, which has been kindly placed at my disposal by the Vicar, Mr Morley.

Elsewhere (*Journ. R. Anthrop. Inst.*, vol. xl., 1910, p. 483) I have given my reasons for believing that these are the bones of mediæval English people who died in the thirteenth and fourteenth century, and, after being buried in the churchyard, were exhumed, according to the custom of the Middle Ages, and deposited in the disused chapel of the crypt.

These collections of bones in charnel-houses or crypts are plentiful enough in England, though they are usually walled up. I might have used the more accessible bones at Hythe; but a study of the skulls there convinces me that there is a large proportion of some particularly round-headed people among them whose origin is still a puzzle, and so I have felt doubtful whether their femurs could be regarded as fairly typical of those of Englishmen.

Of course I realise that a study of these Rothwell femurs will only entitle us to say what those of Midland Englishmen of the Middle Ages were like, but I hope that they will serve as a standard for comparison with more modern as well as with more ancient ones.

There is one thing which I am especially anxious to try to settle, and that is, how many femurs it is necessary to examine in order to obtain a reasonable working average. At present, writers generalise on groups of 5, 10, 15, or 20, and we do not know what value to attach to their conclusions, but I hope that the detailed examination of 300 may throw some light on this.

Methods of Measuring.

The measurements which I have found necessary in order to reproduce a fairly accurate series of contours of a femur or type contours of a set of femurs are the following:—

1. *The oblique length.*—Measured in the ordinary way with a measuring board, the two condyles being placed in contact with the footplate of the board.

2. *The maximal length.*—The greatest length obtainable between the head of the femur and the internal condyle.

3. *The greatest diameter of the head.*—Measured with a sliding scale the two bars of which are kept parallel to the long axis of the neck of the femur. As a rule the greatest diameter of the head is nearly vertical.

4. *The least transverse diameter of the shaft.*—This is usually about the middle of the shaft, though sometimes, especially in platymeric femurs, it may be as low as the junction of the middle and lower thirds.

I think that this diameter is an important one to take, because it gives a clue to the robustness of the individual.

5. *The greatest antero-posterior diameter of the shaft.*—This is also, as a rule, best marked about the middle of the femur; it gives a record of the development of the linea aspera and should be contrasted with the index of bowing.

6. *The presence of a roughness or depression on the front of the neck of the femur.* This is quite close to the head and may be covered with articular cartilage. It is made by the anterior margin of the acetabulum close to the anterior inferior spine in full flexion of the hip, combined with internal rotation (see fig. 1).

7. *The antero-posterior width of the shaft just below the lesser trochanter.*—The measurement is taken from the inner side, and the bars of the sliding scale are not pushed far enough to take in the gluteal ridge, an abnormal development of which would vitiate the measurement.

8. *The transverse width of the shaft at the same place.*—This is always a larger measurement than the last, and by dividing it into the antero-posterior measurement multiplied by 100 the platymeric index of the femur is obtained. I should describe any femur giving an index under 75 as being distinctly platymeric to the eye.

9. *The width of the lower extremity.*—Taken with a sliding scale as in diagram No. 2. The importance of this measurement is that it is of value

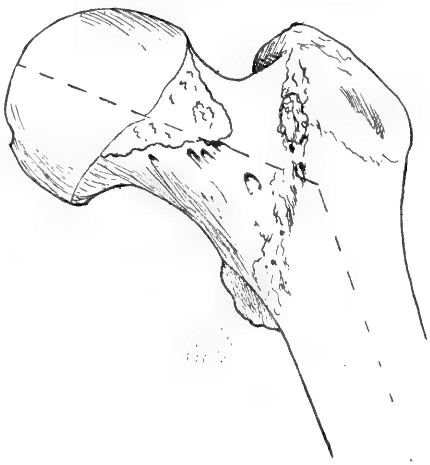

Fig. 1.

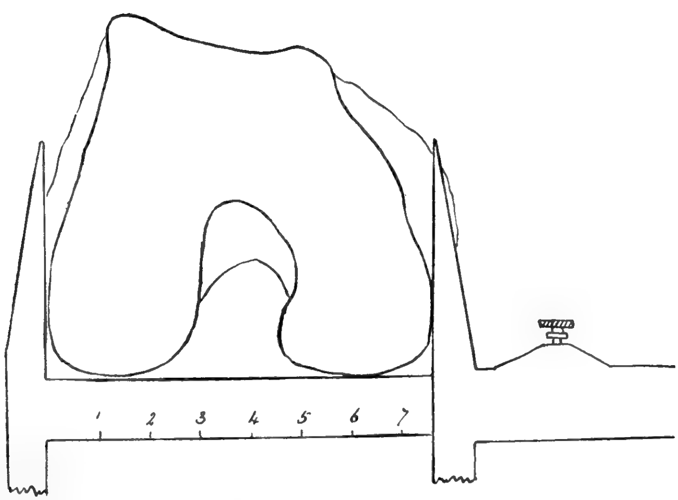

Fig. 2.

in sexing the bone, and, since it corresponds very closely with the width of the head of the tibia, it is likely to be valuable in sexing that bone too.

10. *The amount of antero-posterior bowing of the shaft.*—Taken by laying the femur close to the edge of a flat table in such a way that the posterior surfaces of both condyles are in contact with the table. The

sliding limb of the scale is then removed, and the scale placed vertically against the edge of the table, in such a way that the fixed limb touches the point of greatest convexity of the femur about the middle of the shaft. The distance of the most convex point from the surface of the table is then shown on the scale. By keeping the scale pressed against the side of the table edge, any deviation from the vertical is prevented.

11. *The index of bowing.*—As the mere amount of bowing would mean little unless it is taken in conjunction with the length of the femur, I have worked out an index of bowing by dividing the oblique length into the amount of bowing multiplied by 100; in this way the greater the index the greater is the bowing compared with the length of the femur.

12. *The angle of the neck.*—I am not quite clear how this angle has been taken by other writers. It will be evident to anyone looking at a femur that the angle which the upper border of the neck makes with the shaft is seldom the same as that which the lower border makes, because the neck widens from above downward as the junction with the shaft is approached. In taking the axis of the neck, I have drawn a line from the middle of the head to the middle of the base of the neck as seen from in front. The angle which this makes with the long axis of the middle of the shaft is the one I have taken (see fig. 1).

The length of the neck.—This is a variable and important measurement in reconstructing a type of a series of femurs. I measure it by resting a sliding scale along the front of the long axis of the neck, obtained as above. The head rests against the fixed bar of the scale, and the length is taken to the place where the long axis of the neck cuts the spiral line of the femur. Where this line is broad, the middle of it is taken.

The angle of torsion of the femur.—A special apparatus is made for measuring this, but I find that I can estimate the angle with considerable accuracy in the following way:—

A hole is drilled with a bradawl in the centre of the head of the femur —that is to say, in the upper and front part of the fovea capitis. The direction of the hole does not follow the long axis of the neck as seen from above, but is drilled in such a way that it would come out of the shaft just below the great trochanter, midway between its anterior and posterior margins (see fig. 3, line AB). This, I think, is important, as it is the torsion of the shaft which we wish to obtain. A long steel knitting-needle is placed in this hole.

Another hole is drilled in the internal condyle of the femur, starting on its inner side in front of the summit of the inner tuberosity, and running parallel to the surface of a table on which the femur is lying, so that the back of each condyle is touching the table (see fig. 3, line CD). Into this another knitting-needle is placed. The points at which the two needles come out of the femur are then got into a line with the eye and the angle between the two rods measured with a transparent celluloid protractor while the bone is resting on a flat surface about the level of the eye.

Formerly I threw the shadows of the two rods on to a screen by a lamp placed in a line with them, then pencilled the shadows and measured the angle between them; but I find that I can get just as accurate results without this extra detail.

The method is not really as tedious as it sounds, but needs practice to be successful, and I should advise anyone adopting it to remeasure several femurs after an interval until he can be sure of not allowing more than two or three degrees of discrepancy.

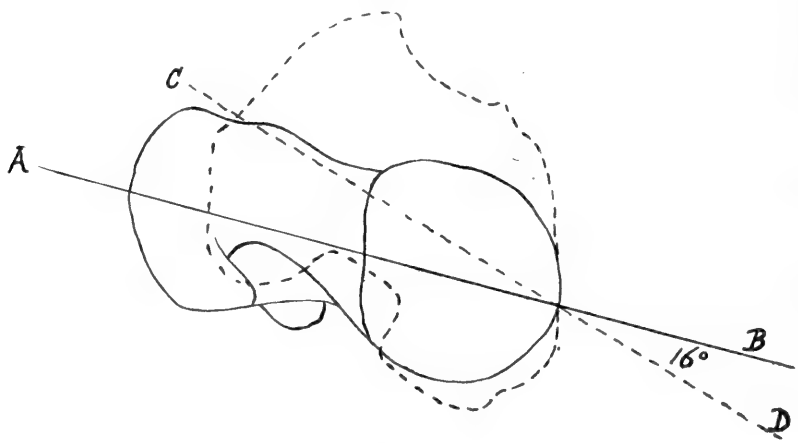

FIG. 3.

The obliquity of the shaft.—I measure with a goniometer having a long pointer, which can be placed in front of the long axis of the femur, the two condyles of which are resting on a flat surface. The angle recorded is that between the obliquity of the shaft and the vertical.

It will now be advantageous to consider the main points which can be learnt from the accompanying tables of measurements:—

1. *The oblique length.*—On the left side this averages 456 mm. in the male bones, and 453 mm. on the right side, while in the female bones the left average 418 mm. and the right 415 mm. It will thus be seen that in both sexes the left side averages 3 mm. more than the right. It must, of course, be remembered that the right bones measured were not necessarily the fellows of the left: indeed, it is not very likely that many were, because 22,000 heads of femurs were counted in restacking the bones, showing that

the remains of at least 11,000 people are in the vault. In relation to this I have lately measured the two femurs of 16 bodies in the dissecting-rooms of St Thomas's and Guy's Hospitals, and find that the average of the left femurs is also 3 mm. more than that of the right.

The maximal length is more important, because from it Pearson has prepared his valuable charts for the reconstruction of the stature. In the males the left femurs average 460 mm. and the right 456, while in the females the left average 422 and the right 416. In the male bones, therefore, there is a difference between the oblique and the maximal lengths of 3 to 4 mm., while in the female bones there is a difference of 1 mm. on the right side and 4 on the left. This is rather a serious discrepancy between the two sides, which makes me a little uneasy, and I can only say that the measurements were taken with great care, and I can detect no flaw in my calculations. Possibly if the numbers of the female bones had been greater the discrepancy might have disappeared. Pearson (*Phil. Trans.*, vol. cxcii., series A, p. 197) says that 3·2 mm. should be added to the oblique length in the male in order to get the maximal length, and 3·3 mm. in the female. This, from my figures, seems a fair enough average, but it must be borne in mind that the individual variation is very great, some bones having as much as 11 mm. difference between the two measurements, and others none at all.

It seems reasonable to suppose that when there is an unusual difference between the maximal and oblique measurements, it is due to a greater obliquity than usual in the femur. In order to test this, I took the average obliquity of 21 male femurs in which there was a difference of more than 5 mm. between the maximal and oblique lengths. I found this average to be 11°, which is 2° above the average obliquity of all the male bones.

Among the left female femurs the average obliquity is 11°, but the average of those with more than 5 mm. between the two lengths is 12·7°.

The right female femurs give an average obliquity of 10°, but the average of those with more than 5 mm. between the two lengths is 11·5°.

It has been said that from the maximal length Pearson deduces the average stature of the series. I am not quite clear why he chooses the maximal in preference to the oblique length, since the latter is the one which really forms a fraction of the body height; but as I have not the mathematical knowledge to adapt his work to the oblique length, I am only too glad to avail myself of it as it stands.

The average maximal length of the right male Rothwell bones is 456 mm., and of the left 460 mm. This, according to his chart, would give a height of 167 cm., or 5 feet $5\frac{3}{4}$ inches, for the men.

RIGHT MALE FEMURS FROM ROTHWELL.

Number of Femur measured.	Oblique Length.	Maximal Length.	Diameter of Head.	Least Transverse Diameter of Shaft.	Greatest Ant.-Post. Diameter of Shaft.	Facet in Front of Neck.	Width of Lower Articulation.	Platymeria. Ant.-Post.	Platymeria. Transverse.	Platymeria. Index.	Amount of Bowing.	Index of Bowing.	Angle of Torsion.	Length of Neck.	Angle of Neck.	Obliquity of Shaft.	Remarks.
1	...	453?	51	31	31	...	...	23	39	59	65	144	° ...	62	124°	° ...	
2	463	468	50	31	35	...	78	30	38	79	60	130	10	65	118	9	
3	447	452	48	27	33	No	76	29	31	93	62	138	10	57	132	8	Third trochanter present.
4	454	457	49	30	35	,,	75	28	34	82	62	138	7	59	128	8	
5	453	455	47	30	33	Yes	75	29	34	85	55	122	8	65	130	7	
6	406	410	46	29	28	,,	74	26	33	79	60	146	13	59	120	9	
7	475	479	51	32	31	,,	79	28	39	72	60	128	−5	71	116	10	
8	466	469	49	31	33	,,	78	29	35	83	61	130	4	69	130	7	
9	453	461	52	29	29	...	83	28	35	80	59	131	18	68	123	12	
10	483	485	54	31	33	Yes	83	31	38	82	65	135	15	69	127	7	
11	455	463	49	27	35	,,	68	28	31	90	69	153	23	60	132	10	
12	438	444	50	29	31	,,	78	28	36	78	64	145	10	67	130	10	
13	472	473	51	31	33	,,	81	29	37	78	64	136	20	71	124	5	
14	492	495	51	31	31	,,	83	28	31	90	59	120	17	70	126	7	
15	455	457	51	33	34	,,	76	29	31	93	71	158	24	63	125	8	
16	..	455?	49	30	31	,,	...	26	31	84	61	136	...	72	130	...	
17	455	457	50	28	34	,,	76?	32	35	91	67	149	25	63	127	8	
18	461	465	47	28	31	,,	75	28	32	87	58	126	3	64	125	11	
19	452	455	49	29	30	No	77	28	32	87	64	142	9	58	135	10	
20	464	467	50	30	35	Yes	76	35	39	90	71	154	20	67	121	8	
21	450	452	47	31	32	...	78	33	34	97	65	144	15	59	121	9	
22	460	463	46	30	31	Yes	77	26	37	70	63	137	18	55	130	8	
23	465	467	48	29	29	,,	75?	28	35	80	55	119	...	64	125	10	
24	463	469	50	31	30	...	77	29	35	83	55	119	8	65	122	11	
25	457	459	54	31	32	Yes	87	31	37	84	58	126	28	69	123	9	
26	...	465	46	32	30	,,	...	28	33	85	60	130	25	62	130	13	The sex of this is doubtful.
27	473	474	54	32	33	,,	81	30	38	79	65	138	6	86	121	7	
28	482	485	49	30	31	...	79	29	38	76	65	135	17	67	131	8	
29	439	442	47	29	31	Yes	81	30	33	91	69	157	25	62	125	9	
30	426	431	46	30	31	,,	69	32	33	97	60	140	20	59	122	13	
31	404	409	46	30	28	...	76	28	35	80	63	157	17	58	117	11	
32	453	455	50	28	26	...	75?	24	38	63	58	129	19	57	122	11	
33	474	478	49	32	33	Yes	75	25	34	73	55	117	17	63	133	10	
34	438	440	49	32	36	No	75	28	43	65	63	143	20	65	113	8	
35	457	460	48	29	33	Yes	81	28	35	80	67	146	−1	67	120	8	
36	487	490	51	30	33	...	78	28	34	82	68	139	...	65	131	8	

37	480	483	52	...	...	Yes	78	32	38	84	...	...	30	67	127	10	Signs of an early greenstick fracture [of shaft.
38	440	445	45	28	30	...	...	31	36	86	...	...	...	64	124	12	
39	459	465	51	30	30	Yes	77	29	34	85	60	130	10	64	130	9	
40	470	473	...	33	38	...	79	32	40	80	56	119	−2	74	140	8	
41	438?	..	...	30	32	...	76	28	37	76	53	120	...	...	128	7	
42	442	445	...	27	29	...	74	30	30	100	55	125	15	65	138	7	
43	445?	...	...	30	30	...	78	30	34	88	60	136	...	...	...	9	
44	460	464	50	29	31	Yes	77	28	37	76	60	130	12	70	126	8	Slight osteo-arthritis of lower end.
45	457	460	47	27	27	,,	72	25	34	73	54	118	8	66	120	10	
46	448	448	52	30	33	...	76	33	34	97	60	133	12	70	122	4	
47	438	444	47	26	32	No	70	26	32	81	71	161	12	67	136	10	
48	455	458	47	27	31	Yes	75	28	33	85	59	131	0	66	130	9	
49	...	440?	51	29	30	,,	..	27	35	77	56?	127	12	66	130	...	
50	471	475	49	31	31	No	...	29	40	72	59	126	20	67	117	11	
51	430	432	52	29	30	...	74	28	34	82	53	123	22	73	128	8	
52	451	454	48	28	34	No	76	29	33	88	64	142	−2	61	131	10	
53	470	475	54	30	32	Yes	87	30	39	77	63	133	11	78	125	11	
54	417	418	48	25	28	No	77	28	33	85	59	140	11	60	127	6	
55	479	490	48	31	30	...	77	27	34	79	58	121	20	64	124	13	
56	482	484	54	32	33	Yes	83	29	37	78	65	135	12	75	131	10	
57	474	...	52	30	31	...	...	31	37	84	...	...	...	63	125	...	
58	...	432	51	24	34	No	...	28	31	90	65	151	20	66	130	...	
59	475	479	49	26	31	...	...	28	31	90	...	...	...	71	135	...	
60	444	452	47	30	29	Yes	73?	25	36	69	60?	136	...	67	123	...	
61	444	449	50	28	28	,,	75	26	36	72	53	120	18	65	123	12	Osteo-arthritis of head.
62	465	471	45	28	30	,,	77	28	33	85	63	137	12	71	130	10	Osteo-arthritis of lower end.
63	432	439	49	25	31	,,	71	29	31	94	56	130	10	66	135	14	
64	474	474	54	32	34	No	80	31	38	82	68	145	13	72	122	6	
65	463?	...	52	30	30	Yes	...	30	33	91	...	...	...	74	126	...	
66	448	452	46	29	36	,,	...	29	30	97	68	151	12	67	135	8	Third trochanter.
67	421	423	47	29	28	...	75	26	40	65	61	145	12	55	122	10	Groove outside gluteal ridge.
68	417	422	47	30	29	Yes	73	28	34	82	60	143	20	60	120	12	Groove outside gluteal ridge.
69	440	442	51	31	34	,,	76	31	35	89	75	170	22	61	118	11	
70	441	443	49	26	32	No	82	28	30	93	64	145	7	61	131	6	
71	442	449	47	27	30	Yes	69	27	30	90	59	134	10	67	138	11	
72	449	452	50	29	33	,,	72	29	34	85	65	144	−2	68	128	9	
73	419	422	49	25	30	...	74	27	30	90	62	148	23	62	130	9	
74	450	453	49	30	31	No	...	28	36	67	56	125	...	67	125	...	
75	473	475	48	30	31	Yes	75	27	38	71	60	128	15	65	120	8	
76	424	426	45	27	30	No	77	27	34	79	62	148	7	64	128	8	
77	470	473	48	30	30	Yes	78	29	34	85	65	138	14	65	131	10	
78	444	448	49	27	29	,,	75	28	31	90	55	125	1	66	131	10	
79	427	433	46	27	30	,,	70	24	32	75	60	140	10	62	125	9	Groove outside gluteal ridge.
80	428	440	45	27	31	,,	74	25	32	78	59	137	−13	60	120	17	
Average.	mm. 453 (75)	mm. 456 (76)	mm. 49 (76)	mm. 29 (79)	mm. 31 (79)	Present in 79%	mm. 75 (68)	mm. 27 (80)	mm. 35 (80)	77 (80)	mm. 61 (75)	135 (75)	13° (69)	mm. 65 (78)	127° (79)	9° (71)	

LEFT MALE FEMURS FROM ROTHWELL.

Number of Femur measured.	Oblique Length.	Maximal Length.	Diameter of Head.	Least Transverse Diameter of Shaft.	Greatest Ant.-Post Diameter of Shaft.	Facet on Front of Neck.	Width of Lower Articulation.	Platymeria. Ant.-Post.	Platymeria. Transverse.	Platymeria. Index.	Amount of Bowing.	Index of Bowing.	Angle of Torsion.	Length of Neck.	Angle of Neck.	Obliquity of Shaft.	Remarks.
1	479	485	55	30	38	Yes	81	33	39	85	64	133	7°	72	134°	9°	
2	468	473	49	32	36	No	79	31	40	77	63	133	10	69	124	9	
3	469	471	51	32	32	Yes	77 ?	35	37	95	61	130	18	71	135	...	
4	492	494	55	32	32	,,	...	31	38	82	...	...	...	73	133	...	
5	470	471	49	30	40	,,	79	30	36	83	69	147	7	67	126	5	
6	460	463	47	30	33	,,	...	30	36	83	60	130	0	65	130	14	
7	452	452	53	29	35	,,	77	30	38	79	60	133	8	70 ?	122	7	
8	467	467	47	31	37	...	76	28	35	80	63	133	12	64	128	10	
9	480	483	54	33	32	Yes	82	31	39	79	64	133	20	70	127	8	
10	480	484	52	29	32	,,	79	28	36	78	58	121	20	74	133	9	
11	454	458	47	28	39	No	78	30	33	91	72	160	20	60	126	12	Least breadth above middle of shaft.
12	469	472	50	30	34	Yes	77	31	36	86	63	133	3	68	132	10	
13	474	476	...	28	36	...	75 ?	31	38	82	61	130	22	72	126	7	
14	480	...	49	35	35	Yes	...	30	39	77	...	...	5	72	112	...	
15	451	453	54	33	31	No	84	29	42	69	62	138	35	70	124	10	
16	482	485	55	32	29	Yes	82	33	39	85	58	121	16	65	129	8	
17	475	479	49	32	36	No	82	31	37	84	73	155	10	62	124	9	
18	474	480	49 ?	32	33	...	79	29	41	71	68	145	15	71	128	13	
19	481	486	53	33	34	Yes	80	34	41	83	52	109	0	67	118	10	
20	...	...	51	34	35	No	...	33	45	73	...	...	...	70	118	...	
21	463	468	52	25	37	?	82	30	32	94	78	170	7	69	125	7	Least breadth above middle. Rickets.
22	460	461	48	29	34	Yes	75	31	36	86	55	119	8	73	131	9	
23	475	482	49	32	32	,,	72 ?	30	35	86	55	117	3	68	120	10	
24	494	496	49	32	32	No	80	27	36	75	65	133	25	70	138	9	
25	464	467	53	28	33	Yes	78	32	35	91	65	141	25	65	126	9	
26	454	459	49	28	33	No	75	32	32	100	...	...	19	60	133	9	
27	451	459	50	30	35	Yes	75	33	34	97	67	149	12	60	121	14	
28	467	468	53	31	33	,,	78	28	38	74	62	132	17	70	128	8	Groove outside gluteal ridge.
29	441	444	51	30	30	,,	79	28	37	76	55	125	7	70	125	10	
30	430	432	47	35	30	,,	65 ?	30	42	71	...	...	0	62	114	13	Groove outside gluteal ridge.
31	450	450	49	31	33	...	75	29	38	76	68	151	11	67	129	7	
32	459	464	48	25	27	No	79	29	33	88	60	130	17	60	126	10	
33	477	479	50	32	31	...	...	29	35	83	60	125	13	71	134	10	

34	472	474	48	29	32	No	75	30	35	86	61	130	26	63	128	7	Slight groove outside gluteal ridge.
35	431	435	49	29	32	,,	76	27	35	77	65	151	5	60	122	11	[Slight third trochanter.
36	469	472	49	33?	34	?	82	32	37	86	60	128	10	60	123	9	
37	431	433	47	30	33	Yes	71?	26	35	74	67	156	2	70	127	9	
38	436	438	46	30	30	,,	75	27	36	75	59	134	18	60	125	9	
39	483	485	53	31	33	,,	79	30	39	77	63	131	12	73	128	11	
40	457	462	46?	28	34	...	78	30	35	86	57	124	30	64	125	10	
41	471	478	50	30	29	No	72	26	34	76	58	123	0	65	130	13	
42	433	434	45	31	32	Yes	76	29	36	81	60	140	8	61	117	7	
43	481	485	49	28	33	Yes	75	29	36	81	65	135	40	65	128	8	Slight groove outside gluteal ridge.
44	443	448	48	32	31	No	82	30	38	79	62	141	15	62	118	12	
45	414	416	47	29	30	...	73	28	34	82	58	141	17	67	123	10	
46	450	457	51	32	33	Yes	...	29	38	76	63	140	−2	70	130	11	
47	459	462	50	27	33	,,	71	27	33	82	63	137	7	63	137	11	Groove outside gluteal ridge.
48	452	454	50	29	30	,,	75	30	35	86	60	133	17	75	134	10	
49	461	465	49	30	31	...	...	28	35	80	58	126	17	59	134	11	Slight groove outside gluteal ridge.
50	445	449	46	29	31	Yes	75	28	33	85	60	136	11	61	131	11	
51	442	444	52	29	31	No	81	29	39	74	59	134	25	72	120	8	
52	468	472	47	27	28	Yes	72	28	30	93	55	117	19	67	125	11	
53	460?	...	...	30	28	...	77	28	33	85	60	130	...	...	132	7	Third trochanter.
54	480	482	51	30	36	Yes	80	30	35	86	63	131	15	66	120	9	
55	432?	...	47	27	32	,,	...	28	36	78	57	133	13	60	123	...	
56	480	482	50	27	33	,,	82	28	35	80	57	119	5	72	128	8	
57	430	434	...	28	30	,,	73	28	36	78	62	144	27	63	127	10	
58	448	452	50	27	29	,,	75	27	35	77	65	144	16	68	128	9	
59	467	472	49	30	33	,,	79	33	34	97	58	123	12	65	130	8	
60	442	446	47	28	38	,,	77	29	35	83	71	161	9	61	115	9	
61	446	447	47	31	31	,,	75?	38	38	100	54	120	23	70	122	8	
62	447	457	47	29	28	,,	71	29	35	83	47	104	20	60	131	12	
63	538	543	51	30	37	,,	82	28	35	80	68	126	17	83	135	9	
64	458	459	49	31	33	No	79	29	36	81	65	141	6	63	120	4	
65	455	461	52	30	30	Yes	76?	29	36	81	55	122	16	66	123	13	
66	417	420	47	30	32	,,	76	29	37	78	61	145	10	60	117	10	
67	441?	...	45	28	33	,,	71?	33	34	97	67?	152	28	58	127	...	
68	442	442	47	30	31	...	82	30	36	83	55	125	20	71	120?	8	
69	421	424	47	28	30	...	72	27	36	75	55	131	8	55	130	8	
70	437	439	...	28	31	...	74	27	32	84	62	141	...	67	125	8	
71	433	436	49	27	30	...	76	27	33	82	56	133	22	65	127	10	
72	455	459	45	28	29	...	69	28	35	80	52	116	25	62	127	10	
73	455	458	47	30	33	Yes	73	28	36	78	61	135	20	62	119	8	
74	461	465	53	27	27	No	76	27	31	87	55	119	15	60	124	10	
75	447	449	47	30	35	Yes	76	28	35	80	65	144	0	64	127	10	
76	450?	...	...	31	31	...	82	32	38	84	60	133	17	...	115	10	
77	483	486	50	32	38	...	77	30	40	75	70	146	13	65	120	10	
78	435	439	47	29	29	Yes	72	29	37	78	59	137	17	62	130	10	

LEFT MALE FEMURS FROM ROTHWELL—*continued.*

Number of Femur measured.	Oblique Length.	Maximal Length.	Diameter of Head.	Least Transverse Diameter of Shaft.	Greatest Ant.-Post. Diameter of Shaft.	Facet on Front of Neck.	Width of Lower Articulation.	Platymeria. Ant.-Post.	Platymeria. Transverse.	Platymeria. Index.	Amount of Bowing.	Index of Bowing.	Angle of Torsion.	Length of Neck.	Angle of Neck.	Obliquity of Shaft.	Remarks.
79	467	469	51	31	31	Yes	79	27	38	71	61	130	5°	64	128°	8°	Slight groove on outer side of gluteal [ridge.
80	448	451	49	29	35	,,	78	30	36	83	60	133	12	66	125	10	
81	457	459	52	33	33	,,	78	29	39	74	57	124	5	68	120	10	
82	444	445	47	30	31	,,	78	29	35	83	61	139	7	61	126	10	
83	...	466	49	28	33	,,	...	27	36	75	62	135	9	65	121	...	
84	439	442	51	32	31	,,	78	29	38	76	58	132	18	70	126	11	Slight groove on outer side of gluteal [ridge.
85	443	450	48	29	31	,,	77	31	39	79	54	123	0	65	121	11	
86	464	465	49	32	31	,,	78	29	38	76	60	130	21	73	124	7	Slight groove on outer side of gluteal [ridge.
87	445	450	50	30	31	,,	77	31	40	77	59	134	5	65	...	10	
88	472	475	50	32	34	,,	82	32	40	80	62	132	10	65	120	9	
89	475	479	48	31	35	,,	82	31	36	86	62	132	−6	70	127	8	Very marked muscular ridges.
90	453	456	45	30	32	,,	74	28	36	78	60	133	13	65	127	11	
91	438	443	48	29	30	,,	79	31	35	89	56	127	13	67	137	11	
92	455	457	45	30	34	,,	77	31	34	91	53	118	5	66	127	9	
93	440	442	48	28	32	,,	76	28	38	74	57	129	15	66	125	8	
94	450	453	52	32	28	...	77	28	35	80	53	118	11	69	126	12	
95	454	458	49	32	34	Yes	72	31	35	89	53	118	15	70	127	11	
96	428	432	49	29	31	...	81	31	34	91	55	128	3	61	126	8	
97	445	449	47	29	32	No	73	28	35	80	55	125	22	60	117	10	Groove on outer side of gluteal ridge.
98	477	480	47	30	31	Yes	77	30	34	88	62	129	28	63	127	11	[Third trochanter.
99	421	424	48	32	31	No	80	28	35	80	71	171	28	60	127	8	
100	443?	446?	...	28	30	Yes	...	28	34	82	54?	123	...	...	120	9	
101	440	446	49	28	32	,,	76	31	32	97	64	145	21	63	130	11	
102	...	438	47	31	32	...	..	26	38	68	51	119	...	60	126	11	Groove on outer side of gluteal ridge.
103	458	463	47	29	30	Yes	...	29	37	78	52	113	18	65	126	9	
104	440?	...	...	31	33	...	...	28	37	76	...	...	...	70?	122	...	
105	463	468	49	32	33	Yes	77	27	39	69	59	128	6	67	128	10	Groove on outer side of gluteal ridge.
Average.	mm. 456 (102)	mm. 460 (98)	mm. 49 (98)	mm. 30 (105)	mm. 32 (105)	% 79	mm. 77 (92)	mm. 29 (105)	mm. 36 (105)	81 (105)	mm. 62 (95)	135 (95)	13° (98)	mm. 66 (102)	126° (104)	9° (97)	

Right Female Femurs from Rothwell.

Number of Femur measured.	Oblique Length.	Maximal Length.	Diameter of Head.	Least Transverse Diameter of Shaft.	Greatest Ant.-Post. Diameter of Shaft.	Facet in Front of Neck.	Width of Lower Articulation.	Platymeria. Ant.-Post.	Platymeria. Transverse.	Platymeria. Index.	Amount of Bowing.	Index of Bowing.	Angle of Torsion.	Length of Neck.	Angle of Neck.	Obliquity of Shaft.	Remarks.
1	397	400	42	30	28	No	67	26	33	79	57	143	10°	50	119°	10°	
2	462	464	41	24	28	,,	63	22	30	73	58	126	30	52	127	5	Groove external to gluteal ridge.
3	471 ?	477	44	28	32	,,	66 ?	27	33	82	58	123	15	57	130	...	Groove external to gluteal ridge [(slight).
4	400 ?	402	43	30	30	Yes	...	24	35	69	65	163	30	56	120	9	
5	412	413	45	27	28	,,	70	27	33	82	61	149	12	58	127	8	
6	423	428	42	26	26	,,	66	27	30	90	60	143	15	59	128	9	
7	406	408	43	24	26	...	...	27	32	84	57	139	11	54	129	8	
8	452	458	46	31	33	...	74	29	36	81	60	133	5	63	130	10	
9	415	422	42	27	31	No	67	27	33	82	62	151	17	53	125	11	Groove external to gluteal ridge.
10	408	412	43	27	27	..	...	25	34	73	56	137	...	56	116	10	
11	399	404	43	26	27	Yes	66 ?	24	35	69	57	143	30	57	119	11	
12	394	398	41	28	24	...	65 ?	25	32	78	55	141	22	57	127	10	
13	413	419	42	26	28	...	70	27	34	79	52	125	20	60	128	11	
14	414	420	45	26	28	Yes	72	28	39	72	55	134	31	59	121	11	
15	389	393	42	26	26	No	68	26	33	79	60	154	18	52	122	9	
16	423	425	44	26	29	...	64	27	32	84	45	107	13	56	127	8	
17	423	425	42	27	28	Yes	68	25	34	73	53	126	25	55	133	7	Exostosis in origin of short head of [biceps femoris.
18	450	454	45	28	31	No	71	27	35	77	67	149	17	59	120	12	
19	393 ?	...	39	26	26	Yes	...	25	31	81	49	126	25	52	122	...	
20	445	453	43	25	28	No	67	25	27	98	58	132	28	58	132	12	
21	432	436	45	27	30	...	70	26	35	74	56	130	10	62	126	11	Groove external to gluteal ridge.
22	399	403	48	28	27	...	67	23	34	68	54	135	8	55	126	10	Obviously ♀ in spite of size of head.
23	...	425 ?	42	28	29	No	...	26	30	87	...	...	...	54	127	...	
24	425	432	45	29	30	Yes	69	24	31	77	55	131	14	59	131	11	
25	404	406	44	28	29	No	69	24	32	75	52	130	17	52	124	7	Groove external to gluteal ridge.
26	450	453	45	24	30	Yes	...	22	30	73	59	131	5	62	134	9	
27	448	451	44	27	29	...	67	29	32	91	59	131	5	62	114	10	
28	396	399	41 ?	27	30	...	66	25	33	76	65	162	21	...	130 ?	10	
29	425	429	44	30	29	Yes	67	28	36	78	65	155	18	58	122	10	
30	399	407	42	29	24	,,	64	24	31	78	50	125	32	50	130	12	
31	379	382	40	27	24	,,	64	23	32	72	52	137	18	58	124	8	
32	420	425	43	25	28	...	68	24	29	83	57	136	12	57	126	9	
33	407	416	44	29	31	...	69	28	33	85	63	154	18	56	129	10	
34	434	437	45	28	27	Yes	71	23	34	68	61	142	2	58	127	9	
35	356	358	36	22	25	No	63	23	27	85	52	144	22	53	122	9	
36	425	436	43	25	29	Yes	71	27	28	96	57	136	24	62	120	14	
37	447	455	43	28	28	,,	72	26	32	81	57	127	2	61	129	11	

Right Female Femurs from Rothwell—*continued.*

Number of Femur measured.	Oblique Length.	Maximal Length.	Diameter of Head.	Least Transverse Diameter of Shaft.	Greatest Ant.-Post. Diameter of Shaft.	Facet in Front of Neck.	Width of Lower Articulation.	Platymeria: Ant.-Post.	Platymeria: Transverse.	Platymeria: Index.	Amount of Bowing.	Index of Bowing.	Angle of Torsion.	Length of Neck.	Angle of Neck.	Obliquity of Shaft.	Remarks.
38	388	394	41	25	27	No	65	26	31	84	48	123	11°	54	130°	8°	
39	400	404	40	25	26	...	...	24	27	89	58	145	...	53	130	10	
40	406	415	40 ?	28	31	No	69	27	31	87	60	146	11	54	122	13	
41	420	...	43	25	26	...	...	26	34	76	51	121	34	60	126	...	
42	411	413	43	26	26	No	65	24	31	78	55	134	10	53	126	8	
43	442	448	45	25	27	...	67	24	30	80	65	148	22	55	...	10	Groove external to gluteal ridge.
44	398	405	40	25	25	...	68	24	32	75	55	137	30	55	132	12	
45	402	405	45	28	31	...	71	26	33	79	59	148	20	54	125	9	
46		383 ?	43	26	26	No	...	23	30	77	45	118 ?	...	55	126	...	Deep pit in long axis of front of neck.
47	397	401	41	23	23	,,	64	23	30	77	48	120	25	51	128	10	
48	413	420	45	25	26	Yes	...	28	31	90	49	120	29	58	120	13	
49	412	421	40	29	25	,,	70	27	32	84	50	122	10	63	126	13	
50	403	408	42	24	27	...	67	25	28	89	53	133	25	50	133	8	
51	388	392	41	25	24	...	...	23	31	74	48	123	8	62	123	10	
52	422	425	45	30	26	Yes	72	27	31	87	55	131	17	59	124	10	
53	...	373 ?	41	25	25	,,	...	24	28	86	54	146	...	54	126	...	
54	420	427	45	26	30	...	68	26	34	76	60	143	27	52	132	12	
55	...	396 ?	41	27	26	...	...	24	33	73	57	146	...	55	125	...	
56	414	422	41	21	23	...	...	23	29	79	...	...	...	60	126	13	
57	406	412	43	25	26	...	68	25	30	83	50	122	12	49	129	11	Marked osteo-arthritis of head.
Average.	mm. 415 (52)	mm. 416 (53)	mm. 43 (55)	mm. 26 (55)	mm. 28 (55)	Present in 58%	mm. 68 (42)	mm. 25 (55)	mm. 32 (55)	78 (55)	mm. 56 (54)	137 (54)	18 (49)	mm. 56 (54)	126 (54)	10 (49)	

Left Female Femurs from Rothwell.

Number of Femur measured.	Oblique Length.	Maximal Length.	Diameter of Head.	Least Transverse Diameter of Shaft.	Greatest Ant.-Post. Diameter of Shaft.	Facet in Front of Neck.	Width of Lower Articulation.	Platymeria: Ant.-Post.	Platymeria: Transverse.	Platymeria: Index.	Amount of Bowing.	Index of Bowing.	Angle of Torsion.	Length of Neck.	Angle of Neck.	Obliquity of Shaft.	Remarks.
1	414	418	43	27	28	...	69	27	32	84	63	154	−3°	58	123	14°	
2	457	461	39	26	27	Yes	63	23	32	72	53	115	30	57	126	6	Groove outside gluteal ridge.
3	429	432	44	26	30	No	69	24	33	73	58	135	30	57	126	9	
4	412	413	45	26	27	...	69	24	35	68	60	146	23	58	122	6	Groove outside gluteal ridge.
5	422	425	43	25	31	Yes	75	25	33	76	57	136	18	60	128	9	
6	412	416	...	26	26	...	67	25	32	78	53	129	20	...	129	10	Osteo-arthritis of head.
7	420 ?	...	43	27	30	No	...	27	33	82	55	131	10	54	127	...	
8	438	444	...	28	28	...	68	25	32	78	57	129	12	55	118	13	

9	403	409	40	26	24	...	67	25	32?	78	50	125	11	...	127	13	
10	444	450	44	27	25	Yes	71	24	39	61	44	100	15	64	125	13	
11	443	448	43	27	31	,,	73	27	31	87	58	132	−8	62	118	10	
12	403	407	41	25	24	,,	67	25	35	71	55	137	28	57	127	9	
13	409	413	44	27	27	,,	69	26	33	79	58	141	30	55	119	12	
14	386	389	41	27	26	No	68	26	33	79	56	144	10	49	122	10	
15	444	447	43	31	31	Yes	69	27	37	73	58	132	12	57	120	12	
16	425	429	44	29	31	,,	68	29	34	85	53	126	17	60	126	14	
17	388	390	40	25	28	,,	...	27	29	93	45	115	22	55	121	9	
18	422	424	43	27	29	,,	65?	26	34	76	52	124	25	56	126	17	
19	443	451	42	28	28	,,	70	27	35	77	55	125	20	53	122	11	Groove outside gluteal ridge.
20	439	442	44	28	31	No	70	25	34	73	57	129	20	57	129	10	
21	411	414	44	31	27	Yes	68	26	38	68	50	122	15	62	118	16	
22	434	439	43	28	29	,,	71	27	34	79	53	123	10	57	118	14	
23	428	433	45	25	29	,,	67?	26	31	84	57	133	22	62	130	12	
24	410	415	39	26	28	No	63	21	33	63	56	137	12	51	121	11	Arthritis at lower end.
25	400?	...	42	25	26	Yes	...	24	29	83	...	...	...	59	129	...	
26	414	422	42	27	25	,,	63?	23	29	79	53	129	−12	57	131	10	
27	410	414	43	25	25	No	67	27	36	75	52	125	24	55	122	11	Slight third trochanter.
28	428	431	43	27	25	Yes	70	25	34	73	49	114	26	58	129	11	
29	439	442	41	27	30	...	69	25	35	71	59	134	26	57	130	9	
30	420	421	44	26	29	Yes	70	27	33	82	46	110	30	55	127	10	
31	395	397	41	26	28	...	68	27	33	82	54	138	22	58	125	12	
32	453	463	43	26	32	No	68	27	35	77	60	133	30	61	125	13	Arthritis at lower end. Large bony
33	443	443	42	30	24	,,	...	25	39	64	47	107	−5	59	118	2	boss in external supracondylar
34	391	394	40	27	29	Yes	66	27	33	82	56	144	1	59	122	11	ridge.
35	439	442	39	24	27	...	65	26	31	84	60	136	32	56	130	9	Slight groove outside gluteal ridge.
36	398	407	43	26	29	No	67	27	36	75	56	140	14	57	128	16	
37	408	414	41	24	26	Yes	67	...	...	...	50	122	20	53	122	12	
38	408	411	43	25	26	...	69	26	29	90	57	139	12	55	122	11	
39	416	420	41	30	29	...	68	28	38	74	56	133	19	57	124	12	
40	394	399	37	25	25	No	60	22	32	69	48	125	10	53	133	14	
41	407	410	46	27	33	Yes	67	28	38	74	58	141	15	55	120	12	
42	409	411	40	27	25	,,	69	24	34	71	55	134	17	61	125	11	
43	422	424	42	26	28	...	65	24	30	80	52	124	15	58	125	9	Slight osteo-arthritis of lower articulation.
44	425	435	42	29	28	No	65	26	35	74	57	136	18	57	126	14	
45	409	411	41	27	28	,,	69	25	33	76	57	139	20	56	128	10	
46	385	391	41	26	26	Yes	65	23	30	77	58	153	23	50	118	13	
47	431	434	42	29	27	No	67	24	37	65	48	112	2	56	129	10	
48	421	422	41	26	30	Yes	66	27	33	82	51	121	10	59	132	8	
49	399	401	40	26	28	...	64	25	32	78	52	130	4	52	127	10	
50	403	405	46	27	27	Yes	64	27	35	77	58	145	4	58	123	9	
51	398	405	...	25	26	,,	...	23	29	79	51?	128	18	56	129	12	
Average	mm. 418 (51)	mm. 422 (49)	mm. 42 (48)	mm. 27 (51)	mm. 28 (51)	Present in 67%	mm. 67 (46)	mm. 26 (50)	mm. 33 (50)	79 (50)	mm. 54 (50)	129 (50)	16° (50)	mm. 57 (49)	125° (51)	11° (49)	

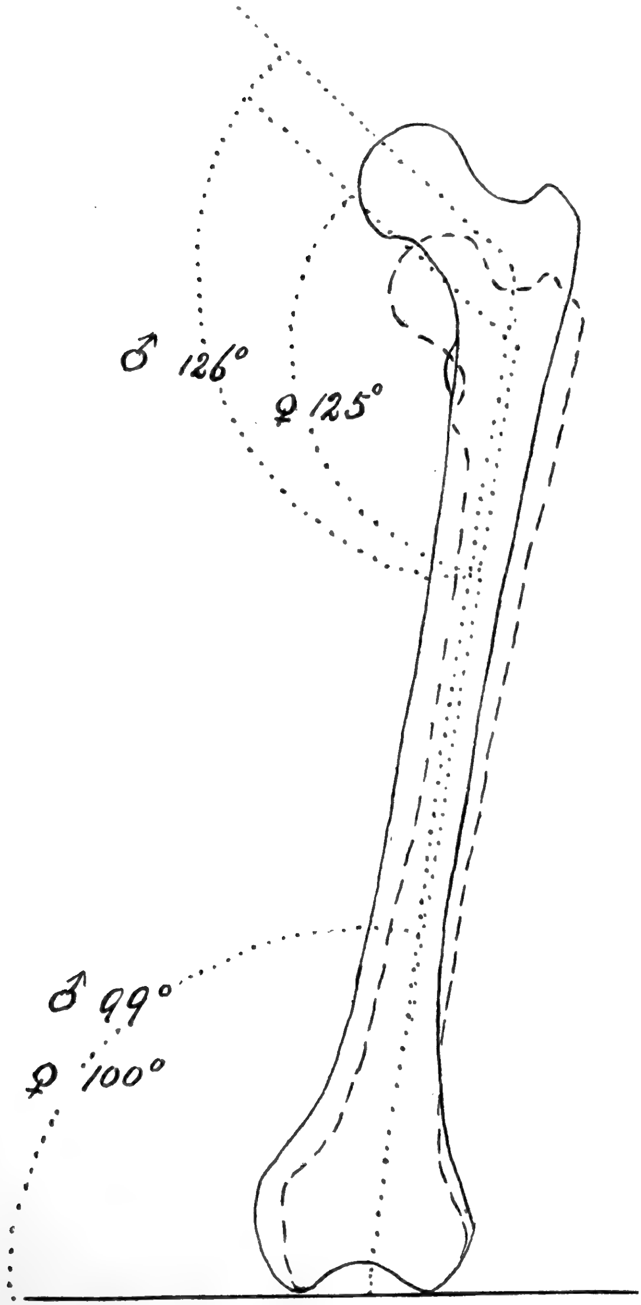

Fig. 4.—Left ♂ and ♀ femurs from Rothwell. (Type contours of 97 ♂ and 49 ♀ bones.) $\frac{1}{3}$ nat. size.

The average maximal length of the right female Rothwell femurs is 416 mm. and the left 422, giving an approximate stature of 160 cm., or 5 feet 3 inches, for the women.

I am only able to check Pearson's chart to a very small extent, but I have the measurements of 21 male femurs removed from bodies the stature of which was known. By Pearson's chart the average height of the 21 men should have been 5 feet $5\frac{3}{4}$ inches, and their actual average was 5 feet $5\frac{4}{5}$ inches. I do not think that we can hope for much greater accuracy than this. I do not know what the actual average of the present-day lower orders is, though the late Mr Gray told me that he believed it to be 5 feet 6 inches. Pearson finds the average of 1000 middle-class English males is 5 feet 10 inches, while 100 of my own students average 5 feet 9 inches. There does not, therefore, seem to be any reason to believe that the English race has grown smaller since the fourteenth and fifteenth centuries, while numerous measurements of Saxon femurs convince me that the males of this race averaged rather less than 5 feet 6 inches.

It is, of course, not enough to give the average lengths in the two sexes without considering the range of variation, and this I have endeavoured to do in the accompanying curves (fig. 5).

The diameter of the head is one of the most useful indications we have of the sex of a skeleton, because it is almost always available, while the pubic portion of the pelvis is one of the first parts to be disintegrated. Dwight (*American Journal of Anatomy*, vol. iv., No. 1, p. 19) gives measurements of 200 male and 200 female American bones in the recent state, and of the 200 male only 4 had femur heads less than 45 mm. in diameter. In the females 16 are over 47 mm., so that if we find a bone with a diameter of less than 45 mm. for the head it is almost certainly female, while a head of over 47 mm. will be that of a male 92 times out of a hundred.

In sexing these Rothwell femurs, therefore, I have paid special attention to the size of the femoral head, but where this measurement came between 45 and 47 mm. I have been specially careful to attend to other points, such as length, thickness, and width of lower end. Often this examination was quite enough to convince me of the sex, but still it is quite possible that a small percentage of the bones I have regarded as male are really those of females, though I do not think it at all likely that I have included more than one or two male bones among the female.

It will be seen from my tables that in 174 male (as I judge them) subjects (98 left and 76 right) the average diameter of the head is 49 mm., and this agrees closely with Dwight's record, for he found that in 200 cases the average was 49·68 mm. I have not gone into fractions of a mm., as I consider it an unnecessary refinement, but, since his average is over 49·5, I should have reckoned it as 50 mm. This slight discrepancy is no doubt

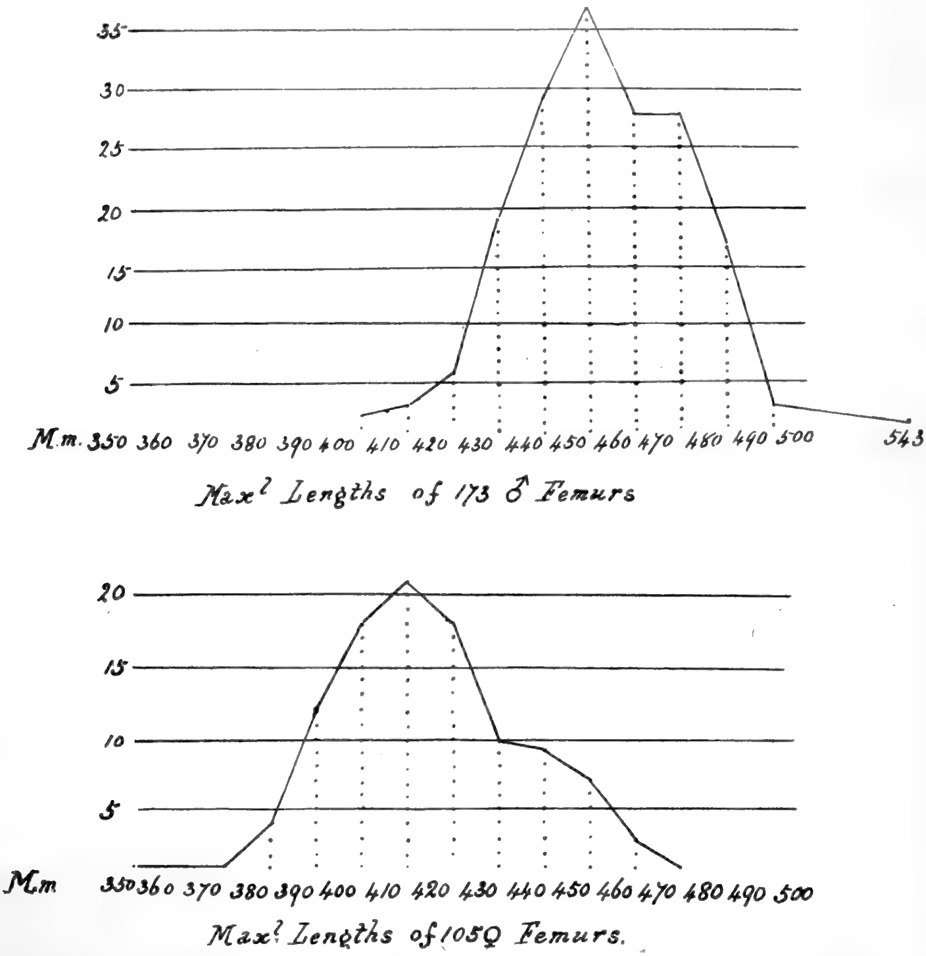

Fig. 5.—Range of variation in the maximal lengths of femurs of both sides from Rothwell.

accounted for by his examining the bones with the cartilage present, while in mine, which were mediæval bones, the cartilage was absent.

In the female Rothwell bones 48 of the left side gave an average of 42 mm., while in 55 right it was 44 mm. Dwight found that in 200 female femurs of which the side is not stated the average was 43·84. In my 103 bones of both sides the average is 43·4 mm., and no doubt the presence of the cartilage largely accounts for the slight discrepancy. On the whole, I am pleased to see how substantially my work confirms Dwight's researches.

The smallest male femoral head in my Rothwell series was 45 mm., the largest 55 mm. I have been able to measure the femoral heads of 31 male and 11 female bodies from the dissecting-rooms of Guy's and St Thomas's Hospitals, and find that all the males were over 45 mm. with the exception of one head on the right side, which was 44 mm., but on the left side of the same body the head measured 46 mm. The average of each side in the males was 49 mm. The smallest female (as I judge it) femoral head from Rothwell was 36 mm., the largest 48 mm.

The least transverse diameter of the shaft is usually a little below the middle, and in male bones averages 30 mm. on the left side and 29 on the right. I have not much at present with which to compare this, but I found that in 8 right Anglo-Saxon male bones the diameter was 28, while in 10 left bones the measurement was the same. This number is probably a small one on which to generalise; but, as far as it goes, it shows that the Saxons were of a slighter build than were mediæval Englishmen. In 31 male bodies from Guy's and St. Thomas's the width of the right femora averaged 28·5 mm. while that of the left was 28·7 mm. In the Rothwell series the left female bones were 27 mm. and the right 26 mm. in breadth, so that in both sexes the left bones were stouter than the right.

In the Saxon female femora there were 6 right and 7 left, and in both the average diameter was 25 mm. (see "Saxon Bones from Folkestone," *Journ. R. Anthrop. Inst.*, vol. xli., 1911, p. 101).

The range of variation at Rothwell is for male bones 24 mm. to 35 mm., for female 21 mm. to 31 mm.

The greatest antero-posterior diameter of the shaft is for the male bones 32 mm. on the left and 31 mm. on the right. In the female it is 28 mm. on both sides.

The facet in front of the neck (see fig. 1) is sometimes covered with cartilage, but at others a rough depression. It is present in 79 per cent. of male bones on each side, while in female bones it is present in 67 per cent. on the left and in 58 per cent. on the right. It is curious that though it is so often present, it is seldom noticed in text-books. In my opinion this facet or depression is just as often present in modern bones as in mediæval or prehistoric, and I cannot believe that it is of the least value as an indication that its possessor was in the habit of squatting, since, in order to get the facet in contact with the margin of the acetabulum it is necessary to flex strongly and rotate internally the thigh. This internal rotation would keep the heels far apart in squatting instead of allowing them to touch; moreover, it is absurd to think that the majority of modern English dissecting-room subjects were in the habit of adopting the squatting position.

The transverse diameter of the lower end of the femur, taken in the manner I have already described (see fig. 2), averages 77 mm. for left male femurs and 75 mm. for right, while in females it is 67 mm. for left and 68 for right.

There seems to be a general, though by no means absolute, ratio between the diameter of the head and that of the lower end, as the following table shows.

Sex.	No. of Observations.	Diameter of Head.	Average Diameter of Lower End.
		mm.	mm.
♀	1	36	63
,,	1	37	60
,,	3	39	64
,,	8	40	67
,,	14	41	66
,,	12	42	67
,,	18	43	69
,,	12	44	68
,,	12	45	70
,,	4	46 and over	68
♂	8	45	74
,,	8	46	74
,,	29	47	74
,,	17	48	78
,,	31	49	77
,,	19	50	76
,,	13	51	79
,,	10	52	78
,,	6	53	78
,,	8	54	83
,,	2	55	82

From the accompanying chart (fig. 6) it will be seen that a femur with a lower-end breadth of 71 or 72 mm. may be of either sex; above 72 it is probably male, below 71 probably female. It is useful to have been able to show that the head-breadth only varies more or less directly with that of the lower end, so that in many femurs in which the measurement of one articular end is negative the other will give a definite clue to the sex.

Platymeria.—As I have said, I do not know that there is any definite index below which a femur may be called platymeric; but to my eye one with an index below 75 attracts attention, and if this be taken as the dividing line, the following results are obtained :—

Out of 105 left ♂ femurs the average index was 81, and of these 9 (8·6 per cent) were below 75, *i.e.* platymeric.

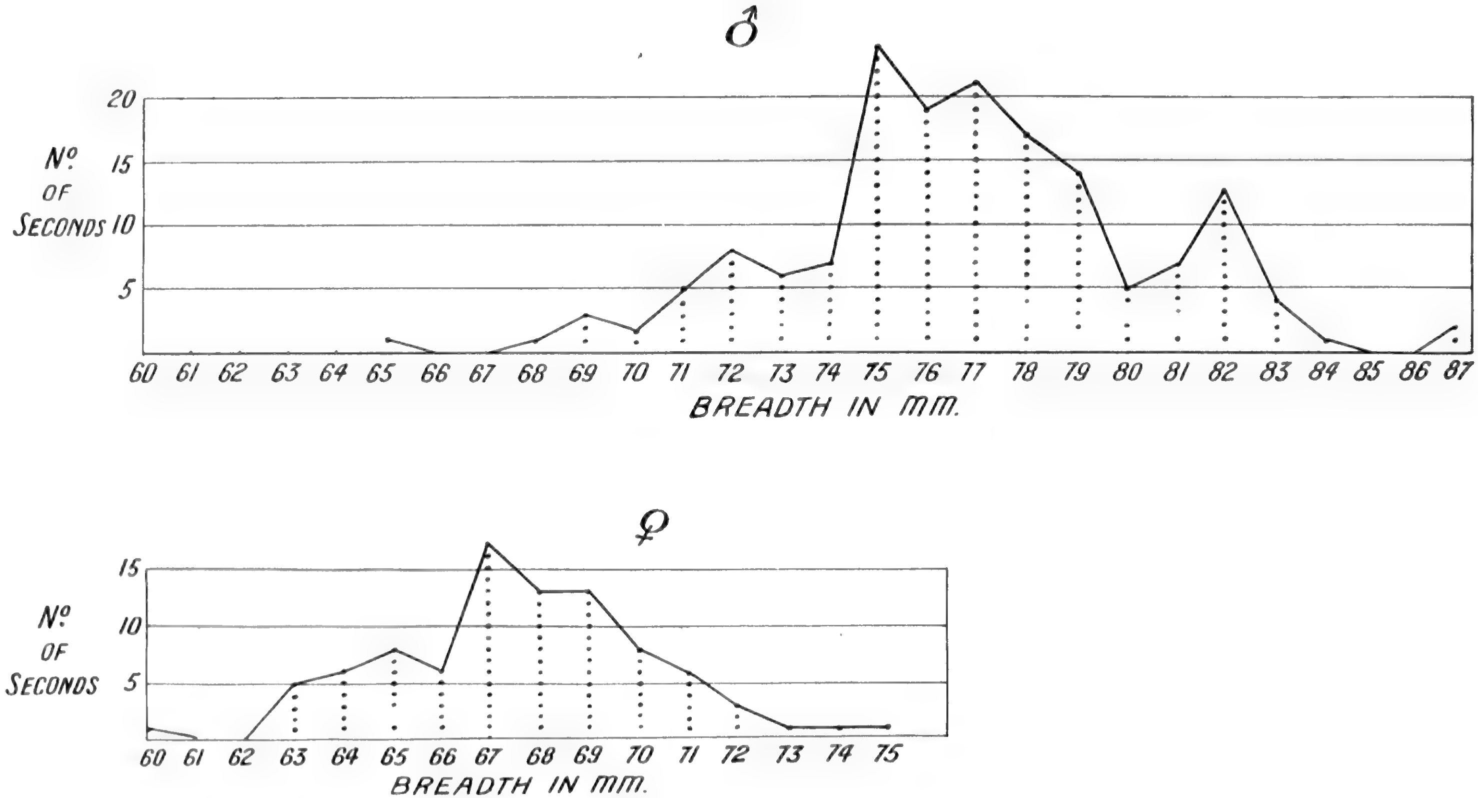

Fig. 6.—Chart of breadth of lower articular end of femur in the two sexes.

Out of 80 right ♂ bones the average index was 77, of which 12 (15 per cent.) were below 75.

Out of 50 left ♀ with an average index of 79, 17 (34 per cent.) were below 75.

Out of 55 right ♀ bones with an average index of 78, 12 (22 per cent.) were below 75.

The average index of the 185 ♂ bones of both sides was 79, while that of the 105 ♀ bones of both sides was 78.

Taking this last paragraph alone, it does not look as if sex made much difference to platymeria, but the foregoing paragraphs show that in the 185 male bones 11·4 per cent. were below the 75 index, while in the 105 females 27·6 were below. This is so marked a difference that I cannot help thinking that platymeria must have been commoner in women than in men

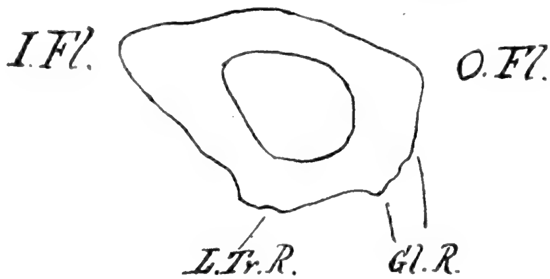

Fig. 7.

at Rothwell—a fact which is directly opposed to Manouvrier's experience, and one which shows that further research on this point is necessary.

The section shown in fig. 7, from a platymeric femur with an index of 63·5, indicates that four ridges are present: (1) the inner flange (I.Fl.), where the strongest pull of the vastus internus comes; (2) the outer flange (O.Fl.), where the vastus externus is most strongly attached; (3) the gluteal ridge (Gl.R.), marking the insertion of the gluteus maximus muscle; and (4) the lesser trochanteric ridge (L.Tr.R.), running from the lesser trochanter to the linea aspera. In most cases the inner flange is better developed than the outer, but occasionally the reverse is the case, as in fig. 8, B. It must be remembered that the fibres of the vasti run obliquely forward and downward from these ridges to the quadriceps extensor tendon, while the fibres of the gluteus maximus run inward and upward from the gluteal ridge, so that it is extremely unlikely that there is any good reason for accepting the suggestion that the latter muscle has anything to do with the production of the outer flange; moreover, fig. 8 shows that the two flanges may reach their maximum some distance below the region of the lesser trochanter and the insertion of the gluteus maximus. Another point is that in these platymeric femora the great trochanter and spiral line are often drawn forward, apparently by the traction of the upper and strongest attachment of the crureus.

To my mind, everything which I have seen in connexion with platymeria points to the action of the vasti as its cause.

I believe that the Rothwell people were more platymeric than are modern Englishmen for the following reason. Through the kindness of my anatomical colleagues at Guy's Hospital I have been able to examine the right

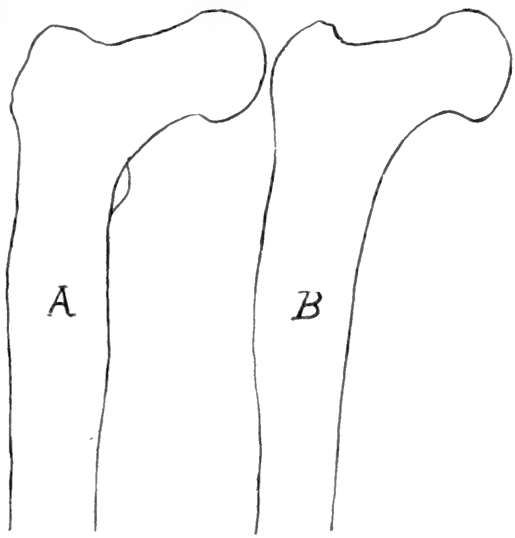

FIG. 8.

femurs of 27 subjects in that hospital and at St Thomas's; the average platymeric index of these was 83, while in 26 left femurs the index was 86.

The following comparison may be instructive:—

Male Platymeric Indices.

	Right.	Left.
Jutes from Folkestone	79 (8)	79 (4)
Mediæval English from Rothwell	77 (80)	81 (105)
Modern English from Guy's and St Thomas's Hospitals	83 (27)	86 (26)

The number of Jutes (in brackets) is too small to generalise upon; but, taking them for what they are worth, it looks as though the same cause which produced platymeria in these early English was operative in the mediæval English of the fourteenth century and is not nearly so active now.

The above table also seems to show pretty conclusively that platymeria is and was more marked on the left side than the right.

Antero-posterior bowing of the femur.—The following table shows the average amount of actual bowing of the femur measured by the method described on p. 241:—

		Maximal.	Minimal.
	mm.		
75 R. ♂	61	75	53
95 L. ♂	62	78	47
54 R. ♀	56	65	45
50 L. ♀	54	63	44

The index of bowing, which shows the amount in proportion to the length of the bone, is—

		Maximal.	Minimal.
75 R. ♂	135	170	117
95 L ♂	135	171	104
170 both sides ♂ . .	135		
54 R. ♀	137	162	107
50 L. ♀	129	154	100
104 both sides ♀ . .	133		

It is usually held that the shortest femora are most liable to bowing, and this is borne out in this collection, because I find that the 12 actually most bowed femora average 3 mm. below the average length, while 24 relatively most bowed average 5 mm. below.

Again, the 21 longest femurs in the collection are less bowed than the average in the proportion of 129 to 135.

The angle which the axis of the neck makes with the long axis of the shaft is as follows:—

	Average.	Maximal.	Minimal.
79 R. ♂	127°	140°	113°
104 L. ♂	126°	138°	112°
54 R ♀	126°	133°	114°
51 L. ♀	125°	133°	118°

From this it is evident that the angle of the neck is of no value as an indication of sex.

It is usually held that the longest femurs have the most vertical necks. To test this, I took the 18 right femurs which had a maximal length of over 470 mm., and found that the average angle of their necks was 127°, which is the average for the right side, so that the result is negative; but on picking out the 11 femurs of both sides which have an angle of 135° and over, I find that their average length is 466 mm. against a general average of 458. It therefore seems probable that the femurs with the most vertical necks are the longest, though it does not seem correct to say that the longest femurs have necessarily the most vertical necks.

The length of the neck, measured as directed on p. 241, gives the following results:—

	Average.	Maximal.	Minimal.
	Mm.		
78 R. ♂	65	86	55
102 L. ♂	66	83	55
54 R. ♀	56	63	49
49 L. ♀	57	64	49

The two maximal lengths of 86 mm. on the right side and 83 on the left were so phenomenal that I have gone over all their other measurements

Fig. 9.

with great care, in the hope of finding some other characteristic correlated with length of neck; but I have been unable to find any clue to the meaning of this curious abnormality, which in the case illustrated by a dioptographic tracing in fig. 9 amounts almost to a deformity. That the two bones

(L. ♂ No. 63, and R. ♂ No. 27) did not come from the same individual is quite clear from the difference in their lengths.

Hirsch (*Anatom. Hefte*, Bd. xxxvii., 1899) states that a long neck to the femur is accompanied by a high angle of the neck, and a short neck with a low angle. To test this, I worked out the average of the angle of all those femurs whose neck was above the average length as well as of all those in which the neck was the average length or below—with the following results:—

	Average Angle.
51 ♂ left femurs whose neck was over 65 mm. (average) .	126°
51 " " " " " 65 mm. or below .	124°
37 ♂ right " " " over 65 mm. (average) .	128°
46 " " " " " 65 mm. or below .	126°
18 ♀ left " " " over 57 mm. (average) .	125°
31 " " " " " 57 mm. or below .	125°
25 ♀ right " " " over 56 mm. (average) .	125°
30 " " " " " 56 mm. or below .	126°

As far as these English femurs go, therefore, the males bear out Hirsch's contention: the necks above the average length have on each side a wider angle by 2° than the average necks or those below the average. In the female bones, however, there is practically no difference in the angle of the long and the short necks.

The degree of torsion of the shaft, measured as described on p. 241, gives the following results:—

	Angle of Torsion.	Maximal.	Minimal.
69 R. ♂	13°	30°	− 13°
98 L. ♂	13°	40°	− 17°
49 R. ♀	18°	34°	+ 2°
50 L. ♀	16°	32°	− 12°

This table points to the female bones being more twisted than the male. I cannot find, however, that length by itself is correlated in any way with torsion, because I have picked out all the femurs with a torsion above and below the average, and find that their average lengths vary hardly at all from the normal.

The point which has struck me most is the enormous range of variation in the twisting of the femur, and that in a certain number of cases the lower end is actually twisted outward instead of inward—in one case to the amount of 17° (see fig. 10).

I cannot find, after going over my material carefully, that excessive torsion is correlated with any other constant physical characteristic of the femur, though it may well be with that of some other part of the skeleton.

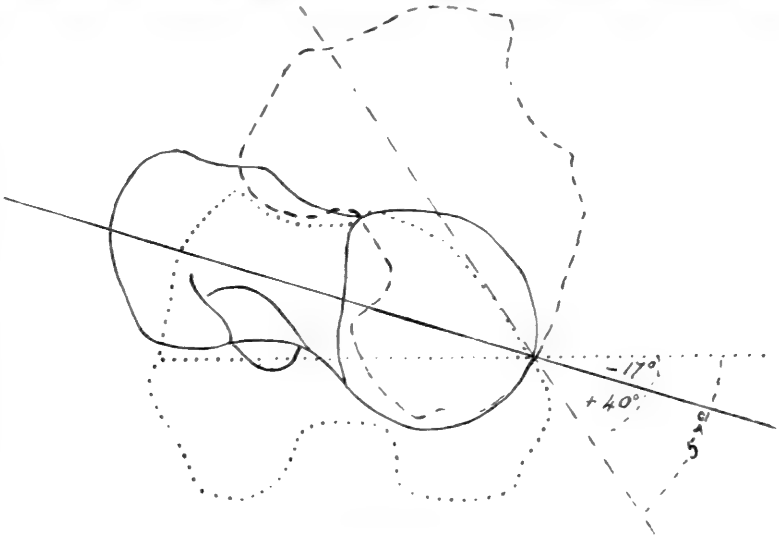

FIG. 10.

It is something, however, to have demonstrated what a great range of variation is possible.

The obliquity of the shaft, measured as described on p. 242, gives the following results:—

	Average Obliquity.	Maximal.	Minimal.
71 ♂ R.	9°	17°	4°
97 ♂ L.	9°	14°	5°
49 ♀ R.	10°	14°	5°
49 ♀ L.	11°	17°	2°

From this it appears that the female femur is one or two degrees more oblique than the male, but it is obvious that the amount of obliquity would be of no use in determining the sex of any particular bone.

Other things being equal, one would expect that the shorter bones would be more oblique than the longer, though the breadth of the pelvis, the length of the neck, and the angle of the neck would be disturbing factors.

To test this theory, I picked out the 82 male femora of both sides in which the obliquity was more than 9° (the normal), but to my surprise their average maximal length was 456 mm., against the normal for all male femora of 458 mm. I am therefore compelled to believe that the disturbing factors above mentioned must play a more important part than I had thought

Of these I was able to check the length and obliquity of the neck, but not the breadth of the pelvis, and I therefore took 79 of the 82 male femora above mentioned, to see whether the average length of their necks was greater than the normal. I could not take all the 82, because in 3 of them the measurements were not all available.

In these 79 the average length of the neck was 65 mm., which is the normal for the whole male series; while the average angle of the neck was 126°, which, again, is practically the normal, so that the result of this work was negative, and I have no reason to believe that in a large series special obliquity of the femur is associated with (1) diminished length of shaft, (2) increased length of neck, or (3) diminution in the angle of the neck. It is, therefore, presumably associated with increased breadth of pelvis, and this is the more likely since the obliquity is greater in the female than in the male bones.

The next point upon which I want some definite information is the number of observations upon which one may venture to generalise.

In working through a Saxon or Bronze Age burial-ground one sometimes finds that perhaps only 10 femurs are available for measurement on the right side or the left. How far is one justified in deducing the average stature of the tribe or race from 10 femurs?

To get some working idea of this, I have divided my measurements of the maximal femur lengths into segments of 10 as they came, and have taken the average of each 10, and noticed how far it departed from the average of all the bones, with the following results:—

In the left male femurs at Rothwell the average length of 98 bones was 460 mm. Of these—

The 1st 10	averaged	474,	or 14 above	the general average.
„ 2nd „	„	472,	„ 12 „	„ „ „
„ 3rd „	„	462,	„ 2 „	„ „ „
„ 4th „	„	459,	„ 1 below	„ „ „
„ 5th „	„	455,	„ 5 „	„ „ „
„ 6th „	„	467,	„ 7 above	„ „ „
„ 7th „	„	445,	„ 15 below	„ „ „
„ 8th „	„	457,	„ 3 „	„ „ „
„ 9th „	„	456,	„ 4 „	„ „ „

In the right male femurs the average length of 76 bones was 456 mm. Of these—

The 1st 10 averaged	459, or	3 above	the general average.
„ 2nd „ „	463, „	7	„ „ „ „
„ 3rd „ „	461, „	5	„ „ „ „
„ 4th „ „	460, „	4	„ „ „ „
„ 5th „ „	452, „	4 below	„ „ „
„ 6th „ „	459, „	3 above	„ „ „
„ 7th „ „	443, „	13 below	„ „ „

In the left female femurs the average length of 49 bones was 422 mm. Of these—

The 1st 10 averaged	432, or	10 above	the general average.
„ 2nd „ „	421, „	1 below	„ „ „
„ 3rd „ „	428, „	6 above	„ „ „
„ 4th „ „	415, „	7 below	„ „ „

In the right female femurs the average maximal length of 53 bones was 416 mm. Of these—

The 1st 10 averaged	428, or	12 above	the general average.
„ 2nd „ „	433, „	17	„ „ „ „
„ 3rd „ „	419, „	3	„ „ „ „
„ 4th „ „	415, „	1 below	„ „ „
„ 5th „ „	411, „	5	„ „ „ „

From this I gather that if these bones had come to me in groups of 10 I should probably have over- or under-estimated their average length by about 7 mm. on an average. In 13 of the 25 groups of 10 I should have been within 5 mm. of the general average, but in 1 group I should have been out by 17 mm.

A mathematician would no doubt state the case much more satisfactorily, but I fancy that the above method gives the field or charnel-house worker a fair idea of this position, since the greatest error, that of 17 mm., when applied to Pearson's tables (*Phil. Trans.*, vol. cxcii. pp. 169–244) only makes a difference of 2 cm. in the average height of the group.

I cannot help believing that one would be quite justified in estimating the height of a race to within an inch on the evidence of 10 femurs, provided their lengths were accurately taken, though no doubt a series of 20 or 30 would be more desirable.

In other measurements, such as those of the diameter of the head or the breadth of the lower end, where the range of variation is less, the evidence of 10 femurs would be more reliable still.

Summary.

1. In the thirteenth, fourteenth, and fifteenth centuries the Midland English, on the evidence of 300 of their thigh-bones, had an average stature of 5 feet 5¾ inches for the men, and 5 feet 3 inches for the women.

2. No absolute information can be drawn from the Rothwell series as to the sexual value of the diameter of the head, since the sex of the bones was unknown and was largely determined by the size of the head. The sexing was done on the evidence of Dwight's observations in New York, checked by my own records of 42 modern English femurs the sex of which was known. When the head is more than 47 mm. in diameter, it is regarded as male; when below 45 as female. Between these measurements the length, thickness of shaft, and width of the lower end are taken into account, and in this way the error of sexing is probably so small as to be negligible in a large series

3. The left femur, both in males and females, averages 3 mm. more in its oblique length than the right.

4. There is an average difference of 3 mm. between the maximal and oblique lengths, but there is a range of variation from 0 to 11 mm.

5. Speaking generally, the greater the obliquity of the femur, the greater is the difference between the oblique and maximal lengths.

6. In the Rothwell bones, as in those of modern English people, the diameter of the head of the male femur averages 49 mm., while that of the Rothwell females is 43·4 mm.

7. The width of the lower end of the femur forms a valuable clue to the sex in many of those cases in which the diameter of the head is negative or impossible to obtain. A breadth of 71 or 72 mm. may be of either sex. Below 71 it is probably female, above 72 probably male.

8. At Rothwell platymeria is quite common, but is much less so in modern English femurs; it is commoner here in women than in men, and is more marked on the left side than on the right.

9. The amount of antero-posterior bowing of the shaft is greater in short bones than in long; the index is also slightly greater in male than in female bones.

10. The angle of the neck seems a trifle (1°) less on the left side than on the right, and also about 1° less in females than in males. Femurs with very vertical necks are usually the longest.

11. In the male femurs those with necks above the average length have a more open angle to the neck by 2° than those with necks of the average or below the average length. In the females there is no appreciable difference.

12. The pressure facet on the front of the neck was present in over three-quarters of all male, and in over half of all female bones. It seems quite as common in modern dissecting-room bones, and, since I have no reason to believe that it is associated in these latter with a squatting posture, I am disinclined to regard it as the result of squatting in ancient bones.

13. The amount of torsion of the shaft of the femur is very variable, but appears to be greater in women than in men. In a certain number of cases there is an external instead of an internal twist of the lower end of the bone.

14. The female femur is 1° or 2° more oblique than the male. The amount of obliquity does not seem to vary with the length of the bone, the angle of the neck, or the length of the neck. It is possibly associated with the breadth of the pelvis, though I cannot check this in this research.

15. It seems possible to estimate the size of a race to within an inch from the lengths of 10 femora, though doubtless a greater number is desirable.

Finally, I should like to call attention to a small prominence on the popliteal surface of the femur a little above the internal condyle. I have not hitherto seen it described, though it is usually to be found if looked for. I believe that it is caused by the pull of the uppermost fibres of the inner head of the gastrocnemius. In one specimen from the dissecting-room of Guy's Hospital it was of great size, and the records of abnormalities, which at this hospital are very accurately kept, show that the inner head of the gastrocnemius was larger than usual and rose from the eminence. The point is of some slight interest in showing that, although this muscle rises chiefly from the epiphysis of the femur, some of its fibres extend up to the diaphysis.

THE LOWER ENDS OF THE WOLFFIAN DUCTS IN A FEMALE PIG EMBRYO. By Frederic Wood Jones, D.Sc., *The London School of Medicine for Women.*

The present communication is intended to deal with a mere presentation of the conditions that are actually illustrated, and, like a previous communication on the External Genitalia of the Human Female (*Jour.*, xlviii. p. 73), is to be regarded only as an isolated study carried out as part of a wider survey of the mammalian genitalia. The sections which are illustrated were cut some ten years ago. The facts which they illustrate are by no means new, but I think it is advisable to record them as showing a definite phase in the evolution of the genital ducts in the pig. The stage recorded and illustrated is that found in fœtuses of 12 centimetres rump-vertex length. The series of sections is shown in order from head to tail, and the photographs represent on the average every fifth section of the series.

In the most cephalad sections (see figs. 1 and 2) the fused Müllerian ducts have constituted a wide and patent canal (vagina, fig. 1), seen upon the dorsal side of the section, and towards the ventral side of the section is the cavity of the urethra, both chambers being surrounded by a well-defined common musculature.

Upon the ventral aspect of the fused Müllerian ducts, and embedded in their mesenchyme stroma, are the minute Wolffian ducts (W.D.).

As the sections are traced towards the caudal end, the lumen of the Müllerian ducts diminishes and becomes again bilateral by the closure of the central part of the canal (see fig. 3). After a short distance traversed in this fashion, even the bilateral Müllerian elements become reduced to solid columns of cells (see fig. 4).

Meanwhile the lumen of the Wolffian ducts is becoming increasingly large.

Still further towards the hind end the solid Müllerian columns become difficult to trace, and are closely applied to the dorsal aspects of the ever-enlarging Wolffian ducts (see figs. 5 and 6).

In the section represented in fig. 7, the two enlarged Wolffian ducts have met and fused in the middle line, forming a single median Wolffian chamber; and the Müllerian elements have become still further reduced.

Finally, in the section shown in fig. 8, the Wolffian chamber has opened into the urinary canal, forming a uro-genital sinus.

I think it is not unreasonable to interpret the condition shown as being a definite phase in the development of the female pig embryo, in which the Wolffian ducts are the only genital channels opening into the uro-genital sinus. In this phase the Müllerian ducts are reduced to solid epithelial cords, and the uterine cavity has no outlet into the uro-genital sinus. The single median genital opening is a Wolffian chamber into which apparently the Müllerian ducts will open when they become patent later on in fœtal life.

For the production of the microphotographs which illustrate this paper (pp. 270–273) I am indebted to the kind help and skilled assistance of the Anatomical Department of King's College.

[FIGS. 1–8.

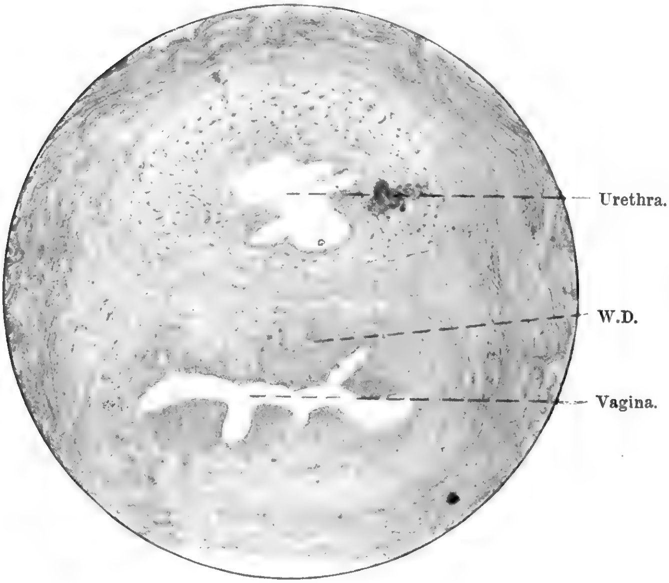

Fig. 1.

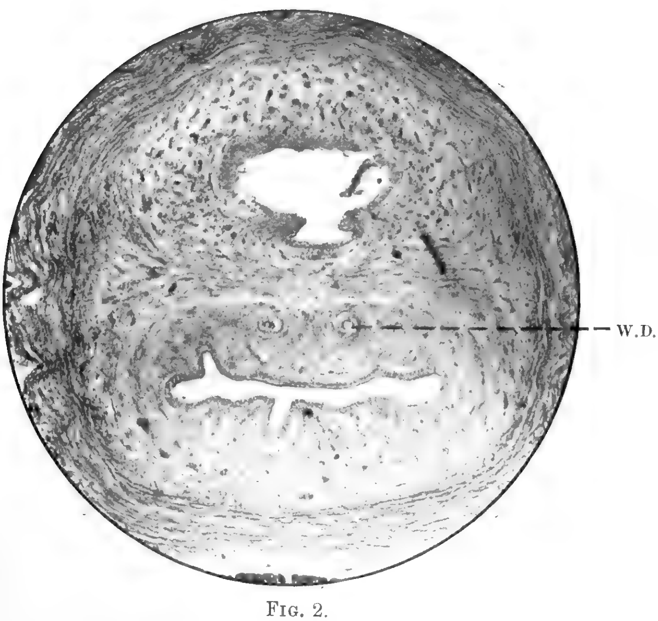

Fig. 2.

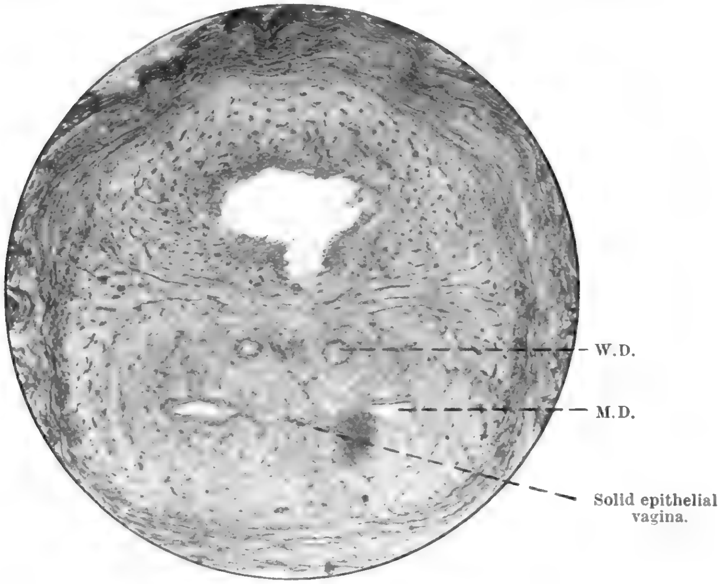

Fig. 3.

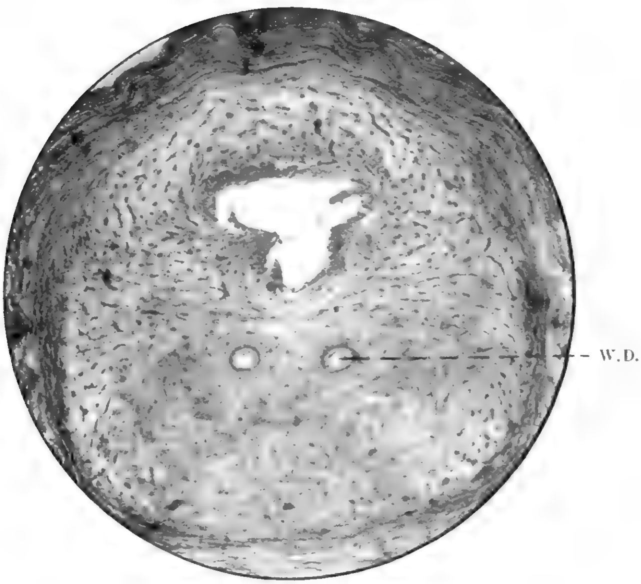

Fig. 4.

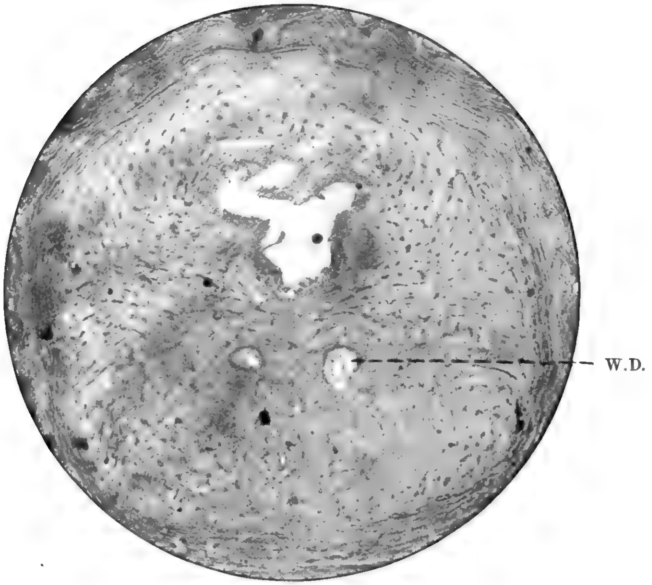

Fig. 5.

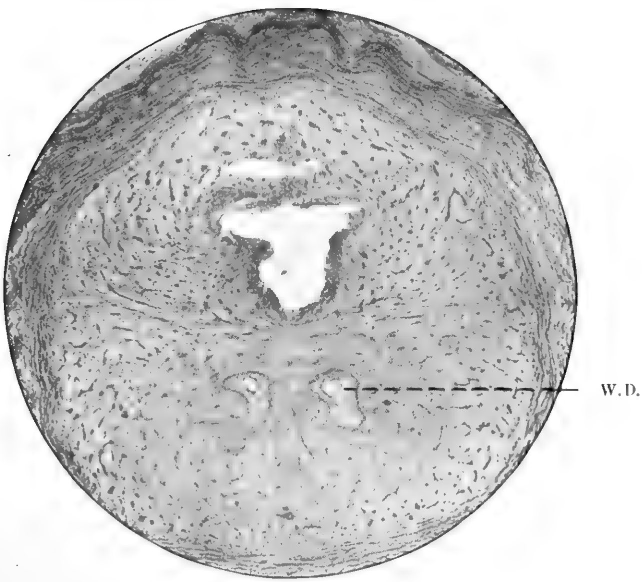

Fig. 6.

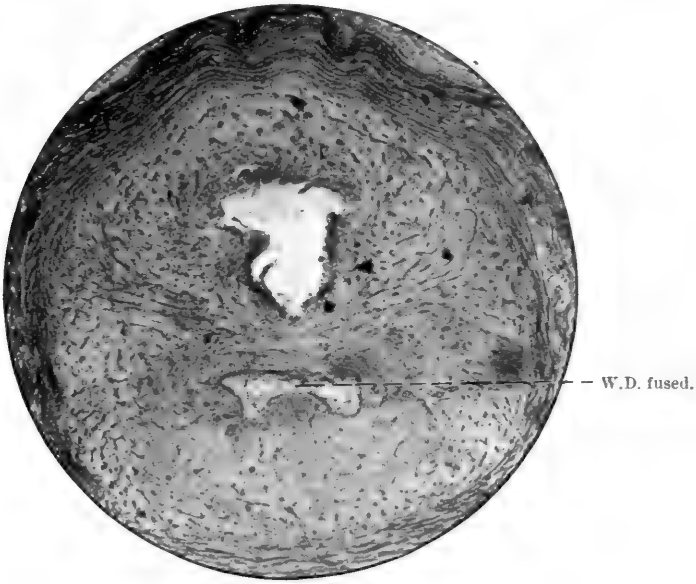

Fig. 7.

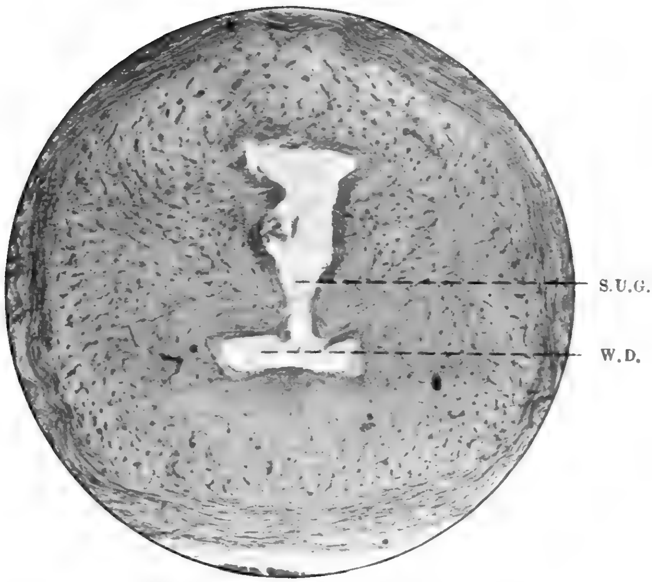

Fig. 8.

TWO CASES OF CARDIAC MALFORMATION—MORE ESPECIALLY OF THE INFUNDIBULAR REGION.

By D. Davidson Black, B.A., M.B. (Tor.), *Assistant Professor of Anatomy, Western Reserve University, School of Medicine, Cleveland, Ohio, U.S.A.*

The two specimens of malformed heart which form the subject of this communication are of interest in view of the recent work by Keith on the relation of cardiac malformation to the development of the heart (1), (2), (3). The present cases offer further examples of anomalous infundibular development.

Both cases came to autopsy at the Cleveland City Hospital, and I am indebted to Dr A. A. Johnston, resident pathologist, and Dr Harrison G. Wagner, upon whose service the patients were admitted, for the opportunity of examining the material.

Specimen I.—The specimen was obtained from a male negro, æt. 22, labourer, weight 130 lbs., height 5 feet 10 inches. A clinical diagnosis was made of pulmonary tuberculosis and congenital pulmonary stenosis. Chronic circulatory stasis was indicated by a condition of club-fingers and enlargement of the ends of the long bones. There was no sign of œdema to indicate cardiac failure. No cyanosis was observed, but this may readily have been overlooked on account of the patient's colour.

Description of Heart (fig. 1).—The organ as a whole is enlarged (weight 425 gms.). The right atrium is normal; the foramen ovale is patent to a considerable extent in its superior portion. The tricuspid valve shows several slight roughenings on its atrial surface near the free margin. The wall of the right ventricle is increased in thickness to 1·3 cm., and the infundibular portion is separated from the body of the ventricle, giving the heart the appearance of a triventricular organ. Communication is established between these two portions of the right ventricle by a well-marked ostium bulbi (1 cm. in diameter), and by several irregular openings towards the apical portion of the ventricle between the trabeculæ carneæ. These relations are shown semi-diagrammatically in fig. 1. The pulmonary artery, which arises from the infundibulum, is markedly stenosed in the region of the semilunar valve. The valve is formed of two modified cusps, which are thick and fibrous, and so united as to leave between them only a small slit-like opening 5 mm. in diameter (*v.* fig. 2). Above the level of the valve the vessel is thin-walled and increased in diameter to 15 mm. The interventricular septum is deficient in its superior portion, giving rise to a large interventricular foramen situated immediately behind the septal cusp of the tricuspid valve.

The left mitral valve is normal. The left ventricle is also normal, with the exception of the foramen interventriculare already noted. The aorta, which is 25 mm. in diameter at its base, is somewhat smaller than normal, and is provided with a well-formed semilunar valve. The average diameter of the aortic base in the normal adult is 27–28 mm. (4 and 5). The relation of the coronary arteries at their origin is normal. The condition of the ductus arteriosus could not be determined, for the greater

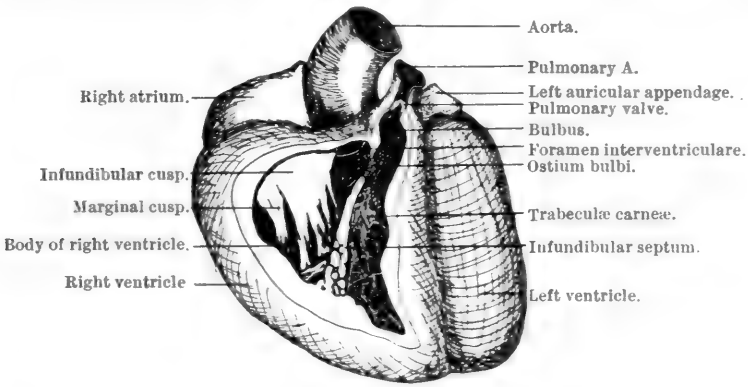

Fig. 1.

part of the pulmonary artery and aortic arch had been removed from the specimen, and no note regarding the ductus was made at autopsy.

The position of the foramen interventriculare is such that, owing to the stenosed condition of the pulmonary orifice, the major portion of the blood from both ventricles passed directly into the aorta. This relation of the base of the aorta to the interventricular septum and the ventricles is shown diagrammatically in fig. 2.

Of the nineteen hearts described by Keith (2) as having infundibular subdivisions of the right ventricle, in only one case did the infundibular chamber reach the apex of the organ. In the present case, the infundibular cavity extends to the apex, and although there is a partial communication between the body of the right ventricle and the apex of the infundibulum through the meshes of muscular trabeculæ, yet the division between the two chambers is obvious.

The infundibular septum is wholly muscular in the case under discussion, and the ostium bulbi is guarded by an incomplete fibrous ring on the ventricular side. This orifice is situated immediately in front of the interventricular foramen. In most of the cases described by Keith which showed almost complete suppression of infundibular development with consequent pulmonary stenosis, the branches of the pulmonary artery were very thin-walled and frequently much enlarged in diameter. A similar enlarged condition of the pulmonary trunk obtains in the present case. In 70 per cent. of Keith's cases, no patent ductus arteriosus was present. Thus, the increased diameter of the pulmonary vessel above the level of the semilunar valve cannot be considered as indicative of the presence of a patent ductus.

The presence of a large foramen interventriculare may be accounted for by the incomplete infundibular development. Keith (2) observes: "In the majority of such cases (85–90 per cent.) an interventricular foramen is

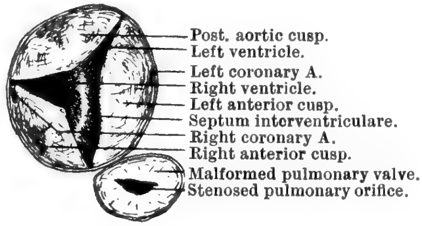

Fig. 2.

present." These facts support Hunter's view that pulmonary obstruction is the essential factor preventing closure of this foramen. Indeed, it would be difficult to imagine the attainment of adult life by an individual whose heart presents an advanced condition of pulmonary stenosis, accompanied by a well-developed right ventricle, and yet exhibits no interventricular communication.

Specimen II.—The specimen was obtained from a male child, æt. 6 months, whose death was due to accidental causes. The case showed no evidence whatever of any cardiac insufficiency.

Description of Heart (fig. 3).—The right atrium is normal, and the fossa ovalis presents the normal small aperture at its superior margin. The tricuspid valve shows several slight roughened areas on the atrial surfaces near the margins of its cusps. The adjacent margins of the infundibular and septal cusps are adherent to the interventricular septum, and between these cusps is an opening (7 mm. in diameter) leading through the membranous portion of the interventricular septum into the left ventricle. The pulmonary artery, which appears enlarged, measures 12 mm.

in diameter at the semilunar orifice. The ductus arteriosus, which is 5 mm. in diameter, arises from the pulmonary artery at its bifurcation. The attachment of the ductus to the aortic arch could not be made out, as the latter had been removed from the specimen. The mitral valve is normal. The left ventricle is normal, with the exception of the foramen interventriculare already noted. This foramen is situated immediately below the origin of the aorta. The aorta measures only 8 mm. in diameter at the level of the aortic valves, and is thus barely more than two-thirds the diameter of the pulmonary artery. This is unusual, as the normal ratio between the diameter of the pulmonary artery and aorta in early life is 4 : 3. The walls and valves of the aorta are of normal texture. The origin of the coronary arteries is normal.

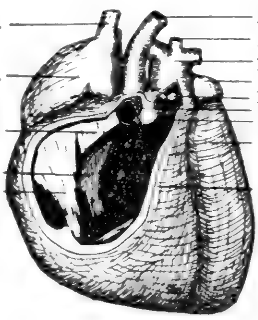

FIG. 3.

This specimen appears to be one of those rare cases in which there is no stenosis of the pulmonary artery or isolation of the infundibulum to account for the presence of the interventricular foramen. As in the similar cases recorded by Keith (2), the margins of the interventricular foramen are membranous. The relation of the tricuspid valve to this foramen is of interest. In the heart illustrated in fig. 3, the infundibular cusp is cut, otherwise the foramen could not be seen in the view represented.

The relations of the *supraventricular crest* point to its identity with Keith's *right infundibular band*. It certainly forms a distinct boundary between the bulbus and the body of the right ventricle. Notwithstanding the presence of a comparatively large interventricular foramen, the walls of the right ventricle are thinner than those of the left ventricle.

In the absence of stenosis in the aorta, the small diameter of the vessel is unusual. It may be that the persistence of the interventricular foramen is related in some way to the undersized aorta. In such a case the excess of blood not accommodated by the aorta in ventricular systole would find vent through the interventricular foramen, and become one of the factors contributing to the increased size of the pulmonary artery.

Specimen II. is thus an example of a heart which presented several fundamental anomalies, and yet performed its function adequately. Its irregular structure had no bearing on the death of the individual.

It is a well-known fact that in cases of more or less prolonged respiratory embarrassment there is a marked tendency toward polycythæmia. Dixon Mann (6) has pointed out that the rise in the number of red corpuscles is apparently related to a decreased power of internal respiration. He further observes that any of the factors causing the latter condition may produce an increase in the number of red cells. In the congenital heart malformations under discussion, there is a free admixture of venous and arterial blood in the systemic arteries. In other words, these cases must have a decreased internal respiratory power, which demands a compensatory polycythæmia.

In the first case described in this paper, the red corpuscles were increased to 7,228,000 per cubic mm., and no observations were made as to cyanosis. In Case II., no cyanosis was present, but unfortunately no blood-count was made.

From the number of cases on record of patent interventricular foramen in which the patients showed but little if any signs of cyanosis during life, there can be no doubt that simple admixture of venous and arterial blood in the systemic arteries does not necessarily produce this condition. To quote Lorrain Smith (7): "In general, cyanosis is due to any cause which prevents due oxygenation of the blood." This must mean that, if the absolute quantity of oxygen in the blood falls below a certain minimum, cyanosis will result. The limit of the power of the organism to react successfully to the anomalous circulatory condition is thus marked by the appearance of cyanosis.

The question of tissue respiration and the relation of cyanosis to polycythæmia leads to an interesting line of inquiry regarding the evolution of the homoiothermic type of circulation.

Arrested development in a mammalian heart, allowing a free admixture of pulmonary and systemic blood in the systemic arteries, gives rise, physiologically at any rate, to a reptilian type of circulation. This circulation being unsuited to the needs of an homoiothermic animal, must be reinforced in some way in order to provide an oxygen supply sufficient to maintain life.

In the case reported by Dixon Mann (6), and also by Young (8), and Young and Robinson (9), there was a total lack of interventricular septum, and yet the patient lived to the age of 35 years, and showed no sign of cyanosis till the last three weeks before his death, and but few signs of cardiac embarrassment during his life. Such a case demonstrates the ability of the mammalian organism to cope more or less successfully with a reversion to ancestral circulatory conditions.

Thus the mammalian organism reacts toward this condition of circulation in at least two ways: by reduction of the general activities, and by an increase in the number of oxygen carriers in the blood. It would be of interest to determine whether this latter reaction could be rightly considered as an ancestral reversion, and if so, whether, in the primitive homoiothermic forms, an increase in the number of oxygen carriers in the blood preceded the changes in the mechanics of circulation which result in the formation of the two-sided heart typical of birds and mammals.

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FIGURES RELATIVE TO CONGENITAL ABNORMALITIES OF THE UPPER URINARY TRACT, AND SOME POINTS IN THE SURGICAL ANATOMY OF THE KIDNEYS, URETER, AND BLADDER.

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THE facts to be recorded in this paper are gathered from the post-mortem records at Guy's and the London Hospitals, as well as those of the Victoria Hospital for Children. The Guy's records include the years from 1890 to 1909, the London Hospital 1909 and 1910, and the Victoria Hospital 1889 to 1912.

No reliance has been placed upon indexes, but each report has been carefully read through, in order to arrive at some definite conclusion with regard to the percentage of congenital defects and other lesions of the genito-urinary apparatus.

The total number of records consulted is 13,505, of which 8218 are males and 5287 females, or practically 10 males to 6·4 females. All the three hospitals showed the same proportion. It is important to bear these figures in mind when discussing the relative incidence of disease, or anatomical peculiarities, in the two sexes.

The paper deals especially with the incidence of congenital defects of the upper urinary tract. The frequency of disease in the right kidney, when compared with the left, is worthy of the closest attention; and it is plain that the anatomical differences which exist in the relations of the two kidneys may have something to do with this fact, which is now very generally recognised.

Finally, it is intended that attention should be drawn to a very important anatomical point in connexion with the bladder, which every anatomist probably knows, but which text-books either ignore, or upon which they give wrong advice.

The congenital defects of the upper urinary tract are considered under three headings, namely:—

1. Solitary kidney. 2. Horseshoe kidney. 3. Double ureter.

1. Solitary Kidney.

Figures with regard to solitary kidney vary very much. White and Martin give solitary kidney as occurring in 1 in 400 cases. Sir Henry Morris gives 1 in 4000. I strongly suspect that some of the figures given are based on very scanty evidence, such as is supplied, for example, by indexes of records. Be this as it may, the figures which are given here are as follows:—There are 23 cases of solitary kidney in the 13,000 odd reports consulted, or practically 1 in 587. Of these 23 cases, there were 14 males and 8 females, and 1 whose sex is unrecorded. Bearing in mind the preponderance of male post-mortem records over female, we see that the incidence of solitary kidney is practically equal in the two sexes.

Further details with regard to these cases of solitary kidney may be briefly summarised thus:—

Right kidney present	8
Left kidney present	13
Doubtful side	1
Sacral kidney present	1

Adrenals recorded as present in 6 cases.

Both testicles recorded as present in 3 cases.

Other abnormalities were noted as being present in 3 cases, viz.:—

Imperforate anus and deformity of lower limb	1
Four-lobed right lung	1
Right tube and ovary not connected with uterus; right kidney absent	1

In all cases the solitary kidney was larger than usual.

In 3 cases the solitary kidney was provided with two ureters, opening either together or separately at or near the bladder orifice.

In 4 cases the bladder ureteric outgrowth was present—patent for about an inch, and terminating in a fibrous cord.

A very interesting case of solitary kidney is that of a male child aged 6 weeks. The autopsy was performed by Professor H. R. Dean, at the Victoria Hospital. In this case there was a lobulated left solitary kidney, reaching as low as the bifurcation of the aorta, with three segmental vessels passing to the kidney from the left side of the aorta; and with two ureters, one from the front and upper part, and extending downwards in front of the organ to the pelvis, and another ureter passing from the lower and narrow end of the kidney. The upper ureter passed to the bladder and opened into that viscus in the usual position of the left ureter; the lower ureter cut across the bifurcation of the aorta lying superficial to that vessel, and, passing into the pelvis, opened into the bladder in the position of the right ureter. Is this a double kidney? Is it a misplaced or displaced horseshoe kidney, or a single segmental kidney, or is there some deeper significance? I suggest, with deference and regard for the opinion of workers in this field, that it may be perhaps a condition allied to the descent of the testicle, which hears, as it were, the call of the mammary line and turns thither, and that the right ureter passing upwards heard no right renal call, but, determined to do its duty, was attracted by the left kidney, and passed across the middle line to join the left kidney.

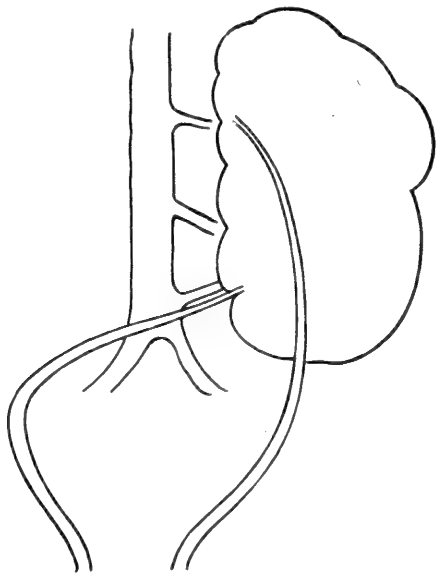

Diagram of case of solitary kidney with double ureter.

2. Horseshoe Kidney.

From the records of Guy's and the Victoria Hospital, comprising approximately 11,150 cases, there have been collected 16 cases of horseshoe kidney, or roughly 1 in 620 cases of all subjects. In this series males show a large preponderance over females—14 males to 1 female and 1 uncertain. I tabulate a brief summary:—

The concavity was directed upwards in 10 subjects.

" " downwards in 2 subjects.

Not recorded in 4 subjects.

A bridge of renal tissue is said to have existed in 5 subjects.

The ureters lay in front of the renal mass in 5 cases, and in 2 they lay behind.

There was a single ureter in 2 cases—in 1 of which it lay behind, in the other in front.

The renal mass was displaced downwards in 5 cases.

Other abnormalities of the body were noticed in only 2 cases, viz.:—

Recto-urethral fistula	1
Lobeless right lung	1

3. Double Ureter.

Attention may now be directed to the occurrence of a double ureter. By the term "double ureter" is meant that condition in which the ureter is double along the whole distance from kidney to bladder.

From conversations which I have had with some of my surgical colleagues at Guy's, I gather that the condition is very rarely met with at operations. The statistics quoted below show that the surgeon might expect to find it more frequently than operation records indicate hitherto. There are cases in which X-rays show a ureteral calculus which is not found at the operation. In such instances the calculus may be in the second ureter.

Fer many reasons I have preferred to rely upon the London Hospital records. These are so carefully kept, especially with regard to anatomical features, that I cannot help thinking that a certain distinguished member of the Anatomical Society must have kept a very watchful eye upon the post-mortem room at that hospital.

Out of 2456 cases at the London Hospital, 16 had double ureters, or roughly $\frac{2}{3}$ per cent., a figure sufficiently large to warrant the surgeon to look for it when operating on the kidney. Of these 16 cases, which do not include those cases which showed abnormal kidneys, the extraordinary feature is the large preponderance of females over males, viz. 13 females to 3 males. This is a point well worthy of consideration, not only from the operative point of view, but also from the clinical, as I think there can be little doubt that more kidneys are cut down upon for purely subjective symptoms in females than in males.

In 2 cases the ureters were double on both sides; in 7 cases they were double on the left side only, and in 7 cases on the right side only.

4. Some Points in the Surgical Anatomy of the Kidneys and Ureters.

In the list of diseases affecting the kidneys which is appended, one astonishing feature stands out quite clearly. The right kidney is affected much more frequently than the left. One reason of this is, perhaps, the relation which the large intestine bears to the kidneys. On the right side the dilated ascending colon and hepatic flexure lie in close relation to the kidney, sometimes in actual contact with its surface. On the left side the contracted descending colon is in contact with the kidney. Other relations, which need only be mentioned here, are the crossing of the right ureter by the mesentery, the more direct crossing of the iliac vessels by the right ureter than the left, and the relation of the liver to most of the pelvis of the right kidney, as compared with the relation of the pancreas to a small part of the left pelvis. Moreover, the duodenum is connected with the pelvis of the right kidney by connective tissue. I believe that all these features may conduce to a retardation of flow of urine along the right ureter, when compared with that along the left. There is absolute proof of this being the fact in six cases I have collected from my records. They are cases in which precisely the same lesions were found in both kidneys, and in which bleeding had taken place into the pelvis of both kidneys. In one of these cases clotted blood was found in both kidneys. In five of them clot was found only in the right kidney, proving, to my mind, that blood, at any rate, escapes with greater difficulty from the right kidney than from the left, and that therefore the flow of urine along the right ureter may be retarded also. Perhaps one of these cases should be rejected, as in it there was primary carcinoma of the bile-duct, which may have led to pressure upon the right renal pelvis; but the left kidney was in precisely the same pathological state as the right.

Morbid Anatomy Statistics (Renal).

	Right.	Left.	Unilateral.	Both.
Injury	22	19	. .	3
Calculus	102	81	5	22
(Clinical, Mr King) . .	59	41	...	...
Infarcts	52	49	...	...
Miliary tuberculosis . .	21	9	1	...
Local tuberculosis . .	11	4	...	7

Retention of blood in renal pelvis:—Right only, 5; left only, 0; bilateral, 1:

Sex.	Age.		
F	62	Growth of bile duct . .	Retention of blood in right renal pelvis.
...	...	Nodule, left kidney . .	
M	3	Multiple hæmorrhages .	
M	38	Acute or chronic nephritis .	
M	16	Cardiac	
M	$\frac{8}{12}$	Hæmorrhagic cystitis .	
		Ascending nephritis . .	
M	17	Purpura hæmorrhagica .	Retention of blood in both renal pelves.

5. The Relation of the Peritoneum to the Bladder.

Since taking up the duties of surgeon in charge of the genito-urinary department, I have been struck with two features, with regard to the relation of the peritoneum to the bladder when it is full or overfull. The first feature is clinical, and is that there is resonance over the full bladder more often than not. This means that there must be bowel in front of the full bladder, and if bowel, then general peritoneal cavity. The second feature is operative. At all operations which I have performed upon the bladder suprapubically, I have always seen the peritoneum on its anterior surface, however full it was. Obviously these features are important, especially as the books, surgical and anatomical, definitely state that the peritoneum is raised off the anterior surface of the bladder as that viscus is being filled.

I have dissected several subjects with a view to finding out what are the actual facts, and they appear to be these:—

First, an elementary point. The fundus of the empty bladder is not the fundus of the dilated bladder. To the fundus of the empty bladder the urachus is attached; as the bladder is filled, or overfilled, the urachus is pulled up, and raises a fold of peritoneum. On either side of this fold of peritoneum the general peritoneal cavity descends to a level below the upper border of the pubic ramus and body. The diagrams in the text-books of the ascent of the peritoneum with the filling of the bladder should on the one hand, if in the middle line, show the urachus, and on the other hand, if not in the middle line, should not show the peritoneum raised.

I consider that we, as anatomists, should warn the surgeon of this relation of the peritoneum to the full bladder; and at the present time I will not have suprapubic puncture performed, as I consider the risk of contaminating the general peritoneal cavity too great for this operation to be justifiable. I have dissected the parts of a man who had a suprapubic puncture performed for the largest bladder I have ever seen. 102 ounces of urine were drawn off. In this case the trocar went very near to the general peritoneal cavity. In some cases of death after suprapubic puncture, uræmia has been assigned as a cause. Let us not forget the possibility of a general peritonitis. In this specimen also the general peritoneal cavity lay in front of the bladder on either side of the urachus.

6. Finally, I have dissected a specimen which indicates the importance of the branch which the renal artery sends to the suprarenal capsule. The renal pedicle had been tied, and the resulting clot in the renal artery stops short at the origin of the suprarenal branch, suggesting that the site of ligature relative to this branch should be carefully considered by the operator when the renal artery is being tied. This may be a very obvious fact which has just been demonstrated, but it affords a very interesting example of the importance of small things in anatomy.

ANOMALY OF THE INFERIOR VENA CAVA: DUPLICATION OF THE POST-RENAL SEGMENT.

By HAROLD RISCHBIETH, M.A., M.D., B.C. (Cantab.), F.R.C.S. (England), *Adelaide, South Australia.*

THE anomalous condition of the inferior vena cava here recorded was found by Professor A. Watson in a body in the Anatomical School of the University of Adelaide. The body was that of a male pauper lunatic who had died of senile decay in the Parkside Lunatic Asylum, Adelaide, at the age of 74 years.

I have to thank Professor Watson for permission to place this case on record. It seems to be of sufficient interest, in comparison with instances of somewhat similar anomalies recorded in the *Journal of Anatomy and Physiology* during the years 1911 to 1913 by Cameron, Gladstone, Johnston, and Waterston, to warrant publication.

There was a large hydatid cyst of the left lung which depressed the left dome of the diaphragm and the spleen, and appears to have caused downward displacement of the left kidney, the lower pole of which was tilted forwards, and caused chronic intestinal obstruction, of a partial kind, at the splenic flexure of the colon. The portion of colon proximal to the splenic flexure was dilated, its wall thickened, its vessels dilated, while the portion of colon distal to it was collapsed.

The conditions shown are as follows:—There are two inferior venæ cavæ posterior to the level of the renal veins; anterior to these only one. The calibre of these paired trunks seems about the same, but the left is, of the two, the lesser. With each of these venæ cavæ an external iliac and an internal iliac vein communicate—at the level of bifurcation of the common iliac artery. The internal iliac vein on each side receives the obturator vein, and, distally, does not appear to receive vessels of notably abnormal origin. But passing obliquely from the internal iliac vein of the right side to the vena cava of the left side, there is a large communicating vein, of about the calibre of the internal iliac veins of either side, which joins the left inferior vena cava above the level of bifurcation of the common iliac artery, and about 1 inch above the level of junction of the external iliac and internal iliac veins of the left side. All the main venous trunks above described have normal relationships to arteries, *i.e.* they pass upwards internal and posterior to main arteries.

The communicating vessel that has been described as passing from the right internal iliac vein to the left inferior vena cava receives three vessels. One, the largest and to the left, is the inferior mesenteric vein.[1] The other two, of lesser calibre, and about equal in this, are lateral sacral veins.

The right inferior vena cava is joined, on its anterior aspect, about $1\frac{1}{2}$ inches below the level of its junction with the right renal vein, by the right spermatic vein, and laterally and posteriorly by three lumbar veins. The right renal vein is single, from its origin in the kidney pelvis to its junction with the "right" vena cava. The left renal vein has a double origin in the kidney pelvis. The two vessels unite to form a common left renal vein, and this, about half an inch from its origin, is joined by the left inferior vena cava. The left spermatic vein communicates with these two vessels at their junction. The common venous trunk thus formed passes obliquely upwards and to the right, immediately "tailwards" of the superior mesenteric artery, anterior to the abdominal aorta, to unite with the "right" inferior vena cava just "headwards" of the confluence of the right renal vein with this trunk. (As has been already stated, the left kidney is situated "tailwards" of the right, and this may account for the obliquity of this vessel.) The renal veins of both sides pass in front of the renal arteries. The left inferior vena cava receives, posteriorly, two lumbar veins; it also receives, at its junction with the "common" left renal vein, a vein which passes "headwards," between the left crus of the diaphragm and psoas muscle, and "headwards," a vein which appears to be musculo-phrenic. There are no transverse communications, either in front of or behind the aorta, between the right and left inferior venæ cavæ. The venous trunks joining the single inferior vena cava formed by the junction of these two (right and left) inferior venæ cavæ are in no way abnormal.

On opening the thorax the lungs were turned forwards and the thoracic venous trunks were dissected. *On the right side*, the vena azygos major arose from the ascending lumbar vein and terminated normally. *On the left side*, the inferior azygos vein arose from the vein described (marked x in the diagram) as passing into the thorax from the posterior aspect of the junction of the left common renal vein with the left inferior vena cava between psoas muscle and the left crus of the diaphragm. The left superior azygos vein was normal. No other abnormality of the venous system was noted. The arterial system in this body was apparently normal. These conditions are broadly shown in the accompanying photograph (fig. 1),

[1] Thus the superior hæmorrhoidal vein communicates with the general venous system and not with the portal system.

and an attempt has been made to represent them more clearly and fully in the diagram (fig. 2).

Fig. 1.

The anomaly may be explained as an abnormal persistence of the posterior cardinal vein on the left side as far "headwards" as the left renal vein. I do not propose to discuss the significance or origin of the condition shown, as the whole of this subject has been recently discussed in the *Journal of Anatomy and Physiology.* It suffices, therefore, to record facts.

It may be of interest, however, to compare this case with some of the

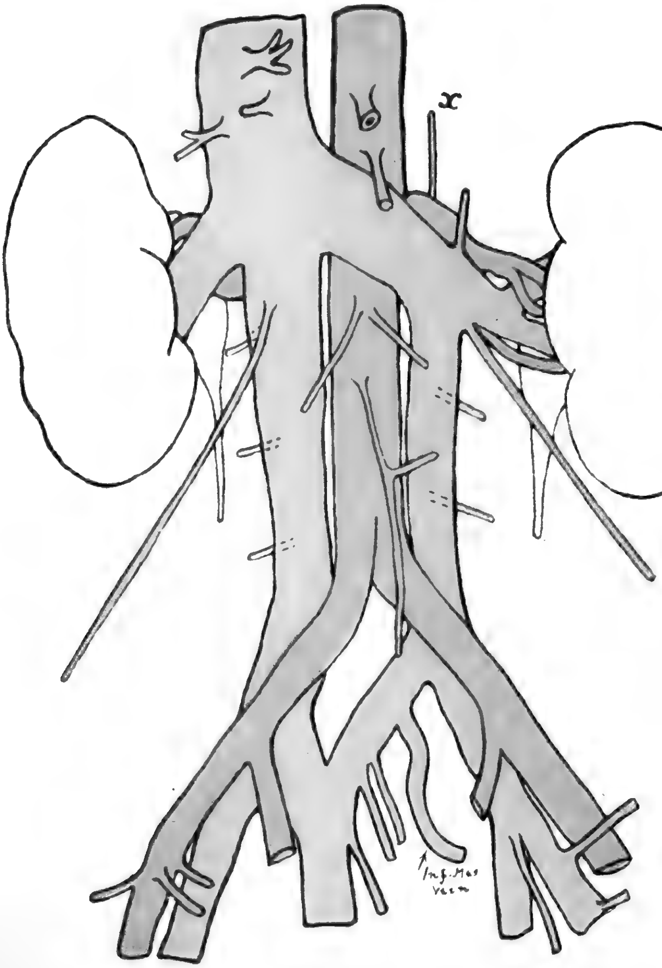

Fig. 2.

instances of somewhat similar anomalies of the inferior vena cava that have been recorded. In the *Journal of Anatomy and Physiology,* vol. v., 1871, p. 227, there is an account quoted from the *Nederlandsch Archief voor Genees. en Natuurkunde,* vol. v., of an anomaly of the inferior vena cava which seems to show some resemblances to the present case. But the description appears to me to be indistinct; at least I cannot clearly perceive what the conditions were from it. Mr Waring (*Journal of Anatomy and Physiology*, vol. xxviii., 1894, p. 46) states: "Many examples of double inferior vena cava have been recorded by Gruber, Kadzi, Nicolai, Petsche, Kollmann, Walter, and Walsham." He then proceeds to describe a case of left inferior vena cava without transposition of viscera. To this one need only refer in passing. In the same volume of this journal, p. 376, Professor Bertram Windle, in a "Report on Recent Teratological Literature," refers to Kollmann's account of a number of abnormalities in connexion with the inferior vena cava. Professor A. Keith, in a paper upon "The Frequent Occurrence of a Divided Inferior Vena Cava in the Genus Hylobates (Gibbon)," which is published, in abstract, in *The Proceedings of the Anatomical Society of Great Britain and Ireland*, November 1895 (*Journal of Anatomy and Physiology*, vol. xxx., 1896, Proceedings, ii.), refers to six specimens that he had dissected, and in four of which the inferior vena cava was divided in the region posterior to the kidneys. (In two of these the left renal vein passed in front of the abdominal aorta to join the right renal vein, as in our case. In the other two, the left renal vein passed behind the aorta.) In this paper Professor Keith referred to the fact that Kollmann had found about thirty cases of this arrangement of veins recorded as having occurred in man; but he, Professor Keith, thought it was probably much more frequent than this small number suggested, probably as frequent as 1 in 150 bodies.[1] In this paper it is stated, upon the authority of Hochstetter, that a divided inferior vena cava occurs in the Ornithorhynchus and Echidna, in dolphins, seals, hedgehog, cat, and rabbit. In some of these animals Professor Keith had verified the statement, but he had not found the condition in fifty Catarrhine monkeys dissected.

"Amongst Gibbons, divided inferior vena cava occurs most frequently in the female; this is probably true also of the human race. The usual persistence of the right cardinal vein as the entire vena cava may be connected with the lower position of the right kidney; at any rate, in the case of a left inferior vena cava, and often in the cases of divided inferior venæ cavæ, the left kidney was lower than the right."[2]

At the same meeting of the Anatomical Society, Mr Parsons showed a

[1] Professor Watson states that in 496 bodies dissected in the Anatomical School of the University of Adelaide, the case here described was the only instance of it that occurred. But in another body in this number the superior vena cava was on the left side.

[2] This is of interest in connexion with the present case; for here the left kidney is lower than the right. There is, however, another possible explanation here. There is a large hydatid cyst occupying the lower lobe of the left lung. This pushes down the left dome of the diaphragm, and, by pressure upon the spleen, may be the cause of the low position of the left kidney, the lower pole of which is also displaced forwards.

drawing of a double inferior vena cava found in the St Thomas's Hospital dissecting room, in a male subject. At this meeting Mr Black also referred to two cases in man. Professor Dwight (*Journal of Anatomy and Physiology*, vol. xxxv., 1901, p. 12), states: "A not uncommon anomaly is the persistence of what is commonly called the lower part of each cardinal as high or higher than the renal veins"; but he is dealing with "Absence of the Inferior Vena Cava below the Diaphragm," and the condition that he shows in the plate is not the same as in our case.

In the same volume of this *Journal*, p. 123, are accounts of four cases of anomalous inferior vena cava from the dissecting room of the University of Cambridge. Two of these appear to have been very like the case here described.

In the *Journal of Anatomy and Physiology*, vol. xlv., 1911, p. 416, is an account by Dr John Cameron of an instance of persistence of the left posterior cardinal vein which presents some slight resemblance to our case, but also considerable differences. Gladstone, in the same *Journal*, vol. xlvi., 1912, p. 220, records a case of left inferior vena cava. This seems to represent a different developmental anomaly, but comparison with the present case may be of interest.

In the *Journal of Anatomy and Physiology*, vol. xlvii., 1913, p. 235, Johnston describes an anomaly of the inferior vena cava with which it also seems of interest to compare our case; while in the same volume of this *Journal*, p. 433, Waterston describes an instance of "duplication of the post-renal segment of the vena cava inferior" which shows a condition almost identical with it—yet not quite.

References to a considerable number of further publications upon the subject of anomalies of the inferior vena cava are given by these authors in their papers; but I cannot obtain these in South Australia. Perusal of the papers above referred to seems, however, to justify the inference that duplication of the post-renal segment of the inferior vena cava is a not very uncommon anomaly. There appears, however, to be some difference of opinion upon the question whether the paired or the unpaired anomalies of the vena cava inferior are the more frequent. For instance, Waterston, if I understand him aright, thinks the latter are the more frequent; but most of the other authorities quoted appear to hold a contrary opinion. The purpose of the present paper is not to determine this point, but to record the facts of our case, which, for purposes of comparison or contrast, seems to be of sufficient interest to warrant publication.

A COMMUNICATION AS TO THE CAUSATION OF LARGE VASCULAR GROOVES FOUND ON THE INNER ASPECT OF THE OS PARIETALE. By BERNARD COEN, M.B., *Demonstrator of Anatomy, University of Sydney.*

THE grooves I wish to draw attention to are to be found close to the grooves formed by the middle meningeal vessels; in fact, they are sometimes the only grooves to be seen. They are not of frequent occurrence and they differ markedly in character from the ordinary meningeal grooves.

Many writers have noted that grooves differing in character from the ordinary meningeal grooves are to be found close to the coronal suture, but have not attributed them to causes other than the meningeal vessels.

Professor Elliot Smith records the case of a man falling as the result of a cerebral hæmorrhage and fracturing the skull from one temporal region to the other along large grooves which were in position just posterior to the coronal suture. The grooves in the case he mentioned were very deep, and extended down to the inner aspect of the outer table of the skull (1).

Poirier and Charpy have apparently described these grooves, and speak of them quite explicitly as being due to the meningeal vessels (2).

In a recent paper of Dr Wood Jones these grooves are attributed to meningeal vessels (3).

In one writer only, Oscar Schultze, have I been able to find an account testifying to the fact that diploic veins have come to the surface of the meninges. The writer, however, apparently describes small veins near the vertex of the parietal bones (4).

With the evidence before me, I must express the view that though some of the larger grooves are meningeal in origin, others are not due to the meningeal vessels, but have been caused by the diploic venous tissue eroding the inner table of the skull and leaving deep gutter-like grooves as the result.

I recently examined, in the dissecting-room, the skull of a Chinaman. The certificated cause of death was "senile decay." The skull showed a large deep vascular groove just posterior to the coronal suture on the left side (fig. 1, *a*). A few millimetres posterior to this groove was another.

much shallower, groove which ran parallel to it in the lower part of its course, but which diverged from it as it was traced up towards the vertex. On the inner aspect of the right parietal bone of the same skull enlarged diploic vessels could be plainly detected through the inner table; they appeared as bluish linear stains (fig. 1, *b*, *c*, *d*). This is, I think, a somewhat unusual condition, and it was this chance finding of the venous diploic tissue visible through the inner table which suggested that the large deep

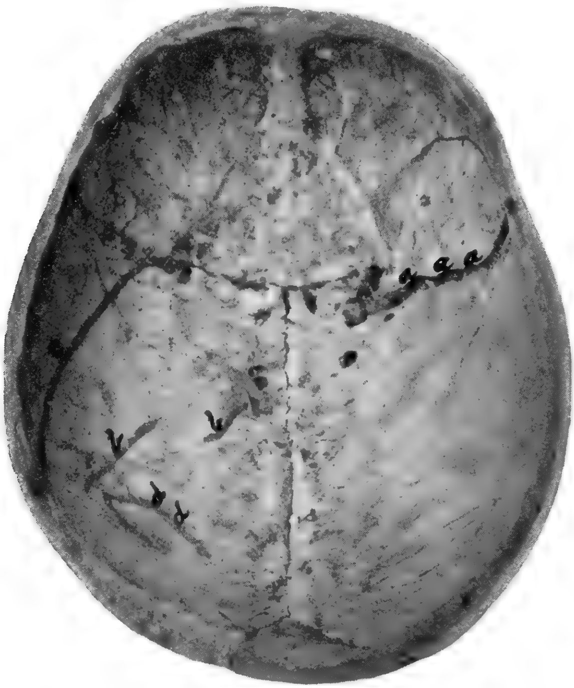

FIG. 1.—Photograph of cerebral surface of calvaria of a Chinaman (senile) showing:—

a, *a*, *a*, large vascular groove of diploic venous origin. Skirting the posterior margin of this groove may be observed a small and shallow "meningeal groove" proper; *b*, *c*, *d*, dark linear stains over right parietal bone due to underlying diploic veins. (During subsequent treatment the specimen was accidentally broken along the line *c*. The inner table was carefully removed along the line of the linear stain *d*.)

groove on the left parietal was of diploic origin. The observation of these facts, and the suggestion they give rise to, may not be sufficient to bear out the contention I have advanced. There are, however, other reasons which may be obtained from (1) a study of the characters of the large groove compared with those of the groove lying posterior to it, which latter is admittedly due to a meningeal vessel; (2) a study of the characters of the grooves that the diploic venous tissue gives rise to on the inner aspect of the outer table of the skull, where this forms the outer wall of a normal diploic canal.

For purposes of further investigation, I firstly removed from the inner aspect of the right parietal bone the inner table, where it overlaid some of the stains, and took away the venous tissue (fig. 2, *d*). Secondly, I filed away the outer table of both the left and the right parietal bones. (Unfortunately, whilst doing this, the skull broke, hence the disparity of

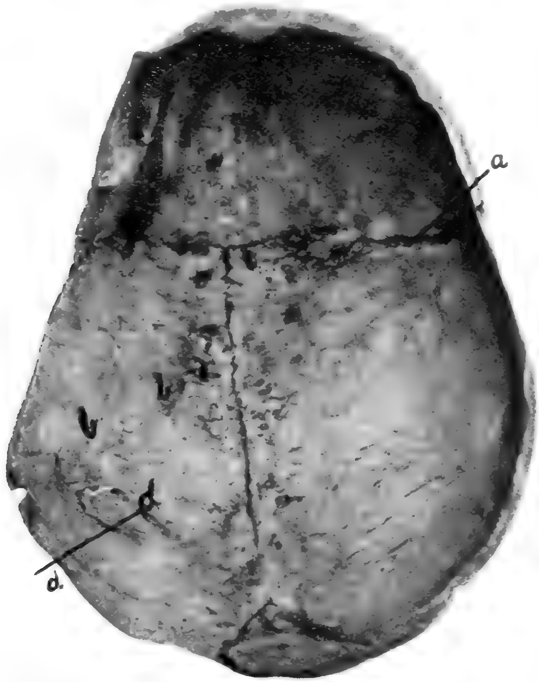

FIG. 2.—Photograph of the same aspect of the same specimen after removal of the thin inner table along the line of *d* in fig. 1. The result is a groove of very similar character to *a*.

b, *b*, these linear stains are no longer so evident as in fig. 1, because the diploic venous tissue has been removed by dissection from the outer aspect.

the photographs.) On the right side, as I approached the diploë, dark stains appeared in places, and on proceeding further these stains were found to overlie venous channels in the diploë (fig. 3, *f*, *f*). I next removed the venous tissue from these channels and found that the inner table on which it rested was at some points remarkably thin, and that it easily transmitted light. After filing away the outer table of the left parietal there appeared to be no marked development of the diploic channels. However, opposite the large deep channel posterior to the coronal suture a dark linear stain appeared similar to the staining noticed on reaching the diploic channels on the right side (fig. 3, *e*, *e*).

In connexion with the two questions above referred to, I note that (1) the characters of the large groove under consideration, as well as of some others I have examined, were as follows:—The groove was deep and rugged, its edges were sharp and overhanging. This appearance is in accordance with what would be expected to follow if the most prominent

FIG. 3.—Photograph of outer aspect of the same specimen after the outer table of the skull has been removed by filing.

e, *e* shows a linear stain corresponding to the groove *a* of figs. 1 and 2; *f*, *f*, *f* shows the diploic channels of the right parietal bone corresponding to the linear stains *b* and *d* in figs. 1 and 2. Note the comparative absence of similar channels over the left parietal apart from groove *a* in figs. 1 and 2 (*e* in fig. 3).

part of an underlying vein had absorbed the inner table by inducing a pressure atrophy. I believe that such an atrophy may and does happen, despite the contrary tendency on the part of the inner table, which may grow over so as to enclose the meningeal vessels, a condition frequently witnessed in adult development, especially near the antero-inferior angle of the parietal bones. But the ordinary meningeal grooves have their edges smooth and everted, and the grooves slope gradually down to their greatest depth. Of such a character was the posterior of the two grooves in the skull under question.

In one markedly senile skull from our collection, with edentulous and atrophied maxillary alveolar arches, the calvaria is also remarkably atrophied, and shows one of these same large vascular grooves lying just posterior to the coronal suture. The edges of the groove are in some places only about 2 mm. apart, whereas the lateral walls of the groove are 5 to 6 mm. apart. If we suppose the subject to whom this skull belonged had suffered from any venous engorgement during his lifetime, we have two very potent factors at work which certainly would tend to bring a diploic vein to the surface of the meninges, and the vascular groove so formed would undoubtedly be of diploic origin.

(2) On the inner aspect of the right parietal bone, after removing the inner table over the linear stains and taking away the venous tissue underlying them, the character of the grooves left on the inner aspect of the outer table was in every way comparable with the large groove on the left side. I have mentioned that the intact inner table overlying some of the venous diploic channels was extremely thin. If this subject had suffered from either venous engorgement or his skull had shown any degree of general atrophy, there can be no doubt that on the right side we would have had marked open vascular channels appearing on the inner aspect of the right parietal bone.

In some cases it is quite possible that ordinary meningeal vessels may come to lie in such grooves. This would occur if the meningeal vessels chanced to be opposite the eroding diploic veins, and I have specimens showing this condition, there being a very thin lamina of bone intervening. This appears to be borne out, too, in those cases in which one edge of these large grooves overhangs the groove and the other edge is smooth and everted.

Summary of Conclusions.

1. That some of the large gutter-like grooves found in the inner aspect of the skull are due to diploic venous tissue which has come to the surface by the erosion of the inner table of the skull.

2. That it is possible that when there is only one large gutter-like groove present the meningeal and diploic vessels may be contained in the same groove.

3. That the factors at work producing these grooves are:—

   (*a*) Large diploic vessels to commence with.
   (*b*) Some degree of venous engorgement.
   (*c*) An atrophying skull consequent on advancing age.

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(2) Poirier and Charpy, tome ii., part ii., p. 930.

(3) Frederic Wood Jones, D.Sc., *Journal of Anatomy and Physiology*, vol. xlvi., third part, April 1912, p. 228.

(4) Oskar Schultze, *Zeitschrift für Morphologie und Anthropologie*, Band i., p. 451.

THE INTERRELATIONSHIP OF SOME TRUNK MEASUREMENTS AND THEIR RELATION TO STATURE.

By RUPERT M. DOWNES, M.D., M.S. (Melb.). (*From the Anatomy Department, Melbourne University.*)

ANTHROPOLOGICAL literature contains many works concerning the length of the limbs and trunk, the transverse diameters of the trunk at the shoulder and in the region of the pelvic girdle, and various correlations arising from these measurements as embodied in the canons of Fritsch and others.

As the standards of the different diameters of the trunk are so much a matter of individual selection, I have undertaken the observations here set down on the transverse diameters in the pelvic region with the intention of deciding which one is the most suitable as a standard measurement, and to compare the ratios of the trunk diameters to one another and to the body height.

I entered on this line of research at the suggestion of Professor Berry that it would be of value to determine the ratio between the interspinous and vertical trunk diameters; he also permitted me the use of two tables of such ratios obtained from measurements he had made himself and that he had prepared from Addison's paper on abdominal topography (1).

He also hoped that some conclusions might be drawn from these measurements as to the value, for clinical purposes, of sections made of trunks of varying stature at fixed levels; for if the vertical trunk diameter were found to be at all constant, the value of such sectional methods would be obvious.

NATURE OF THE INVESTIGATION.

The following diameters were determined:—

1. Total body height.
2. Vertical trunk diameter.
3. Interspinous diameter.
4. Intercristal diameter.
5. Intertrochanteric diameter.
6. Diameter from midline to anterior superior iliac spine.

The relative proportions of these diameters were expressed by the following indices:—

1. Vertical trunk-body height index.
2. Interspinous-vertical trunk index.
3. Interspinous-body height index.
4. Intercristal-vertical trunk index.
5. Intercristal-body height index.
6. Intertrochanteric-body height index.
7. Interspinous-intercristal index.

Number and Nature of the Material.—The number of cases examined was 201; of these 51 were adult women, 50 men, 47 male and 53 female children. The ages of these ranged from six months to ninety years, all the children being under fourteen years. Of the adults, 18 were formalin-hardened subjects from the dissecting-room; the remainder and all the children were live subjects.

Technique.—In all cases the subjects were in the supine position and the measurements were recorded with Martin's anthropometer. The vertical trunk diameter was determined by marking the level of the cranial margin of the symphysis ossium pubis on the skin, placing one limb of the instrument so as to press firmly on the cranial margin of the sternum, then moving the other limb on to the pencil mark.

For the determination of the interspinous diameter the most medial extremities of the anterior superior spines of the ilium were employed as the limits of this diameter, and not the most prominent points of these spines, as is the more usual custom; their positions were then marked on the skin. This was found to be simpler and more accurate than the commoner method of placing the calliper directly on the prominences in the soft tissues formed by these bony points. At the same time the diameter from either spine to the midline of the trunk was measured in the line of the previous diameter. Maximum pressure was used in the determination of the intercristal and intertrochanteric diameters to eliminate as far as possible variations due to the intervening soft tissues; to measure the latter diameter the inferior extremities were approximated and the thighs and legs fully extended.

It has been frequently remarked that body height is greater in the supine than the erect position, so that the supine position was used in determining this diameter as less liable to variation and because it is applicable to cadavera. Unless otherwise stated, the measures are given in centimetres.

Vertical Trunk Diameter.—For the estimation of this diameter several different methods have been employed, one of the most common perhaps being the measurement from the acromion process to the sitting level. As examples of others we have the distance from the spine of the seventh cervical vertebra or the manubrium sterni to the sitting level, and Teumin (2) has recorded seven different methods in all.

If any method be employed which involves the determination of the sitting level, there is the source of error in the measurements due to varying amounts of fatty tissue overlying the tubera ischiadica. In addition great variations in the length of this diameter are produced by differences in the ventro-dorsal curvatures of the spinal column, by scoliosis, and by compression of the intervertebral fibro-cartilages. The alteration of this measurement produced in any individual by sitting rigidly erect from that found when he sits at ease is quite marked; it is produced by change of spinal curvature and also by allowing different portions of the tubera ischiadica to support the trunk with corresponding change in the height of the trunk. Moreover, this method is not applicable to cadavera. On the other hand, if instead of employing the sitting posture the subject be placed in the supine position, these sources of error are eliminated, but the sitting level or tubera ischiadici can no longer be used because of the practical difficulties of determining their positions.

In my opinion, then, the vertical trunk diameter is best determined with the body supine, and in this position the most simple method and the one least open to error is to record the distance between the cranial margins of the manubrium sterni and symphysis ossium pubis respectively.

Teumin, in an important paper on physical dimensions, comments on this question and also favours the manubrio-pubic diameter; she found that this method gives the greatest variations between maximum and minimum trunk lengths. She also found that the manubrium lies caudal to the spine of the seventh cervical vertebra by a true mean of 4·7 cm., obtained from her figures, and in 64 per cent. of cases is cranial to the acromion. She, however, employed the erect attitude in her series of 100 women, using Martin's anthropometer, and including some as young as eighteen years of age. The true mean of the vertical trunk diameter obtained from her figures is 48·2 cm., with variations from 41 to 62 cm., while she quotes the averages of this diameter obtained by other writers who employed this method, and which are tabulated below.

The true mean for the combined cases of Berry and Addison is 52·9 cm. in 49 males and 50 cm. in 24 females, with variation from 47 to 58 cm. in the former and from 46 to 54 cm. in the latter. All were over the age of twenty-one years. My own cases over the age of twenty-one give a true mean in 42 men of 51·12 cm., with a standard deviation of 2·64 cm.; and in 38 women of 48·46 cm., with a standard deviation of 2·93 cm.

The conclusions drawn from my figures is that the range of variation in the vertical trunk diameters of different individuals is not great, as the standard deviations mentioned above are so small. The figures of the other writers now quoted, however, show a considerable variation, though the standard deviation in their cases is not stated.

	No. of Cases.	Males.	Females.
Teumin	(100)	...	48·2 cm.
Jakowenko	(?)	49·46 cm.	...
Downes	(81)	51·12 ,,	48·46 ,,
Standard deviation from the true mean	...	2·64 ,,	2·93 ,,
Gittschenko	(?)	52·35 ,,	...
Berry and Addison	(73)	52·9 ,,	50 ,,
Dibold	(?)	56·66 ,,	...

It is apparent, too, that this diameter in men is appreciably greater than in women.

Interspinous Diameter.—For this diameter I have recorded the distance between the most medial points of the anterior superior iliac spines instead of their most prominent points, which is the usual method, because I have found that there is a variability in the position of the latter points and because of the difficulty of determining these points with accuracy. In consequence of this my measurements are distinctly lower than those of other observers.

It has been stated in some anatomical and obstetrical text-books that this diameter is greater in females than males, but the bulk of evidence is against this view.

According to Cunningham (3), the female diameter is greater, while Waldeyer (4) states that they are equal in the two sexes. The remaining

	Males.	Females.
Downes	22·62 cm.	21·98 cm.
Standard deviation from the true mean	1·21 ,,	1·94 ,,
Verneau (5)	23·1 ,,	22·2 ,,
Quain (6)	24·1 ,,	23·5 ,,
Cunningham	24 ,,	25 ,,
Berry and Addison	24·27 ,,	23·58 ,,
Teumin	...	24·42 ,,
Waldeyer	26 ,,	26 ,,

writers I quote show a larger male diameter. My figures, though lower than others, as mentioned previously, show the male diameter of 22·62 cm. to be greater than the female diameter of 21·98 cm.

Intercristal Diameter.—All writers except Waldeyer and Weissenberg (7) are agreed that this diameter is greater in the male, and my results bear this out. In contrast to the last diameter I find, however, that the standard deviation of 1·8 cm. in females is greater than that of males, which is 1·33 cm.

	Males.	Females.
Waldeyer	26 cm.	29 cm.
Weissenberg	27·7 ,,	28·1 ,,
Verneau	27·9 ,,	26·6 ,,
Cunningham	28·2 ,,	27·3 ,,
Quain	11¼ in. 28·58 cm.	11 in. 27·94 cm.
Downes	29·19 ,,	28·11 ,,
Standard deviation from the true mean	1·33 ,,	1·8 ,,
Addison	29·48 ,,	28·55 ,,

This diameter appears to be most suitable for employment as a standard of transverse trunk diameter, for the following reason :—

As mentioned previously, the most prominent points of the anterior superior iliac spines are variable in position and difficult to determine. Even if we fix on their most medial margins there is still some difficulty in determining these points with exactness, while this trouble is absent if we employ the intercristal diameter. Again, this diameter can be determined more rapidly and with less exposure, which is of some importance in the case of women, and it certainly is less open to error.

Intertrochanteric Diameter.—According to Merkel, from measurements made on the skeleton this diameter is greater in the female, while Waldeyer states that it is equal in the sexes. My results show that what little difference there is, is on the side of the greater male diameter.

	Males.	Females.
Waldeyer	31·5 cm.	31·5 cm.
Downes	32·1 ,,	31·87 ,,
Standard deviation from the true mean	1·36 ,,	1·59 ,,
Merkel (8)	32·5 ,,	34 ,,
Stratz (9)	...	33·5 ,,

Asymmetry.—The generally accepted idea that few individuals are bilaterally symmetrical has led me to test this characteristic at the interspinous level. To make allowance for observational errors, in no case was asymmetry considered to be present unless a variation of ·5 cm. or over was found on either side.

This margin is rather wide, especially in young children, but I found that even among them asymmetry is nearly as common as in adults, using this arbitrary minimum.

Of 201 cases examined, 104 were asymmetrical, in 60 cases the greater diameter being on the left side and in 44 on the right side. The increase in the right diameter is more marked in adults, and is due, no doubt, to some scoliosis produced by habitual usage of the right arm, which is more apparent with increase in age. Asymmetry, moreover, is most present in adult females, and also more so in female than male children.

Vertical Trunk-Body Height Index.—An index to express the ratio of these diameters is obtained by the following formula:

$$\text{Index} = \frac{\text{vertical trunk diameter} \times 100}{\text{body height}}.$$

This ratio is of considerable interest, and Addison has pointed out its remarkable constancy. Reid (10) apparently does not agree with this, for from his observations on University students he states that increased stature seems to be chiefly due to greater trunk length. My results confirm Addison's observation and further emphasise the point, which is not new, that the vertical trunk diameter in the female is relatively greater than in the male, though, as I have shown before, it is less actually. Pittard (11), too, after measurements of over 1200 Hungarians, states that the female trunk is relatively longer than the male; and Weissenberg emphasises the female superiority in this index, drawing attention to the fact that women when sitting frequently appear to be taller than their male companions, while on standing they are obviously shorter. I think that this observation is misleading, and is due to the fact that women usually sit more erectly than men—largely owing to artificial support by corsets,—and that in the female the development of adipose tissue in the buttocks is so frequently greater than in the male. For my results show that the sexual variation in this index, though in favour of the female, is very small, whilst there is a direct contradiction in the previously mentioned figures of Berry and Addison and myself, which show that the absolute vertical trunk diameter is greater in men.

Weissenberg, though employing the acromion to sitting level diameter to indicate trunk height, found—as I have done—that the same small relative sexual difference is present in children. The true mean of the index which I have extracted from Teumin's indices is 30·3, with a range of variation from 21 to 40. Below are tabulated the averages of indices quoted by her. The true mean of the index which I obtained from Addison's measurements is rather higher in each sex than mine, which show so small a variation in the index from each group and so little standard deviation.

	Males.	Females.	Male Children.	Female Children.
Downes	30	30·57	29·89	30·53
Standard deviation from the true mean	1·15	1·54	1·66	1·58
Teumin	...	30·3	...	...
Jakowenko	30·58	...	...	...
Gittschenko	30·77	...	...	...
Wischegrord	31·19	...	...	...
Addison	31·73	32·42	....	...
Eicholz	31·9	...	...	...
Dibold	33·3	...	...	...

Proportion of Trunk and Leg Lengths.—Though I have made no observations on this subject yet it is instructive to quote Teumin, who showed that in women there was a great constancy in the relative height of the manubrium from the ground—about 82 per cent. of the body height. As the relative trunk length is also constant, it follows that the relative leg length in women is constant too. Le Damany (12) found in the new born that this ratio was not different in the sexes.

Interspinous-Vertical Trunk Index.—I have found no record in the literature of this index having been considered previously, and have only the indices prepared from Berry and Addison's figures to compare with my own. These show, as do also mine, that this index is considerably greater in the female, though Berry and Addison's figures are higher than the present writer's owing to differences in the method of determination of the interspinous diameter.

In children, however, this sexual relation is reversed, the male index being greater. In all classes the standard deviation from the mean is high, so that this index is not a suitable symbol of trunk proportions.

	Males.	Females.	Male Children.	Female Children.
Downes	43·56	44·67	44·23	42·06
Standard deviation from the true mean	3·48	4·14	3·14	3·75
Berry and Addison	45·75	46·92	...	...

Note.—In this index table and in those that follow I have included 8 males and 13 females between the ages of sixteen and twenty-one.

Though the elimination of the indices obtained from them raises the true mean, it does so only to an inappreciable extent.

Interspinous-Body Height Index.—The true mean of this ratio shows the same comparative results in accordance with sex and age as in the last index. The index for women is greater than for men, while male children have a higher index than female.

	Males.	Females.	Male Children.	Female Children.
Downes	12·97	13·68	13·22	12·83
Standard deviation from the true mean	3·48	4·14	3·14	3·75
Berry and Addison	14·47	15·12	...	...

Intercristal-Vertical Trunk Index.—The figures show again the same sexual and age relations as the interspinous indices. The standard deviation from the mean in this group is greater in women; this is not found in the other indices.

	Males.	Females.	Male Children.	Female Children.
Downes	56·36	57·88	55·43	53·19
Standard deviation from the true mean	3·82	3·33	3·39	3·8
Addison	55·83	58·27	...	...

Intercristal-Body Height Index. — The relations of the four groups are similar to those of the preceding indices. Addison's true mean becomes considerably higher than mine, and is 16·99 in males and 10·48 in females.

Browein (13) obtained an index of 16 in men and 18·3 in women, while Weissenberg makes the figures 16·8 and 18·3 respectively.

	Males.	Females.	Male Children.	Female Children.
Browein	16	18·3	...	...
Weissenberg	16·8	18·3	...	...
Downes	16·87	17·7	16·42	16·23
Standard deviation from the true mean	1·03	·9	·69	·86
Addison	16·99	18·48	...	...

The measurements and indices so far considered show some remarkable results.

Primarily it is apparent that the actual transverse diameters of the false pelvis, as measured between the anterior superior iliac spines and between the iliac crests, are greater in males than in females. This is contrary to the common loose and unqualified statement that the female pelvis is broader than the male, and is in agreement with the results of the majority of writers already quoted.

A review of the indices, however, shows a very different state of affairs, for now we find that each of these diameters relatively to trunk and body height is greater in women than in men. In other words, the adult female actually has a narrower false pelvis than the male, but relatively it is broader.

In children, however, the relation of the sexes is reversed, for in all four groups the male child has a greater index—that is, a wider pelvis relatively—than the female. It necessarily follows too that the index is greater in women than in the female children in the four groups; the interspinous indices, however, are greater in male children than in men, while the position is reversed for the intercristal indices.

I have already stated that I consider the intercristal diameter as the best for standard transverse pelvic measurements, and the manubrio-pubic diameter as the most suitable to indicate vertical trunk height. It follows from this that the intercristal manubrio-pubic index is most convenient and accurate as a symbol of the form of the trunk.

Intertrochanteric-Body Height Index.—As the true pelvis is said to be both actually and relatively greater in the female, this index is considerably greater by nearly 7½ per cent. in women. In children also the female index, unlike those in the other groups, is slightly greater than in the male. This denotes a marked increase relatively in this diameter in the female after puberty.

In contrast to this the interspinous and intercristal diameters have been seen to be greater relatively in the male before puberty, but in the female in adult life, so that lateral development of the pelvis seems to be more marked in women after puberty. My results are :—

	Males.	Females.	Male Children.	Female Children.
Intertrochanteric body-height index .	18·59	20·09	17·59	17·92
Standard deviation from the true mean	·85	·95	·75	·93

Interspinous-Intercristal Index. — This index shows a very slight sexual difference in adults, women having a slight superiority with an index of 77·25 over the male index of 77. In women the standard deviation from the mean rises to 5, while in men it is 3·97. Teumin has calculated this index, of which the true mean is 88 in women, with a range of variation from 67 to 96, but this can be explained by the different points adopted for the limits of the interspinous diameter. If we can take this small sexual difference to mean anything, we must conclude that the pelvic alæ are less concave in the female, giving a comparative increase in the lateral capacity of the false pelvis.

Conclusions.

1. The vertical diameter of the trunk is most readily and accurately estimated by measurement from the cranial margin of the manubrium sterni to the cranial margin of the symphysis ossium pubis.

2. The vertical trunk diameter, though actually smaller in women, is greater relatively to the body height. This comparative difference is more marked in children. The relation of vertical trunk to total body height, as previously noted by Addison, is almost a constant, and is about 30 per cent. of the latter.

3. The interspinous and intercristal diameters are greater in males; relatively to vertical trunk diameter and body height, they are greater in the female. Amongst children the male has a greater index than the female. The indices are higher in adults than in the corresponding classes of children, except that the interspinous indices are greater in male children than male adults.

4. The intertrochanteric diameter is greater in the male, but relatively to body height it is considerably greater in the female. This relative superiority is also present in children.

5. The pelvic alæ have a smaller concavity in the female.

6. Asymmetry of a recognisable degree is present in over 50 per cent. of all subjects. It is more frequent in females, especially adults.

7. The indices showing the relation of transverse to vertical trunk diameters are greater in adults than children.

8. As a rule, the standard deviation shows that there is a greater range of variation in the female sex.

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[Tables.

Male Children.

Age.	Interspinous diameter.	Intercristal diameter.	Intertrochant. diameter.	Vertical trunk diameter.	Height.	Diff. in sides.	Greater side.	Index No. 1.	2.	3.	4.	5.	6.
8	15	20	20·5	33	121	...	...	27	45	12·4	61	16·5	17
6½	16	19	19·5	36·5	116	1·2	R	31	44	13·8	52	16·4	17
3¼	14·5	17	18	29·5	97	...	...	30	49	15	58	17·4	18·5
4	13	16	16·5	26·5	93	...	...	29	49	14	60	17·2	17·5
4½	12	16	17·5	30·5	100	...	...	31	38	12	53	16	17·5
13	17	22	24	41	141	1·1	L	29	41	12·1	54	15·6	17
9	16·5	20	21	38	129	8	R	29	43	12·8	53	15·5	17
4	12·5	17	17	30·5	97	...	...	31	40	12·9	56	17·4	17·5
6	12·5	16·5	18	32·5	106	...	...	31	38	11·8	56	15·6	17
1¾	10·5	13	14	26	80	...	...	32	40	13·1	50	16·3	17·5
7	15·5	19	20	32·5	114	·8	L	29	48	13·6	58	16·7	17·5
2½	11·5	14	16	24·5	86	...	...	29	43	13·4	57	16·3	18·5
5	12·5	17	19	32	108	·8	L	30	39	11·6	53	15·7	17·5
2	11	12·5	14	25·5	76	·9	L	34	43	14·5	49	16·5	18 5
5	13·5	17·5	18·5	30·5	105	·9	L	29	44	12·8	57	16·7	17·5
12	18·5	22·5	24 5	42	143	·9	R	29	43	12·9	54	15·7	17
$1\frac{8}{12}$	11·5	13·5	14·5	26	80	...	..	33	44	14·4	52	16·9	18
6	14	17·5	19·5	29·5	103	...	...	29	47	13·6	59	17	19
9	15·5	20	21	37	120	...	...	31	42	12·9	54	16·7	17·5
6	14	18 5	20·5	32·5	111	...	...	29	43	12·6	57	16·7	18·5
13	17	22	23·5	38·5	132	...	...	29	44	12·9	57	16·7	18
13	17·5	22	23	39·5	129	·6	R	31	44	13·6	56	17·1	18
3	13	16·5	17·5	27·5	93	1·5	L	30	47	14	60	17·7	19
10	16	19·5	21	38·5	121	...	...	32	42	13 2	51	16 1	17·5
9	16	21	22·5	40·5	133	·8	L	30	40	12	52	15·8	17
9	15·5	19·5	21·5	33·5	133	...	...	25	46	11·6	58	14·7	16
14	21	26	29·5	43	160	...	...	27	49	13·1	60	16·2	18·5
8	15·5	19	20	32·5	114	...	...	29	48	13·6	58	16·7	17·5
3	13·5	16·5	17·5	28·5	93	·5	R	31	47	14·5	58	17·7	17·5
8	15·5	20	20·5	33·5	128	...	...	26	46	12·1	60	15·6	16
11	16·5	21·5	24	41	137	·7	R	30	40	12	52	15·7	17·5
3½	12	13·5	14	24·5	79	...	...	31	49	15·2	55	17·1	17·5
3	13·5	16	16·5	25·5	89	1·3	L	29	53	15·2	63	18	18·5
7	14·5	17·5	19·5	34·5	111	...	...	31	42	13·1	51	15·8	17·5
11	17	21·5	22·5	38	135	1·1	R	28	45	12·6	57	15·9	16·5
5	13·5	16·5	16·5	30·5	102	...	...	30	44	12·2	54	16·2	16
5½	15	19	19	32·5	113	...	...	29	46	12·2	58	16·8	17
12	18·5	22	23	42·5	131	·5	L	32	43	14·1	52	16·8	17·5
12	18·5	23	25·5	42·5	141	...	...	30	43	13·1	54	16·3	18
$1\frac{1}{12}$	11	12·5	15	25·5	81	1·9	L	31	43	13·6	49	15·4	18·5
3	11·5	13·5	15	25·5	83	·5	L	31	45	13·8	53	16·3	18
3½	13·5	16·5	18	30	97	·8	L	31	45	13·9	55	17	18·5
11	18·5	23	24	41	141	·5	R	29	44	13·1	56	16·3	17
12	18·5	21·5	23	41·5	133	1·9	R	31	44	13·9	52	16·1	17·5
13	17·5	23·5	24	38	137	1	R	28	46	12·8	62	17·1	17 5
7	16·5	19	21·5	34·5	113	...	...	31	48	14·6	55	16·8	19
2	11·5	14·5	14·5	27	87	1·1	L	31	43	14	54	16·7	16·5

Female Children.

Age.	Interspinous diameter.	Intercristal diameter.	Intertrochant. diameter.	Vertical trunk diameter.	Height.	Diff. in sides.	Greater side.	Index No.					
								1.	2.	3.	4.	5.	6.
13	17·5	20·5	26	44·5	140	...	...	32	39	12·5	46	14·6	18·5
4	14	16·5	18	33	101	·9	R	33	42	13·9	50	16·3	18
3½	12·5	14·5	16·5	26	89	...	...	29	48	14	56	16·3	18·5
1½	10·5	13	14·5	25	78	...	...	32	42	13·5	52	16·7	18·5
$8\frac{1}{12}$	10	13	14·5	25	74	...	...	34	40	13·5	52	17·6	19·5
12	16·5	22	25·5	42·5	145	...	...	29	38	11·4	52	15·2	17·5
12	18	22	23	40·5	136	·8	L	30	44	13·2	54	16·2	17
10	17·5	21·5	23	42	131	...	...	32	42	13·4	51	16·4	17·5
10	15	21	23	43·5	136	1·	R	32	34	11	48	15·4	17
9	17·5	22	23	42	138	...	...	30	42	12·7	52	15·9	17
4	14	16·5	17	27·5	95	...	...	29	51	14·7	60	17·4	18
8	15	21·5	23·5	39·5	133	·8	R	30	38	11·3	54	16·2	17·5
13	19·5	26	29	44·5	141	...	...	32	44	13·8	58	18·4	21
1½	11·5	13	14	25	75	...	...	33	46	15·3	52	17·3	18·5
13	19·5	24	25	41·5	145	1·1	L	29	47	13·4	58	16·5	17
8	14	20	22·5	40	135	·8	L	30	37	10·4	50	14·8	16·5
3	12	14·5	16·5	26·5	88	1·	L	30	45	13·6	55	16·5	18·5
9	15·5	19	20	32·5	112	·5	L	29	48	13·8	58	17	18
11	14·5	20·5	23·5	37·5	132	...	...	28	39	11	55	15·5	18
5	13·5	17	18	32·5	100	...	...	33	42	13·5	52	17	18
10	17	21·5	23	38·5	126	1·6	R	31	44	13·5	56	17·1	18
10	16·5	21·5	23·5	40·5	138	·8	R	29	41	12	53	15·6	17
12	17	23	26	45	154	·6	L	29	38	11	51	14·9	17
3	13·5	16·5	17·5	29·5	95	1·1	R	31	46	14·2	56	17·4	18·5
13	16	21	27·5	44·5	141	...	...	32	36	11·3	47	14·9	19·5
6	13·5	18·5	20	34·5	118	...	...	29	39	11·4	54	15·7	17
7	14·5	18·5	20·5	37	121	·5	L	31	39	12	50	15·3	17
10	16·5	21·5	22·5	41·5	136	1·	R	30	40	12·1	52	15·8	16·5
14	19	23·5	26·5	43	149	...	...	29	44	12·8	55	15·8	18
13	19	22·5	24·5	42·5	137	1·6	L	29	45	13·9	53	16·4	18
8	16·5	20	21·5	37	123	·6	L	31	45	13·4	54	16·3	17·5
8	15	20	22·5	39	124	·6	R	31	38	12·1	51	16·1	18
2½	12	15	16	27	89	...	...	30	44	13·5	56	16·8	18
6½	12·5	16	17·5	32·5	108	...	...	30	38	11·6	49	14·8	16
11	16	20	23	38	129	·9	L	29	42	12·4	53	15·5	18
11	16	21·5	24	40·5	137	...	...	30	39	11·7	53	15·7	17·5
1½	10	12·5	14·5	23·5	77	...	...	31	43	13	53	16·2	19
2¼	10·5	13	14·5	25·5	79	·5	L	32	41	13·3	51	16·5	18·5
3	11·5	14	17	30	92	...	...	33	38	12·5	47	15·2	18·5
3	12	14	16·5	28·5	89	·6	L	32	42	13·5	49	15·7	18·5
4	14	17	17·5	28	94	·6	L	30	50	14·9	61	18·1	18·5
12	15·5	21	22·5	39·5	128	·8	R	31	39	12·1	53	16·4	17·5
12	17·5	23·5	27	35	133	...	...	26	50	13·2	67	17·7	20
10	14·5	20·5	23	36·5	133	...	...	27	40	10·9	56	15·4	16·5
2½	10·5	12·5	14·5	24·5	77	...	...	32	43	13·6	51	16·2	19
13	20	25·5	27·5	46·5	149	1·6	L	31	43	13·4	55	17·1	18·5
14	16	21	23·5	42·5	132	·6	R	32	38	12·1	49	15·9	18
10	17	21·5	25	42·5	136	...	...	30	40	12·5	51	15·8	18·5
11	17	21	21·5	38	125	...	...	31	45	13·6	55	16·8	17
6	15	18·5	20·5	34·5	116	·5	R	30	43	12·9	54	16	17·5
11	13	16·5	18	34·5	107	2	R	32	38	12·2	48	15·4	17
8	15·5	20	22	34	118	·6	R	29	46	13·1	59	16·9	18·5
6	14	16·5	17	31·5	101	...	...	31	45	13·9	52	16·3	17

Adult Males.

Age.	Interspinous diameter.	Intercristal diameter.	Intertrochant. diameter.	Vertical trunk diameter.	Height.	Diff. in sides.	Greater side.	Index No.						
								1.	2.	3.	4.	5.	6.	7.
87	24	30·5	32·5	46·5	165	·5	R	28	52	14·5	66	18·5	19·5	79
73	22·5	26·5	28·5	48·5	168	1·8	L	29	46	13·4	55	16	17	85
61	19	27	30·5	53	175	...	...	30	36	10·9	51	15·5	17·5	70
55	20·5	28·5	32	50·5	167	...	...	30	41	12·3	56	17	19	72
67	23	27·5	31	55·5	174	...	...	32	41	13·2	50	15·8	18	84
77	22·5	31·5	33	50	169	...	...	30	45	13·3	63	18·5	19·5	71
41	23	29·5	31	49	158	...	...	31	47	14·5	60	18·5	19·5	78
76	22	28·5	31·5	47	165	..	...	28	47	13·3	61	17·3	19	77
87	21·5	29·5	31·5	52·5	164	...	...	32	41	13·1	56	18	19	73
62	22·5	30·5	33	51·5	173	...	...	30	44	13	59	17·6	19	74
90	24	29·5	...	48·5	165	1·3	L	29	49	14·5	61	17·9	...	81
82	21·5	29·5	31	50	169	...	...	30	43	12·7	59	17·4	18·5	73
56	22·5	27·5	31·5	47·5	161	1·1	L	30	47	14	58	17·1	19·5	82
62	22·5	30	33·5	48	166	·7	L	29	47	13·5	63	18·1	20	75
73	23·5	30	33	50	164	...	...	30	47	14·3	60	18·3	20	78
55	24	30	30·5	52	173	·8	L	30	46	13·9	58	17·3	17·5	80
29	23	30	33·5	51	178	...	...	29	45	12·9	59	16·8	19	77
38	21·5	29·5	32	48	167	...	...	29	45	12·9	61	17·7	19	73
18	23	31·5	33·5	57·5	184	...	...	31	40	12·5	55	17·1	18	73
46	22	31	33·5	52	176	1·6	R	30	42	12·5	60	17·6	19	71
54	22	29·5	33·5	49	180	1·4	L	27	45	12·2	60	16·4	18·5	75
59	22·5	31	33·5	51	172	1·9	L	30	44	13·1	61	18	19·5	73
50	22·5	28	31	51·5	175	...	...	30	44	12·8	54	16	17·5	80
75	22·5	27·5	29·5	50·5	165	1	L	31	45	13·6	54	16·7	18	82
25	20·5	28	31	53·5	176	·9	R	30	38	11·6	52	15·9	17·5	73
31	22·5	29	31·5	53	163	1	L	33	43	13·8	55	17·8	19·5	78
42	23	27	29	47·5	159	1·6	L	30	48	14·5	57	18·1	18	85
45	24·5	30·5	34·5	52·5	176	...	...	30	47	13·9	58	17·3	19·5	80
23	23·5	29	32	50	167	...	...	30	47	14·1	53	17·4	19	81
21	21·5	28	31·5	50·5	168	1·4	L	30	43	12·8	55	16·7	19	77
54	22·5	28·5	31	51	172	...	...	30	44	13·1	56	16·6	18	79
60	22·5	29	32	51·5	174	1·9	L	30	44	12·9	56	16·7	18·5	78
47	26	32	34	56·5	171	1·8	R	33	46	15·2	57	18·7	20	81
47	22	29	33	53·5	169	·5	L	32	41	13	54	17·2	19·5	76
25	21	28	31·5	50	173	...	...	29	42	12·1	56	16·2	18	75
22	22	29	31	55	181	1·5	L	30	40	12·1	53	16	17	76
24	22·5	28·5	31	50	169	...	...	30	45	13·3	57	16·9	18·5	79
35	22·5	29	31·5	45	157	...	...	30	50	14·3	64	18·5	20	78
69	21·5	29	32·5	56·5	181	...	...	31	38	11·9	51	16	18·5	74
19	23·5	28	31	55	181	·5	L	30	43	13	51	15·5	17	84
22	22·5	28·5	31·5	50	173	·6	R	29	45	13	57	16·5	18	79
27	20·5	27	31	50·5	165	...	...	31	41	12·4	53	16·4	19	76
19	21·5	27	31·5	52	183	...	...	28	41	11·7	52	14·7	17	80
18	18·5	27	31·5	51·5	173	...	...	30	36	10·2	52	15·6	18·5	69
20	19	27	31	50·5	172	1·1	R	29	38	11	53	15·7	18	70
23	21·5	27	32	50·5	172	...	...	29	43	12·5	53	15·7	18·5	80
20	22·5	28·5	32·5	51·5	174	...	...	30	44	12·9	55	16·4	18·5	79
20	22	29	33	53	182	1	R	30	42	12·1	55	15·9	18	76
22	21	28	33·5	56	181	...	...	31	38	11·6	50	15·5	18·5	75
20	21	27·5	31·5	52	172	...	...	30	40	12·2	53	16	18·5	76

Adult Females.

Age.	Interspinous diameter.	Intercristal diameter.	Intertrochant. diameter.	Vertical trunk diameter.	Height.	Diff. in sides.	Greater side.	Index No. 1.	2.	3.	4.	5.	6.	7.
24	22	27	34	44·5	150	1	R	30	50	14·7	61	18	22·5	81
16	22	28·5	32·5	48	157	1	R	31	46	14	59	18·1	20·5	77
42	22	28	32	42	157	·7	L	27	52	14	62	17·8	20·5	79
31	21	26·5	29·5	48	146	...	...	33	44	14·4	55	18·1	20	79
34	23·5	27	31·5	48·5	161	...	...	30	48	14·6	56	16·8	19·5	87
18	21	29 5	32	47·5	162	1·6	L	29	44	13	62	18·2	20	71
17	18	26	31	46	163	1·8	L	28	40	11	57	15·9	19	69
24	21	28·5	30·5	39·5	157	...	...	25	53	13·3	64	18·1	19·5	74
18	20·5	25·5	29·5	44	150	...	...	29	47	13·7	58	17	19·5	80
27	22·5	28·5	30·5	46·5	152	1·2	L	31	48	14·8	61	18·7	20	79
22	24	28·5	33·5	50·5	164	1·9	R	31	48	14·6	56	17·4	20·5	84
26	19·5	25·5	32	46·5	151	1·2	L	31	41	12·9	55	16·9	21	76
31	23	27·5	32·5	49·5	156	1·3	L	32	46	14·7	56	17·6	21	84
28	22	26	31	48·5	162	1·8	L	30	45	13 6	54	16	19	85
21	25·5	29	34	51	159	...	...	32	50	16	57	18·2	21·5	88
20	21	26·5	29	50	154	·8	L	32	42	13·6	53	17·2	19	79
37	25	31·5	33·5	48	166	1	L	29	52	15·1	66	19	20	79
26	18·5	26·5	30	50	156	·7	L	32	37	11·9	53	17	19	70
26	21	28·5	31·5	52	170	·5	R	31	40	12·3	55	16·8	18·5	74
30	18·5	28	31	50·5	166	...	...	31	36	11·1	55	16·9	18·5	66
33	24·5	31·5	33	50	159	1·7	L	31	49	15·5	63	19·8	21	78
21	22	29·5	34	52	161	·5	R	32	42	13·7	57	18·3	21	75
19	20	26·5	30·5	48·5	160	...	...	30	41	12·5	55	16·5	19	75
23	23	28·5	30	46·5	162	...	...	29	49	14·2	61	17·6	18·5	81
30	18·5	25·5	29·5	46	141	1·6	L	33	40	13·1	55	18·1	21	73
18	22	30·5	36·5	45·5	164	1·3	L	28	48	13·4	67	18·6	22	72
82	25·5	30	33	46·5	152	...	...	31	55	16·8	64	19·7	21·5	85
30	22	27·5	33	51	164	·6	R	31	43	13·4	54	16·8	20	80
40	19·5	28·5	34	52	165	1·1	R	32	38	11·8	55	17·3	20·5	68
24	23	29	33·5	52	160	...	...	32	44	14·4	56	18·1	21	79
29	21	28·5	32	47	154	1·1	R	30	45	13·6	61	18·5	21	74
32	19·5	24·5	29	44	148	·8	R	30	45	13·2	56	16·5	19·5	80
38	19·5	26	30·5	49	156	·5	R	31	40	12·5	53	16·7	19·5	75
28	19	24	27·5	43	146	1·3	L	29	44	13	56	16·4	19	79
19	23	29	31·5	49·5	162	1·5	L	30	46	14·2	59	17·9	19·5	79
39	22	26·5	32·5	47 5	153	...	...	31	45	14·4	56	17·3	29	83
21	22	28·5	34	50	160	...	...	31	44	13·7	57	17·8	21	77
18	20·5	29	30·5	48·5	146	2·2	R	33	42	14	60	19 9	21	71
31	22	28·5	31	46·5	158	·5	R	29	47	13·9	61	18	19·5	77
21	22·5	27·5	30	45·5	149	...	...	31	47	15·1	60	18·4	20	82
18	18·5	27	30·5	47	157	·9	R	30	39	11·8	56	17·2	19·5	69
26	19·5	24	29·5	46·5	148	...	...	31	42	13·2	57	16·2	20	81
20	20	26·5	31·5	47·5	162	...	...	29	42	12·3	56	16·4	19·5	75
30	22·5	30	32	53	163	1·6	L	33	42	13·8	57	18·4	19·5	75
30	22	28·5	31	52	159	...	...	33	42	13·8	55	17·9	19·5	77
20	22	29	30·5	48·5	157	·9	R	31	45	14	60	18·5	19·5	76
19	21	28·5	31·5	46·5	163	...	...	29	45	12·9	61	17·5	19·5	74
22	20·5	29	33·5	50·5	159	...	...	32	41	12·9	57	18·2	21	71
21	19	26	31	46 5	153	...	...	30	41	12·4	56	17	20	73
70	24·5	29	32	50	159	·6	L	31	49	15·4	58	18·2	20	84
70	23·5	29	32	50	154	3·5	L	32	47	15·2	58	18·8	21	81

Addison's Cases.

(27) Males. Age.	Vertical trunk diameter.	Interspinous diameter.	Index No. 2.	(11) Females. Age.	Vertical trunk diameter.	Interspinous diameter.	Index No. 2.
52	50	27	54	60	50	24	48
55	52	23	44	71	52	25	48
59	54	21	39	55	52	20	38
47	52	23·5	45	39	52	23	44
36	49	20	41	39	52	24	46
59	55·5	25	45	55	50	24	48
66	55	28	51	40	48	24	50
30	55	28	51	35	50	22	44
50	55	24	44	43	46	23	50
52	49·5	23	46	35	51	25	49
40	52	24	46	64	48	23	48
61	52	24	46				
45	56	27	48				
31	52	23	44				
24	52	25	48				
35	54	25	46				
29	54	24	44				
29	52	24	46				
42	52	22	42				
63	52	26	50				
38	52	19	37				
65	54	25	46				
64	58	28	48				
35	52	23	44				
35	56	26	46				
55	54	22	41				
65	54	25	46				
Mean	cm. 53·19	cm. 24·26	45·48	Mean	cm. 50·09	cm. 23·36	46·64

Berry's Cases.

(22) Males. Age.	Vertical trunk diameter.	Interspinous diameter.	Index No. 2.	(13) Females. Age.	Vertical trunk diameter.	Interspinous diameter.	Index No. 2.
60	52	26	50	30	48	25	52
44	54	20	37	74	46	24	52
47	52	24	46	48	53	22	42
48	53	26·5	50	64	52	24	46
61	54	24	44	38	48·5	20	41
55	51·5	26	50	84	45·5	25·5	56
60	57.	25	44	69	50	26	52
80	52	24	46	50	54	24	44
55	47	24	51	74	48	24	50
63	54	24	44	68	54	25	46
69	52	24	46	66	49·5	23	46
65	50	24	48	77	51	22	43
70	50	25	50	20	48	24	50
66	51	24	47				
60	47	25·5	54				
72	53	26	49				
28	53	27	51				
57	56	20	36				
60	53	23	43				
66	56	24·5	44				
46	52	20	38				
66	56	26	46				
Mean	cm. 52·55	cm. 24·27	46·09	Mean	cm. 49·92	cm. 23·77	47·69

Mean height	167·64 cm.	154·48 cm.
Mean index—		
No. 1	31·73 ,,	32·42 ,,
,, 3	14·47 ,,	15·12 ,,
,, 4	55·83 ,,	58·27 ,,
,, 5	16·99 ,,	18·48 ,,

Addison's and Berry's cases combined :—

	(49) Males.	(24) Females.
Vertical trunk diameter	52·9 cm.	50 cm.
Interspinous diameter	24·27 ,,	23·58 ,,
Index No. 2	45·75 ,,	46·92 ,,

Note.—Berry's cases hitherto unpublished. Addison's figures were taken from his paper, and the vertical trunk-body height index was prepared by Professor Berry.

OBSERVATIONS UPON YOUNG HUMAN EMBRYOS. By J. T. WILSON, M.B., F.R.S., *Challis Professor of Anatomy in the University of Sydney, Australia.* (With Three Plates.)

PART I.

THE appearance in recent years of Keibel and Mall's *Manual of Human Embryology* (1), following upon Keibel and Elze's *Normentafeln* (2), marked an epoch in the formulation of our knowledge of specifically human development.

The comprehensive summary there offered of our knowledge of the earlier human ontogenetic processes provided for the first time a more or less connected account of these phenomena, but it also served to accentuate the still very sketchy and incomplete character of that knowledge.

Much of our belief in regard to the method of establishment of the human blastocyst is still quite hypothetical, even if probable; and as regards the appearance of the earliest rudiments of the body itself, our knowledge is based on a very few human specimens separated by intervals which it is important to fill in with the aid of intermediate or allied stages.

In the present paper I propose to give an account of the three youngest human embryos in my collection.

Previous writers have described and figured specimens of a stage of development more or less similar to those exhibited by the two older of the embryos which form the subject of this communication. Nevertheless, well-preserved specimens, of ages nearly corresponding to these, are of such comparative rarity that for some time to come it will still be desirable to have accurate records published of the form and structure of any that may become available for detailed examination. As a matter of fact, no two specimens hitherto described, however apparently similar in stage of development, have proved to be precisely identical in detail. It will appear in the course of the paper that each of the individual embryos under consideration presents features entitling it to independent description.

A more special interest attaches to the youngest of the three specimens, inasmuch as it would seem to exhibit a phase of development hitherto unrepresented in the records of early human embryos.

It possessed probably two, possibly three, pairs of somites, and may thus be determined as occupying a position in the gap between stages 2 and 3 of Keibel and Elze's *Normentafel*. These stages are represented respectively by Spee's embryo "Gle" (3), and the Kroemer-Pfannenstiel embryo "Klb."

Hitherto, or as far as I am aware, no human embryo has been recorded as exhibiting a smaller number of somites than five (in "Klb").

I am inclined to believe that the embryo "E," No. 1 of His' *Normentafel* (4), would have turned out to be of very similar character to that now about to be described, in spite of the somewhat greater length of the former (2·1 mm. as against 1·68 mm.).

Eternod's well-known embryo of 1–3 mm. (his "No. 7 Vuill.") (5) may well represent a somewhat earlier phase.

The youngest embryo now to be described—the first of the three referred to—appears in my list of human embryos under the designation of "Hdr." I shall, however, refer to it in future simply under its catalogue number "H 3."

History of Human Embryo "H 3."[1]

The specimen was received by me so long ago as 25th May 1898, from my late friend Dr H. V. C. Hinder of Sydney, who had obtained it from a case of abortion on the previous day. The unopened chorionic vesicle had been placed in diluted alcohol. It was to outward appearance well conserved and perfectly intact when I received it, and it was at once transferred to picrosulphuric acid and then passed through graded alcohols.

From notes procured at the time by my friend Dr A. E. Mills, who was also associated with the case, it appears that the last menstruation period had begun on 12th April 1898 and ended on 16th April 1898. Abortion actually took place on 24th May 1898, but hæmorrhagic discharge had appeared on 22nd May 1898. Thus the period that had elapsed since the beginning of the last menstruation up to the commencement of abortion was 40 days, or 36 days from the end of the last menstruation. The period that had elapsed since the due date of the lapsed menstrual period was 12 days.

According to present-day criteria the age of this embryo may be estimated as included in the period 18–21 days, and probably in the earliest part of this period.[2]

[1] A lantern demonstration of slides of this embryo was given at a meeting of the Anatomical Society of Great Britain and Ireland at a meeting held on 16th January 1914.

[2] Keibel and Elze (*Normentafel* (2), p. 90) quote Born's estimate of the age of embryo "Klb" as 10–14 days. But if we take into account the more recently accepted criteria of age in early embryos, this age must be judged to be considerably underestimated. I shall show reason to regard embryo "Klb" as distinctly more advanced in development than embryo "H 3."

As originally received by me, the specimen was to all appearance in excellent condition. No defect in its preservation was recognisable throughout the period of its examination as an entire specimen prior to embedding, except that a portion of the yolk-sac was accidentally broken away during manipulation.

After embedding in paraffin a complete series of sections at 10 μ was obtained. Unfortunately the histological condition of the sections was most disappointing. The attempt at an adequate fixation must, after all, have been too belated. Possibly also there may have been some overheating in the paraffin oven. So unsatisfactory was the result at the time, that after a somewhat cursory examination the series was put aside for a considerable number of years. Now, however, on re-examination in connexion with the investigation of more recent specimens, it has appeared to me to be well worth while to describe this early embryo in some detail. More especially perhaps do the photographic records of the entire specimen, which shows no external sign of structural deterioration, constitute original documents of some value for comparative purposes. And even the sectional series, although not fully adequate for the purposes of plastic reconstruction, turns out, on closer examination, to be of no little interest and value.

Characters and Dimensions of Chorionic Vesicle.

The chorionic vesicle of "H 3" is illustrated in the photograph reproduced in Pl. I. fig. 1, which was taken after the vesicle had been rendered transparent in cedar oil. It was flattened in its polar axis and measured 5 mm. in its (practically avillous) polar diameter. Its equatorial diameter was about 8·5 mm., inclusive of the villi; or, without villi, 6·4 mm. in its longer and 5·7 mm. in its shorter equatorial diameter.

The chorionic dimensions were thus rather smaller than those of Spee's embryo "Gle" and almost identical with those of His' embryo "E."

As just indicated, the villi were unequally distributed over the surface of the vesicle. There was a richer equatorial villous zone, whilst the polar areas were freer from villi, though at no place completely bald. One of the polar areas, the antembryonic, was barer than the other.

The villi showed a very moderate degree of branching (*cf.* Pl. I. fig. 1).

After having been examined and photographed from both polar aspects, the vesicle was opened and the portion of its chorionic wall carrying the attachment of the body-stalk was separated from the rest. The embryonic rudiment with its associated appendages was then subjected to closer examination and sketched and photographed from various points of view. (Pl. I. fig. 2, taken in cedar oil; also text-figs. 1–3.)

Micrometer Measurements.

The following micrometer measurements were obtained of the embryo and its immediate appendages. The measurements were taken while the specimen was in cedar oil.

Maximum cranio-caudal length of amnion . .	1·78 mm.
Maximum „ „ yolk-sac . .	2·26 „
Apparent „ „ embryo . .	1·64 „
Dorso-ventral extent of amniotic cavity from its dorsal convexity to line of reflection of somatopleure in the head region	0·6 „
Dorso-ventral extent of yolk-sac	1·66 „

N.B.—The yolk-sac was partly collapsed and crumpled, as shown in the photograph (fig. 2).

The specimen was next embedded in paraffin and cut in series of 10 μ sections in a plane intended to be transverse to the long axis of the embryo, but which turned out to be distinctly oblique. The sections constitute a practically unbroken series, but their histological condition is not very satisfactory. They are tolerably well stained in hæmatoxylin. The series was both cut and numbered in caudo-cranial succession. When the sections and figures are viewed with the dorsal embryonic surface away from the observer, the right and left embryonic surfaces are right and left, respectively, to the observer.

Form and Characters of Embryo and its Appendages.

In Pl. I. fig. 2 the embryo, along with its immediate appendages, amnion and yolk-sac, is seen attached to a fragment of the chorion by the body-stalk. The latter is rather acutely reflexed in a cranial direction, thus arching over a considerable extent of the amnion so as to form the actual roof of the caudal portion of that cavity. The serial sections, when followed from behind forwards, show that the amnion only gradually becomes free from superincumbent cellular tissue of the stalk. Rather more than the caudal third of the amnion is thus intimately connected with the body-stalk, whose vascular mesodermal tissue, indeed, spreads out over this portion of the amnion like a hood.

The lateral portions of this hood gradually thin out as they clothe the sides of the amnion. In consequence of this extension of body-stalk tissue over the sides of the amniotic sac, the amnion exhibits in this region the appearance of a more or less vascular membrane (text-figs. 4 and 5).

Within the amniotic chamber the outline of the embryo may be discerned (Pl. I. fig. 2), with its cephalic expansion elevated bilaterally into two prominent medullary folds, separated by a deep and wide medullary groove (*cf.* text-fig. 6).

There is either no dorsal flexure or kink of the embryonic body, or only a faint indication of one (*cf.* text-fig. 1).

Behind the broad cephalic region the embryo shows marked constriction and then appears to widen out into a foliate expansion, which forms the hinder third of the apparent embryonic body.

The superficial appearance of the foliate expansion suggests a widening and opening-out of the medullary plate in this region. This, however, is not the exact condition met with. The still widely open neurenteric aperture, text-fig. 7, is situated near the junction of the middle and posterior thirds of the embryonic region. Its position nearly coincides with the ventrally open angle recognisable in Pl. I. fig. 2, and also in text-fig. 1, at *b*, where also an arrow points to the site of the neurenteric aperture. The open angle at *b* in text-fig. 1 really marks the anterior limit of the leaf-like expansion of the hinder part of the embryonic region. Immediately in front of the neurenteric aperture, the sections show the medullary plate as still markedly infolded so as to form a deep and not very wide medullary groove.

Behind the aperture there is no shallowing out, but, on the contrary, the primitive-streak formation is here actually depressed into a deep cleft which continues backwards between two elongated, bolster-like, caudal swellings containing mesoderm (text-fig. 5).

It is these caudal swellings which form the lateral wings of the posterior foliate expansion of the embryonic region. The ectoderm covering them is not at all, or only slightly, thickened, whilst the primitive-streak ectoderm lining the deep dorsal furrow between them is thick and columnar like that of the medullary plate in front.

Apart from the elongated caudal cushions bounding the deep sulcus in the primitive-streak region, there is no posterior tail-prominence. The part of the embryonic region containing the caudal swellings is, however, placed slightly at an angle with the rest of the embryonic area. This may be recognised in the photograph, fig. 2, Pl. I., and is well shown in the outline in text-fig. 1.

The caudal cushions gradually fade away posteriorly in the floor of the hinder region of the amniotic cavity. This latter tapers into a narrow-pointed prolongation and ends at the plane of the hinder limit of the root of the body-stalk. It has no continuation into the body-stalk. Its floor is formed solely by the continuation backwards of the floor of the vanishing primitive groove (text-fig. 8).

Close to the termination of the amniotic cavity there is a thick "cloacal membrane" connecting with the entoderm at the base of the allantoic duct (text-fig. 9). The position of this cloacal membrane may be compared with that described and figured recently by Grosser in a younger embryo (8, Taf. 27). There was no caudal stalk-like prolongation of the amnion, other than the above, to correspond with that described by Eternod in his 1·3 mm. embryo.

As there is no tail-prominence proper, the posterior limit of the embryo has been reckoned as if coincident with the hinder limit of the furrowed primitive-streak region, although the extremity of the future tail would undoubtedly be formed by hypertrophy of the bilateral caudal cushions far in front of this point. Reckoning, then, from the posterior limit of the primitive-streak region to the cranial limit of the cephalic medullary plate, the length of the embryonic area included 143 sections at 10 μ. In the table

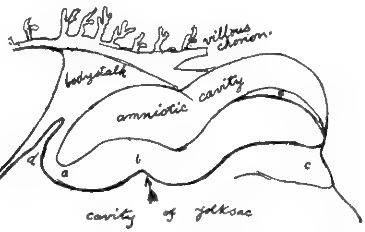

FIG. 1.—Outline showing profile view of embryo "H 3."

of measurements the apparent length of the embryo prior to embedding was 1·64 mm.; the difference just indicated is doubtless to be accounted for mainly by shrinkage during embedding.

In text-figs. 1, 2, and 3 are reproduced the outlines of freehand sketches, from various points of view, that were made in the course of examination of this embryo, *in toto*, in cedar oil.

Text-fig. 1 is the outline of a nearly profile view. It may be looked at along with the photograph, fig. 2, Pl. I., which represents a dorso-lateral view of the specimen. The text-figure shows the degree of vertical curvature of the several regions of the embryo. The approximate position of the neurenteric aperture is indicated by the arrow. The region *a* to *b* is the primitive-streak region: the angle of its inclination to the main embryonic axis is to be noted.

If this figure be compared, *e.g.*, with figs. 19 and 20 of Eternod's monograph *L'œuf humain* (5) (Genève, 1909), illustrating respectively Selenka's outline figure of *Hylobates Rafflesi*, and Eternod's outline of his 1·3 mm. human embryo ("No. 7 Vuill."), it will be seen that the most outstanding difference is due to the acute ventral flexure of the primitive-streak region in these embryos as compared with my specimen "H 3." And this difference in flexure is correlated with the difference observable in relative position of the body-stalk. The absence of a ventral flexure of the primitive-streak region in embryo "H 3" permits of a rather acute reflexion, in a cranial direction, of the body-stalk.

Practically the same comparison may be made with embryo "Klb" (Kroemer-Pfannenstiel) of Keibel and Elze's *Normentafel* (2), which possessed 5–6 pairs of somites and must represent a somewhat similar developmental phase to that of the embryo under consideration. That "Klb" was slightly more advanced is indicated by its possession of a well-marked tail-prominence, of a closed-in hind-gut, and by several other features to be later commented upon.

The possibility cannot be entirely excluded that the extended position of the hinder part of the embryonic area of "H 3" is somewhat abnormal, especially as the flexed attitude of the primitive-streak region was already attained in Spee's embryo "Gle" (3), which is certainly less advanced and is probably perfectly normal.

In any case, it is plain that the absence of ventral flexion of the primitive-streak region in "H 3" involves a reconsideration of the true length of the embryo. If a reliable comparison is to be instituted with other human embryos of approximately the same stage, then we must deduct from the apparent embryonic length given above as 1·64 mm., nearly the whole length of the primitive-streak region behind the neurenteric aperture, since, in the embryos referred to, the neurenteric aperture lies quite close to the angle of a ventrally flexed tail-end of the embryonic body.

The deduction here suggested as necessary includes nearly the whole of the primitive-streak region. In the total of 143 sections of the embryonic area, inclusive of primitive streak, no fewer than 47 lie behind the plane of the caudal boundary of the neurenteric aperture.

Allowing for the slight caudal convexity behind this which is recognisable in comparable embryos, I estimate the true "embryonic length," for comparative purposes, to have been not over 1·25 mm. The actual proportion of the total of 1·64 mm. *in front of* the neurenteric aperture is almost exactly 1 mm.

Text-fig. 2 represents the outline of embryo "H 3," as viewed from above and slightly from the caudal direction. The irregular area which has been hatched in the drawing represents the small portion of chorion connected with the body-stalk. The stippled area represents the dorso-caudal aspect of the body-stalk, and shows how it spreads out laterally over the hinder portion of the amniotic sac. Some indications of the chorio-placental vessels may be noted, but their detailed arrangement has not yet been worked out from the sections.

Text-fig. 3 represents an outline sketch giving the frontal "elevation" (Norma frontalis) of the amnion and head of the embryo, as viewed from

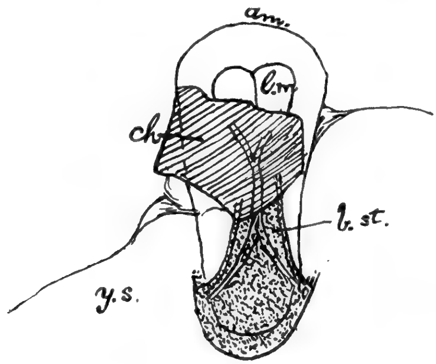

FIG. 2.—Outline showing caudo-dorsal view of embryo "H 3."

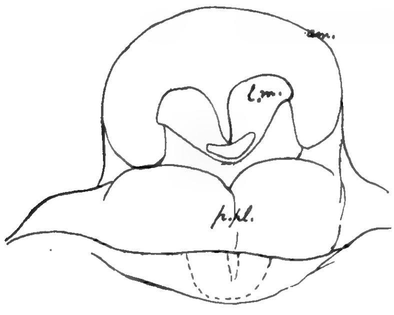

FIG. 3.—Outline showing norma frontalis of embryo "H 3."

the front and very slightly from the ventral side. The wide bulging area below the amniotic sac corresponds to what may be termed the "pericardial plate," although at the present stage the pericardium does not actually reach quite to its surface.

Mesodermal Somites.

Notwithstanding careful and prolonged examination of this embryo while in cedar oil prior to embedding, I was unable to detect the presence of differentiated somites. The other features of the embryo seemed to indicate that some at least of the earliest somites should be already in existence.

Examination of the serial sections has, in fact, confirmed this conjecture. Unfortunately, the histological condition of the paraxial mesoderm is not so satisfactory as to permit of a wholly reliable determination of the number of somites represented. I have only been able to recognise in the section series one line of segmental cleavage with tolerable certainty. I dare not assert that it is the only one present, and a critical examination of good silver prints of the photograph here reproduced on Pl. I. fig. 2 suggests the possible existence of up to three pairs of somites.

In any case, it is evident from the photograph in question that the number of somites could only have been small. And in this connexion it must be pointed out that only a distance represented by about 25 sections intervenes between the tolerably abrupt posterior limit of the crescentic curve of the cephalic medullary fold and the anterior margin of the neurenteric aperture.

The distance between the probably corresponding points in the second of my specimens, "H 98," which possesses 9–10 pairs of somites, includes no fewer than 65 sections of similar thickness.[1]

We have therefore to reckon in embryo "H 3" with 25 sections, against 65 in the latter stage ("H 98"), as representing the possible longitudinal field of somite differentiation.

Now, an inspection of figures of other early embryos suitable for comparison will show that the differentiated somites do not extend close up to the anterior, and certainly not nearly to the posterior, limits as above defined, so that we have to deal with a lesser number than 25 sections, which could pass through mesodermal primitive segments.

In the Kroemer-Pfannenstiel embryo, for example (fig. 111D of Taf. I., Keibel and Elze's *Normentafel* (2)), the five pairs of somites there present do not occupy much more than half the distance between the neurenteric aperture and the hinder end of the cephalic medullary plate. From their figure it would appear that the distance from the cranial limit of the first pair of somites to the neurenteric aperture was about ·7 mm., and the actual segmented zone occupied only about 0·35.

Inasmuch, then, as in embryo "H 3" the entire available length from cephalic medullary plate to neurenteric aperture is represented by only about 25 sections, the actual segmented portion was quite probably not more than about half of that length—say 12 or 13 sections in extent.

I find in the older embryo "H 98" that the somites there met with

[1] It is perhaps necessary here to point out that although in the latter embryo the neurenteric aperture was closed, yet it is quite easy to determine the site corresponding to it, for here the chorda merges in mesoderm which cuts into the overlying medullary plate like an inverted keel (text-fig. 10).

extend over an average distance of about 5 sections each. If, as is highly probable, there is no great increase in size of the individual somites in these early stages, the conclusion may be drawn that only two, or at most three, pairs of somites could possibly have been differentiated in embryo "H 3."

I have already stated that one cleavage line may be definitely established in the sectional series. I can find no positive evidence in the series of any other, and I see little reason to doubt that here we have an example of a human embryo at about the stage of progressive differentiation of the first two, or possibly three, pairs of somites.

Chorda.

The chorda is still in the stage of intercalation in, and is indistinguishable from, the entoderm.

Not only is there no chorda as such, but there is no unequivocal indication of strict delimination, even of a chorda-plate, except for a distance of 3 or 4 sections immediately in front of the neurenteric canal. It is possible that in the pharyngeal region the longitudinal zone of entoderm, which covers the dorsal median prominence, due to the grooved medullary plate, may actually represent definite chorda-entoderm. But, except that a median strip of entoderm *is* thus more or less accidentally delimited, there is nothing to suggest the specific character of just that precise area. Text-fig. 13 illustrates the 4th section in front of the anterior margin of the neurenteric aperture. Even here the chorda-plate is evident, not so much by its differentiation from the rest of the entoderm, as by the appearance here of an entodermal indentation which leads caudally into the neurenteric opening itself.

Excretory Apparatus.

There is no ascertainable pronephric rudiment, nor would one expect to find any at this early stage. In any case, the histological conditions are unfavourable to any critical verification.

Medullary Plate.

The general characters of the medullary plate have already been alluded to in connexion with the form of the embryo. Pl. I. fig. 2, along with text-figs. 1, 2, and 3 and the various sectional text-figures, will sufficiently illustrate its present phase of development. The photomicrographic text-fig. 18 will further elucidate its structural arrangement so far as its rather poor histological condition will allow. Text-fig. 4 illustrates the appearance of the medullary plate and groove a short distance (4–5 sections) caudal to the cephalic expansion of the plate, and 21 sections in front of the anterior lip of the neurenteric aperture. Nowhere is there any closer approximation of the medullary folds than is shown in this section.

The histological conditions are not favourable enough for reliable observations either on neuromeric segmentation or on neural crest formation.

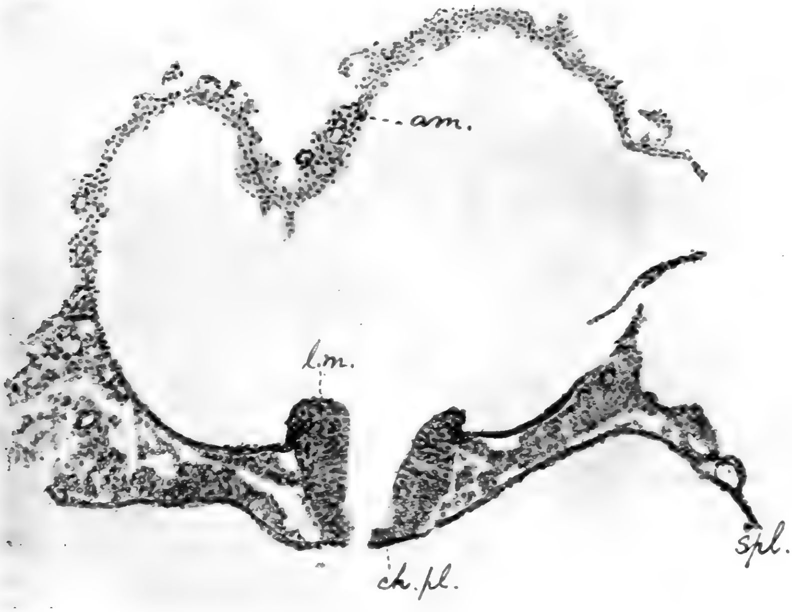

FIG. 4.—Section 95 of embryo "H 3."

Absence of Sense Organs.

There is no trace whatever of optic groove formation nor of auditory areas, although there is a diffuse and rather extensive thickening of the head ectoderm in the posterior cephalic region, which may possibly foreshadow the appearance of such areas.

Oral Region.

On the ventral aspect of the head, immediately in front of the line of reflexion of the ectoderm from the free head to the "pericardial plate" swelling (text-fig. 11), the ectoderm forms a plate, slightly recessed bilaterally, the depressions being separated from one another by a slight median prominence.

This gently recessed area alone represents the oral sinus (stomodæum), which is thus very imperfectly formed.

The ectoderm of this oral sinus is separated from the entoderm of the pharynx by abundant mesoderm. Nowhere do ectoderm and entoderm even closely approach one another, so that the "primary pharyngeal membrane" is here quite thick (0·06 mm.), and composed of all three germ layers. In fact, the mesoderm is here disposed as a specially thick compact mass of cells between the ectoderm and entoderm (text-fig. 11), and is continued backwards as such to the very caudal limit of the region of

FIG. 5.—Section 49 of embryo "H 3."

the rudimentary oral sinus. The area of this imperfectly formed oral sinus extends through sections 159–153 inclusive.

There are no evidences of any hypophysial formation.

Alimentary Canal.

The fore-gut shows a general agreement in character with that of the important Kroemer-Pfannenstiel embryo "Klb" of Keibel and Elze's *Normentafel.* The pharynx of this embryo has been described, modelled, and figured by Grosser (6) (also in the Keibel-Mall *Manual,* vol ii. pp. 446–7). In embryo "H 3" the fore-gut is closed in for a distance represented by 30 sections, in front of the plane of its continuity with the yolk-sac at the "Darmpforte." In the "Klb" embryo, the fore-gut was closed in throughout the extent of 32 sections. Grosser states (6) that its actual length, allowing for curvature, was 400 micra. The fore-gut in "H 3" represents the anterior portion of the future pharynx. It has the usual laterally expanded form (text-fig. 6). It gradually diminishes in width when traced forwards until the cranial limit of the first primary pharyngeal pouch is reached. Here there is a more abrupt diminution in width (text-fig. 12) and then a tolerably rapid tapering into the attenuated

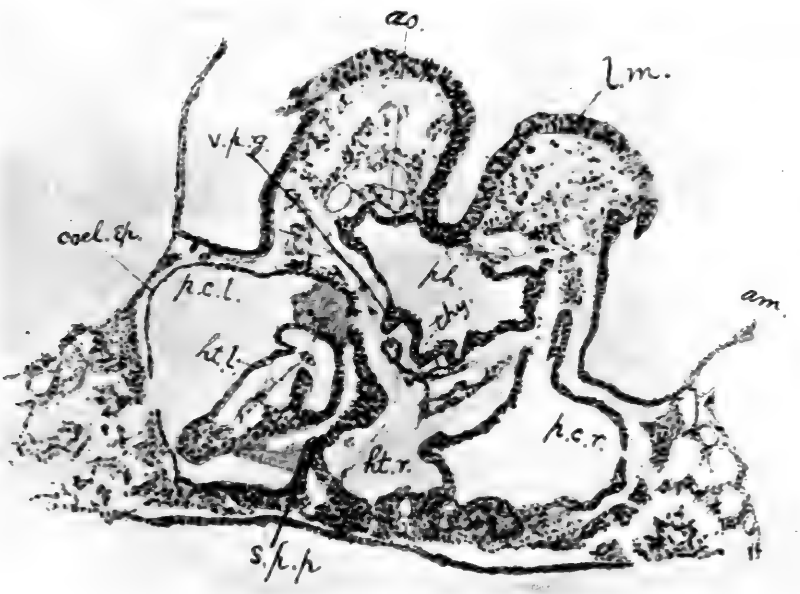

FIG. 6.—Section 140 of embryo "H 3."

blind extremity of the gut, still retaining its dorso-ventrally compressed character. This tapering terminal segment extends in a cranial direction for several sections beyond the ascertainable anterior limit of the oral sinus. No such marked ventral flexion of the narrow terminal segment of the gut as that seen in embryo "Klb" is recognisable. At a distance of 5 sections from its cranial limit, however, the contact which has up to that point been maintained between the dorsal wall of the pharynx and the medullary plate suddenly disappears. This separation corresponds with the now rapidly shallowing character of the medullary groove, as it is traced in the rostral direction. There is no recognisable trace of any Seessel's pouch.

I have made a rough wax-plate reconstruction of the entire pharynx, but unfortunately certain dislocations of structure detract from its value for purposes of publication. In most respects, however, it is reliable enough, and it brings into prominence the tolerably close similarity in various features between embryo "H 3" and embryo "Klb" in respect of the pharynx.

Throughout nearly its entire length the ventral pharyngeal wall is depressed into a median V-shaped furrow. On the exterior of the model this expresses itself in the ventrally keeled appearance which the pharynx

FIG. 7.—Section 76 of embryo "H 3."

thus presents. Though present throughout practically its entire length, the keel-like prominence varies in its degree of salience at different levels. It is already visible even in the region of the "primary pharyngeal membrane." Caudally from the level of the oral sinus it becomes accentuated where it overlies the paired pericardial cavities (text-fig. 12). But it is recognisable even where the dorsal pericardial wall is perfectly level. Nevertheless, text-fig. 18 inevitably suggests that this keel-like form of the early ventral pharyngeal wall is somehow a result of the bilateral constitution of the head region, as are the paired pericardial cavities themselves.

In the reconstruction model two maxima are apparent for the keeled ventral pharyngeal wall. One of these (text-fig. 6) appears to coincide with that in embryo "Klb" in the region between the first and second pharyngeal pouches, which Grosser has determined as the thyreoid rudiment (6).

The second maximal development of the median ventral pharyngeal keel lies further forward (*cf.* text-figs. 12 and 18), in the region opposite the anterior end of the first pharyngeal pouch, and it is this accentuated portion of the keel which seems related to the imperfect interpericardial septum seen in these text-figures. In succeeding sections (proceeding in a caudal direction) there is a diminution of prominence of the ventral keel until it somewhat abruptly develops the second or thyreoid prominence seen in text-fig. 6. This then continues in a caudal direction until it merges in the median cranial boundary of the yolk-sac opening ("Darmpforte"). It thus appears that the thyreoid rudiment, though perhaps tolerably definitely localised in the cranial direction, has at the present stage no definite caudal limit.

There is seen on each side of the thyreoid rudiment in text-fig. 6, a "ventral pharyngeal groove," in Grosser's sense (*cf.* (6), pp. 274–75). This, however, begins more abruptly and perhaps more caudally than in embryo "Klb." It makes its appearance in the same section (142) which shows the first trace of the definite thyreoid rudiment. This is the eighth section behind the cranial limit of the first pharyngeal pouch. It may be noted that this bilateral "ventral pharyngeal groove," appearing as it does very abruptly, shows no sign of being continued from the ventral aspect of the first pharyngeal pouch, as described by Grosser in embryo "Klb." Further, it is more sharply defined, is of less cranio-caudal extent, and is somewhat more medial in position than would appear to have been the case in the latter embryo.

The first primary pharyngeal pouch is first met with in section 150 (text-fig. 12), in the form of an abrupt lateral extension from the side of the pharynx, exactly as in embryo "Klb" (Grosser's figs. 1 and 2 (6), and in Keibel-Mall (1), figs. 314–5). The latter dilatation of the pharynx thus arising, is continued caudally, showing no definite limit in this direction. It does not exhibit the pronounced and progressive diminution in its dorso-ventral dimension visible in Grosser's model, but there is a slight indication of expansion in the region corresponding to the "second pharyngeal pouch" of embryo "Klb," as shown in that model.

The dorsal wall of the pharynx is bulged towards its lumen along three longitudinal zones, corresponding respectively to the grooved medullary plate medially, and the two dorsal aortæ laterally. Grosser's description seems to imply that dorsal aortic impressions on the dorsal pharyngeal wall were absent in embryo "Klb"; but Keibel and Elze's fig. 5*a*, p. 19 (2), shows them quite definitely.

It has already been stated that, from a point 5 sections behind the anterior limit of the pharynx, the dorsal wall of the pharynx is in close apposition with the grooved medullary plate. This contact determines the median of the three longitudinal prominences which are evident along the dorsal wall of the pharynx. The entoderm covering this median prominence is that of the chorda-plate (*cf.* text-figs. 6, 14, etc.), but it is hardly, if at all, distinguishable from the rest of the entoderm at this stage. In the serial sections there are some ruptures of the continuity of the pharyngeal

FIG. 8.—Section 29 of embryo "H 3."

entoderm, but this chorda-entoderm has very generally preserved its intimate relation to the medullary plate, which has afforded it a firm support. There is as yet no closed-in hind-gut. This condition is to be correlated with the absence of any true caudal prominence and the non-flexed condition of the entire primitive-streak region. Underlying the extreme hinder end of the latter, the cavity of the yolk-sac is prolonged, unilaterally, in a dorsal direction on the right side, into an asymmetrically placed *dorsal enteric groove.* Posteriorly (text-figs. 8 and 9), this groove leads into the somewhat dilated proximal portion or vestibule of the allantoic duct. This turns dorsally (text-fig. 9), and rapidly narrows into a canal of practically uniform fine calibre, being carried at first forwards into the cranially reflexed body-stalk.

The more medial wall of the asymmetrically placed dorsal enteric groove of the yolk-sac aforesaid exhibits, close to the proximal end of the allantoic vestibule, a well-marked depression which is closed by the thick cloacal membrane already referred to.

Allantoic Duct.

The proximal portion or vestibule of the allantoic duct has already been referred to, as also its continuation into a narrow canal of uniform calibre

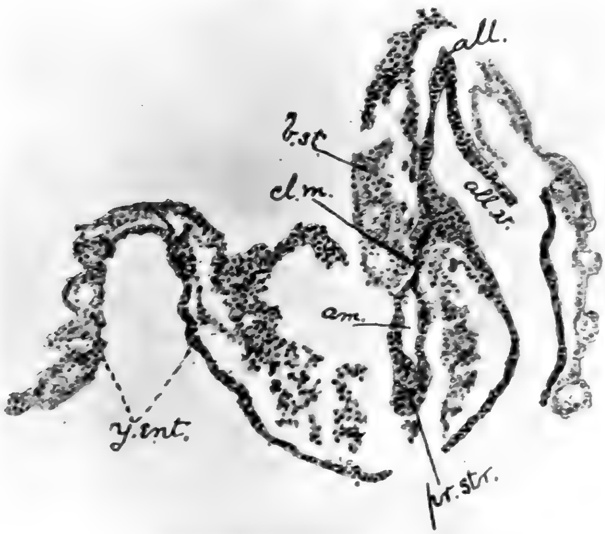

Fig. 9.—Section 28 of embryo "H 3."

prolonged into the reflexed body-stalk. After passing in a cranio-dorsal direction for some considerable distance (0·25 mm.), it bends further dorsally and then finally in the caudal direction and is now very slightly more attenuated. At a further distance of about 0·15 from its latest flexure, it now rather rapidly increases in size, and ends by expanding into a distinct vesicle. Throughout its entire tubular portion, it is lined by relatively thick cubical entoderm. At its expansion, this quite abruptly passes into very thin entodermal epithelium with which the terminal vesicle is lined. The maximum diameter of the lumen of the vesicular expansion is about eight times that of the tubular allantoic canal. Eternod has noted that the allantoic cord of his 1·3 mm. embryo had "no appreciable vesicular enlargement." A distance of 14 sections, or 0·14 mm., intervenes between the commencement of the dilatation and the terminal fundus of the vesicle. The total length of the allantois, exclusive of what I have termed the allantoic vestibule, but including the terminal vesicle and allowing for the flexure of the canal, is over 0·6 mm. It may be said to follow a U-shaped course, the concavity of the U looking in the caudal direction.

Pericardium.

The pericardium lies chiefly ventral to the pharynx, but it extends for a distance of about 0·05 mm. in front of the cranial limit of the latter.

It consists of paired cavities which are in actual communication with one another for a distance of only 9 sections, whilst it is extremely probable

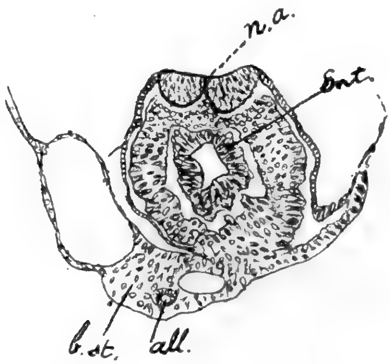

FIG. 10.—Section 128 of embryo "H 98."

that in the case of the three more cranial of these sections the communication is artificial and due to rupture of a delicate septum (*cf.* text-fig. 12).

The separation, partial or total, of the two pericardial cavities is effected differently in different regions of their extent.

Cranially and for a distance backwards of 15 sections (sections 152–137) there exists a genuine *septum proprium interpericardiacum* which is approximately median in position. In no one section does this appear as wholly complete, but there is little doubt that it was actually complete in its most cranial portion, as already indicated (text-fig. 12). As it is traced caudally this *septum proprium* becomes less and less complete (text-fig. 14), and gradually undergoes reduction (text-fig. 6) to the condition of a mere vestigial ridge of the ventral pericardial wall.

But already, considerably in front of the plane at which there is any marked reduction of the septum, the appearance of the heart rudiments, with their dorsal and ventral mesocardial connexions (*cf.* text-figs. 14 and 6), effects the complete temporary separation of the more caudal regions of the two pericardial cavities.

These now, as they are traced further in the caudal direction, diverge gradually (text-fig. 15, right side) more and more from one another and are continued as the parietal (pleuropericardial) recesses.

The parietal recesses end blindly without establishing any communication with any other cœlomic cavity such as occurs later, *e.g.* in Mall's embryo, No. 391 (Dandy (7), pl. ii. fig. 11).

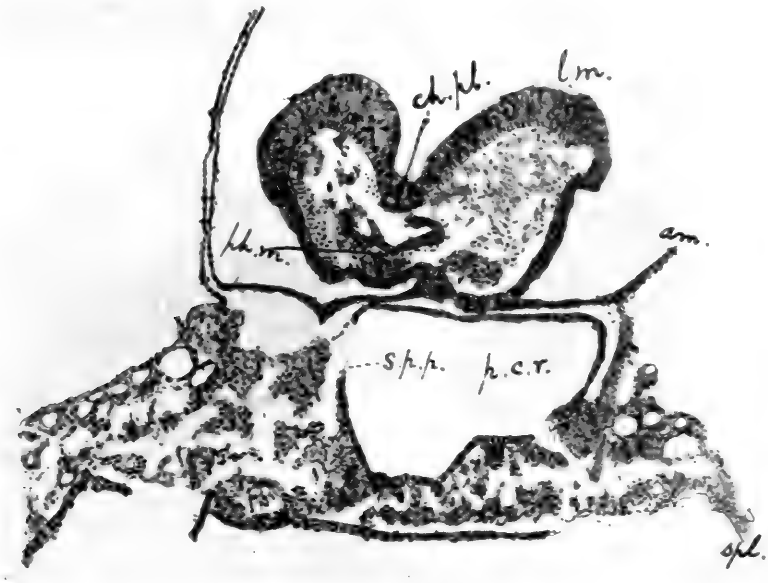

Fig. 11.—Section 155 of embryo "H 3."

Their lumina are only traceable for a distance of about 8 sections behind the termination of the crescentic curve of the cephalic medullary plate, or for a distance of about 12 sections behind the present posterior limit of the foregut (cranial margin of the "Darmpforte").

The paired pericardial cavities are lined throughout by a definite layer of cœlomic mesothelium, which in many of the sections has shrunk away to some extent from the mesoderm surrounding it (text-figs. 16 and 17).

The most cranial portions of the right and left pericardial cavities which are unoccupied by and wholly in front of the heart, occupy a position in the thick, plate-like mass of mesoderm uniting amnion and yolk-sac (*cf.* text-figs. 11, 12, and 16). The dorsoventral thickness of this mesodermal mass is maintained throughout at about 0·3 mm. In the cranial direction, it merges in an accumulation of loose vascular mesoderm which lies in the angle between yolk-sac and amnion, supporting, dorsally, the cephalic fold of the latter, and continuous, ventrally, with the vascular mesoderm of the yolk-sac.

The presence of this mesodermal mass occasions a slight bulging ventral to the head of the embryo between amnion and yolk-sac (*cf.* text-figs. 2 and 3). This mesodermal mass may appropriately be styled the "pericardial

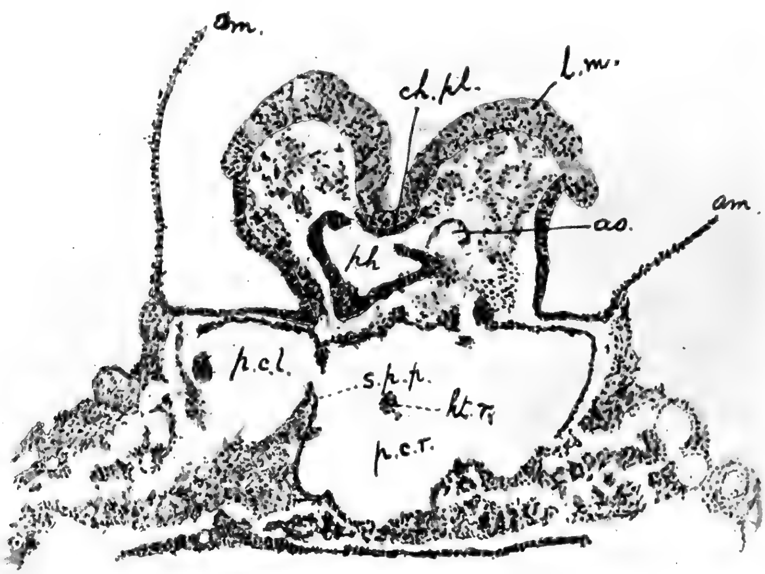

FIG. 12.—Section 150 of embryo "H 3."

plate," inasmuch as it soon gives place, and probably with great rapidity at this juncture, to a bulging pericardium as found in such a closely succeeding stage of development as that represented by embryo "H 98," *v. infra*, or as in Mall's embryo No. 391, F. T. Lewis' reconstruction, fig. 232, Keibel and Mall, vol. 2.

In the present case of embryo "H3" the paired pericardial cavities have already appeared in this pericardial plate (text-figs. 16 and 17), but they have not yet so completely excavated it as to form a bulbous pericardial protrusion anteriorly, as is the case in the succeeding stage.

The pericardial cavity is first met with in the serial sections at a plane lying 5 sections caudally to that of the anterior end of the medullary plate. Here (text-fig. 16) the cœlomic mesothelium lining the fore end of the right pericardial cavity is first encountered. That the right cavity appears as much as 12 sections before the left (text-fig. 17) is largely, but perhaps not wholly, to be accounted for by the obliquity of the sectional plane, which is considerable.

As the serial sections are traced in the caudal direction, the pericardial cavities are found to expand so as to occupy the place of the thick mesoderm of the "pericardial plate," and they gradually supplant that tissue, the interval between the amniotic and yolk-sacs remaining practically unaltered (text-fig. 14).

FIG. 13.—Section 81 of embryo "H 3."

Heart.

The heart itself is still almost completely duplex as regards not only its endothelial but also its myo-epicardial components. The duplicity of the latter may be recognised from a comparison of text-figs. 6 and 14. Text-fig. 6 shows portions of both right and left heart-tubes (myo-epicardial). Text-fig. 14 shows only the right heart. The plane of the latter section lies quite in front of the looped arterial end of the left heart, which is cut through in the section shown in text-fig. 6. To establish the connexions of this looped arterial left heart one must pass caudally from the plane of the last-named text-figure.

The marked dissimilarity of the right and left hearts in that figure is due mainly to the obliquity of the plane of section already referred to. It is somewhat difficult to state accurately the extent of this obliquity, but it may be indicated by the statement that the cranial limit of the first primary pharyngeal pouch on the right side lies some 8 or 9 sections in front of the corresponding point on the left. Were it not for this obliquity the right and left heart-tubes would appear tolerably symmetrically arranged, though both of them already show a marked degree of individual flexure. The relations of each heart-tube to the interpericardial septum may be easily recognised in the text-figs. 6 and 14. It is evident that each heart-tube, in so far as it is separate, occupies its own pericardial cavity.

I have not yet been able to undertake a plastic reconstruction of this highly interesting state in cardiac development. This I hope to see carried

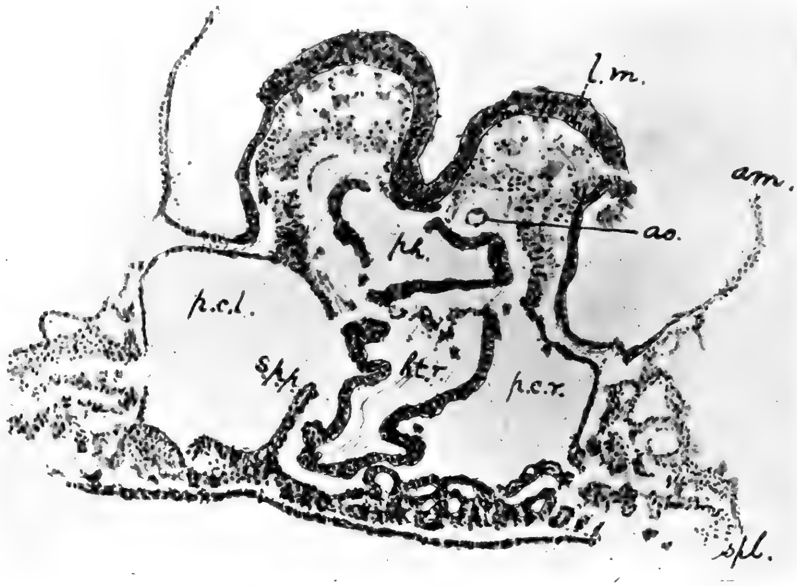

FIG. 14.—Section 144 of embryo "H 3."

out later on, although I fear that the degree of accuracy attainable will only be approximate. The section series is complete and quite intelligible, but there are histological imperfections which may be troublesome. This will be more especially the case with the endothelial heart-tube and the aortic arch system.

The arrangement of the latter I have not been able thus far to clear up satisfactorily from mere examination of the section series. So far as my observations go at present, I am disposed to regard the connexions between the arterial heart-tubes and the dorsal aortæ as still of a more or less plexiform character. Perhaps this relationship would also best explain the condition met with by Eternod in his 1·3 mm. embryo. And I can well imagine the cardiac condition I find in embryo "H 3" to be immediately preceded by some such duplex tubular cardiac condition as that figured by Eternod in that interesting specimen. In any case, it is clear to me that there are several highly interesting pages of the history of early human cardiac development which are yet unwritten.

It is clear from the conditions met with in embryo "H 3" that the ordinarily accepted account of the origin of the single pericardium and heart in human development will not hold good without considerable modification. Thus Tandler, in Keibel and Mall's *Manual* (English edition, vol. 2),

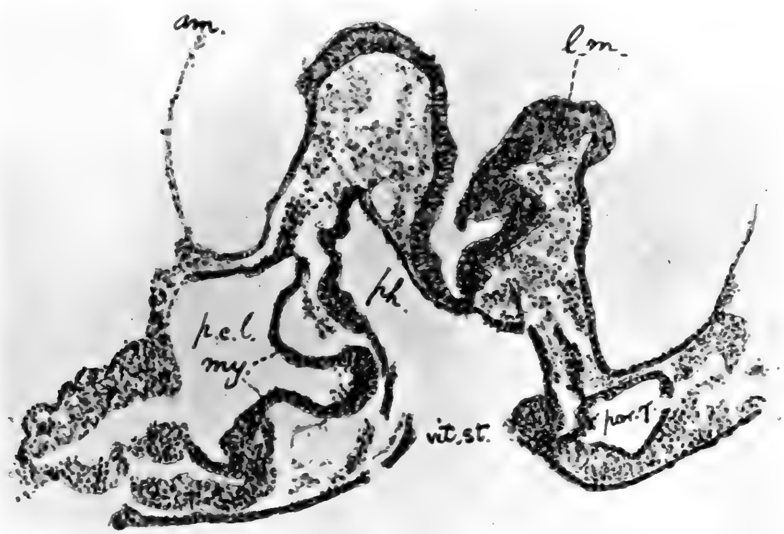

Fig. 15.—Section 127 of embryo "H 3."

says:—"On the closure of the fore-gut ventrally the hitherto symmetrical pleuropericardial cavities come together anteriorly and fuse in this region, the median partition between them, the *mesocardium anterius*, disappearing, while the *mesocardium posterius* persists for some time longer. The closely approximated but not yet fused endothelial tubes are now surrounded by a continuous *myo-epicardial mantle* (Mollier). Finally, the two endothelial tubes come into contact, their partition wall disappears, and the unpaired heart cylinder is formed from the paired heart-tubes. This stage of the development of the heart occurs in the Krömer-Pfannenstiel embryo 'Klb,' etc. etc."

The final result here referred to as manifest in embryo "Klb" may be quite correctly described, but the hypothetical preliminary phases leading up to it are in all probability neither so simple nor so direct as Tandler represents them.

The fusion of the right and left pericardial cavities is, as we have seen, for a time incomplete anteriorly, and the imperfect septum separating them is not a "mesocardium" at all in the ordinary sense, but an interpericardial septum of mesoderm, quite independent of the heart-tubes themselves. Further, there occurs, prior to the state of single and continuous myo-epicardial mantle, a stage of an at least nearly complete duplex heart in which both right and left hearts possess myo-epicardial mantles which are,

Fig. 16.—Section 165 of embryo "H 3."

at least throughout the greater part of their extent, independent of one another, and which cannot be regarded as mere semitubular elements completing a simple median heart-tube by their coalescence.

I may say here that through the courtesy of Professor J. P. Hill, F.R.S., I have had the opportunity of looking through a superb section-series of an embryo of Perameles in which the stage of cardiac development—evident with diagrammatic clearness—is obviously essentially identical with that which obtains in my embryo "H 3."

The condition in Perameles clearly shows that fore-gut closure in a mammalian embryo does not of itself at once determine median fusion of the primitively paired heart-tubes, for in this mammalian embryo one finds a completely closed fore-gut very greatly expanded in the transverse direction, and, attached to its floor but widely separated from one another, there are seen independent right and left myo-epicardial tubes. These appear to be of essentially similar character to those of embryo "H 3," and, like them, each shows a definite and more or less symmetrical (in Perameles apparently quite symmetrical) primary flexure, definitely marking the venous and arterial subdivisions of the tube.

No further discussion of either cardiac or vascular systems can be

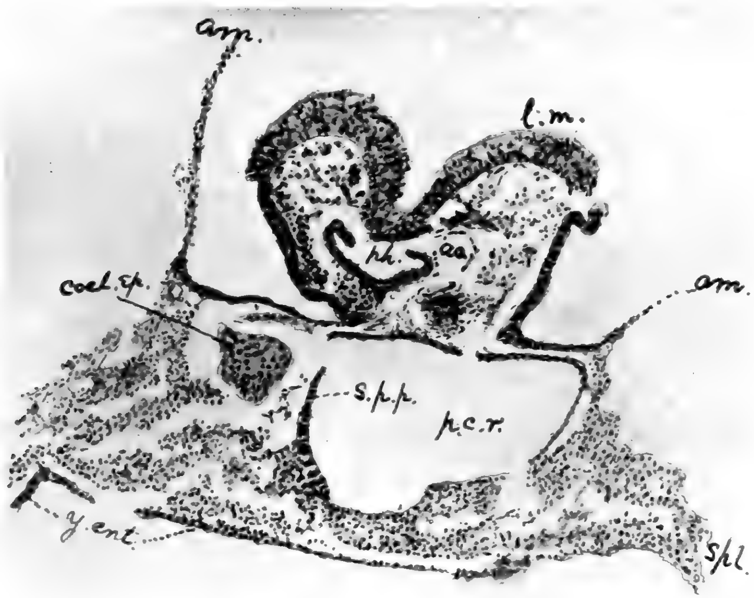

FIG. 17.—Section 153 of embryo "H 3."

undertaken on the present occasion. Many details of the vascular arrangements have not yet been ascertained with sufficient precision.

It may be stated that the vascular network in the wall of the yolk-sac is not only well established, but many of its channels show clear lumina with a definite endothelial lining.

Relative Position of Embryo "H 3" in the Human Embryonic Series.

The relative position, in a "Normentafel" of human embryonic development, to be assigned to embryo "H 3," has already been discussed in an earlier section of this paper. I place it in the interval between stages 2 and 3 of Keibel and Elze's *Normentafel* (2).

Although His' embryo "E" (No. 1 of his *Normentafel* (4)) is only known to us by its external characters, I believe that, notwithstanding its greater length, it offers the nearest parallel to "H 3." Both of these embryos I believe to be slightly more advanced than Eternod's "No. 7 Vuill." of 1·3 mm. length.

I have attempted to summarise the characteristics of embryo "H 3" on the general lines of the paradigm of Keibel and Elze's *Normentafel*, with a few modifications, so that the corresponding characters of various known

Fig. 18.—Section 149 of embryo "H 3."

embryos may be readily compared. That "H 3" is distinctly in advance of stage 2 of the *Normentafel* (Spee's embryo "Gle") is at once evident on comparison of the figures and descriptions. In particular the medullary plate and the pericardium and heart in "H 3" show a marked advance on the earlier stage.

The more outstanding characters which seem to differentiate "H 3," as earlier, from embryo "Klb," representing stage 3 of the *Normentafel*, are the following:—

1. In "H 3" the embryonic length, *as interpreted in the body of this paper*, is slightly less than that of "Klb."

2. In the former embryo no brain subdivisions were apparent in the otherwise well-marked cephalic medullary plate. On the other hand, the

brain region seems rather more prominent in "H 3" (fig. 2, Pl. I.) than in the published figures of "Klb."

3. The neurenteric aperture was widely patent, and was both relatively and absolutely closer to the head region in "H 3" than in "Klb."

4. In embryo "H 3" there was no hind-gut. On the other hand, the fore-gut, both in its dimensions and its degree of differentiation, differed only slightly from that of "Klb."

5. The chorda rudiment is in a much more backward stage in "H 3." Hardly any indication of it is visible, even in the form of a chorda-plate.

6. The somites, although not quite conclusively determined in "H 3," were certainly fewer (not more than three) in number.

7. The pericardium in "H 3" is still in the condition of bilaterally paired and nearly symmetrical cavities, separated by a *septum proprium interpericardiacum.*

The extent of the intercommunication between the two pericardial cavities is very limited.

8. The heart of "H 3" is still largely duplex, consisting of right and left myo-epicardial mantles.

Summary of Characters of Embryo "H 3."

Designation.—Human embryo "H 3" (Hdr). Collection J. T. Wilson.

Dimensions.—Chorionic vesicle 6·4 × 5·7 × 5 mm., ex. villi.
" " 8·5 × 5 " incl. "
Length, amniotic sac 1·78 mm., yielding 151 sections.
" embryonic region 1·64 mm., yielding 143 sections.
" yolk-sac (distorted) 2·26 mm.
Depth, yolk-sac (dorsoventrally) 1·66 mm.
Length (cranio-caudally) of cephalic medullary plate, estimated as to the caudal limit of its prominent fold, 0·6 mm. ± (plus or minus).

Age.—Period elapsed since beginning of last menstruation to commencement of abortion, 40 days. Period since end of last menstruation, 36 days. Period elapsed since due date of lapsed menstruation, 12 days. Estimated age of embryo, 18–21 days. No conjugal history. Menstrual history as above.

Body Form.—No dorsal bend of embryonic body.

Primitive-streak region (= tail end) deeply furrowed, and forming only a very slight angle with the body proper. No tail-prominence other than caudal cushions bordering the furrow of the primitive-streak region.

Head end of brain-plate flexed ventrally over a pericardial-plate-prominence, which is already visible.

Primitive-Streak Region. — Neurenteric canal still widely patent Primitive-streak region tolerably lengthy (0·47 mm. in the section series) and deeply furrowed, and bordered by elongated, cushion-like caudal swellings.

Entire primitive-streak region still appears as the nearly direct caudal continuation of the embryonic body proper. Cloacal membrane posteriorly.

Mesodermal Segments.—Somites not visible on external examination; certainly fewer than five pairs, probably not more than two pairs, and not less than two.

Chorda.—Chorda entirely absent as such. Median strip of entoderm forming chorda-plate only recognisable with any degree of certainty just in front of the neurenteric aperture. But probably also in head region.

Nervous System.—Medullary plate expanded in front to form a brain-plate elevated laterally into prominent crescentic folds and flexed ventrally at its anterior end. Medullary groove well formed throughout but nowhere closed. No clear evidence of intrinsic brain segmentation. No traces of commencing formation of eye, ear, or nose.

Hypophysis.—No indication of hypophysis.

Mouth Cavity.—Very faint indication of oral sinus. Primary pharyngeal membrane shows abundant mesoderm between ectoderm and entoderm.

Digestive Tract.—Fore-gut ends blindly at cranial end. Consists solely of wide pharynx. Extends for 30 sections (0·3 mm.) in front of "Darmpforte." Hind-gut not yet closed in. A proximal dilatation or "allantoic vestibule" at root of allantoic duct opens widely into a unilateral dorsal groove of the yolk-sac, or "dorsal enteric groove," whose medial wall exhibits a well-marked depression closed by a cloacal membrane.

Pharyngeal Derivatives.—First primary pharyngeal pouch is differentiated, but is separated from the ectoderm of the head by thick layer of mesoderm. There is a general ventral median groove of the pharyngeal wall, whose maximal point of depression answers to the median thyreoid rudiment. "Ventral pharyngeal grooves" (paramedian) are also present. There is a possible faint indication of the appearance of a second primary pharyngeal pouch.

Urogenital System.—No indication of any urogenital apparatus.

Heart, Pericardium, and Vascular System.—Heart largely duplex; right and left myo-epicardial mantles occupy paired pericardial cavities, which are imperfectly separated by an incomplete *septum proprium inter-pericardiacum.* Right and left epimyocardial hearts each exhibit subdivision into venous and arterial segments. Paired dorsal aortæ.

Blood-vessels of yolk-sac contain corpuscles, but many show clear lumina lined by endothelium.

Amnion.—Amniotic sac extends for a distance of 8 sections in front of anterior end of head. It tapers at its hinder end, first gradually, then abruptly, into a narrow-pointed recess floored by the continuation of the primitive streak. The cloacal membranous connexion with the ectoderm lies at the right dorsolateral wall of this recess, very nearly at its apex. Mesoderm of the body-stalk extends like a hood over the hinder third of the amnion, and even in front of the body-stalk, the mesoderm of the amnion is thickened.

Allantois.—The allantoic duct opens by a dilated "allantoic vestibule" into a "dorsal enteric groove."

Sinuous in its course, it ends in a definite thin-walled, terminal vesicle. The total length of the canal, including the vesicle, is about 0·6 mm.

Second Embryo "H 98."[1]

For the second of my specimens, to be referred to as "H 98," I am indebted to the kindness of Dr F. P. Sandes, who obtained it as the result of abortion in a patient who had exceeded her menstrual period by 10 days.

Technique.

Dr Sandes brought the perfectly fresh and intact specimen direct to my laboratory, where it was at once placed in isotonic 10 per cent. solution of formalin. After fixation in this solution the specimen was transferred to alcohol. After complete dehydration, it was cleared *en bloc* in cedar oil, when the embryo in its interior became clearly discernible.

The chorionic vesicle was then carefully opened up under the stereo-binocular microscope, and the embryo, with body-stalk, amnion, and yolk-sac, was isolated from the greater part of the chorion. Micrometer measurements were made of the various dimensions of the embryo, etc., and the specimen was subjected to very careful and prolonged examination under the stereo-binocular microscope. It was also repeatedly photographed. On completion of the examination of the specimen *in toto,* it was double-embedded in cedar-oil-celloidin and paraffin, cut in faultless series of 10 μ sections transversely to its long axis, in caudo-cranial succession, mounted on albuminised slides, and double-stained in Benda's hæmatoxylin, followed by eosin. The quality of the sectional series thus obtained is exceptionally good for early human embryonic material. A rent in the right wall of the

[1] A lantern demonstration of slides of this embryo was given before the Anatomy Section of the International Medical Congress at its meeting in London in August 1913.

yolk-sac is visible in the sections, but this must have occurred prior to fixation, since there is a small collection of effused blood adherent to one area of the interior of the yolk-sac wall.

The sections being cut in caudo-cranial succession and mounted with their latest cut surfaces downwards, it will be evident that when the sections are looked at with the dorsal aspect away from the observer, the right embryonic surface is to his right, and the left to his left. This relationship is preserved in the photomicrographs and drawings of the sections.

It should be noticed that the sections, though cut in caudo-cranial succession, are not numbered in this order as they are in "H 3." The numbers of the sections in "H 98" run *cranio-caudally*.

Chorionic Vesicle of "H 98."

The chorionic vesicle of "H 98" (stereographic fig. 3, Pl. II.) was somewhat oval and flattened, and whilst still in the formalin fixative, it measured $6{\cdot}6 \times 5{\cdot}3 \times 4$ mm., exclusive of the villi. If the villi be included in the measurements, the dimensions were $9 \times 8 \times 5$ mm.

The chorionic wall was more or less villous throughout, except over part of one of the polar areas. As is so frequently the case with vesicles of approximately the same size, the villi were more luxuriantly developed around the equatorial zone of the flattened vesicle. As is also usual, the comparatively bald polar area of the vesicle was antembryonic.

The stereographic fig. 3, Pl. II., shows the chorionic vesicle, translucent in cedar oil, viewed by transmitted light. The embryo with its yolk-sac is visible in the interior.

When the chorionic vesicle was opened the interior was found to be filled with the normal "magma reticularis," clear and transparent and of semigelatinous consistency.

Appearance and Configuration of the Embryo and its Immediate Appendages.

As was to be expected from the circumstances of its reception and subsequent treatment, the condition of the embryo, etc., when isolated from the general chorion, appeared to be quite perfect. This judgment was borne out by the subsequent microscopical examination of the sectional series.

Apart from the one fact of its having been procured from a case of abortion (causation undetermined), there is no ground for regarding the embryo as in any way abnormal.

Figs. 4, 5, and 6, Pl. II. and III., illustrate the appearance presented by the embryo, etc., after isolation from the general chorion. In fig. 4, Pl. II., is reproduced a stereo-photograph obtained by enlarging the negatives taken with Zeiss' "a 3" paired objectives in the Braus-Drüner camera.

Fig. 5, Pl. III., represents a photomicrograph of the same at a magnification of 28 diameters; whilst fig. 6, Pl. III., represents a very careful drawing by Mr Herbert Beecroft, made with the aid of various photographs both stereoscopic and other.

Dimensions of Embryo "H 98."

Length from anterior limit of amniotic collar in front of head to posterior limit of body-stalk at chorionic attachment	1·8 mm.
Length of embryo, without body-stalk, from tip of anterior end of brain-plate to tip of tail, measured in a straight line	1·27 ,,
Greatest cranio-caudal length of *amniotic sac* .	1·38 ,,
Greatest cranio-caudal length of *yolk-sac* . .	1·46 ,,
Greatest dorsoventral extent of amnion in head region	0·86 ,,
Greatest dorsoventral extent of *yolk-sac* measured from line of reflection of amnion	1·32 ,,

From the illustrations given, it will be seen that embryo "H 98" possessed 8 pairs of somites completely differentiated. My original notes of the examination of the specimen contain the statement that there are "probably 9 or 10 pairs of somites, of which the first pair appear to be very small."

The figures, *cf.* especially fig. 6, Pl. III., show indications of the existence of 10 pairs. But a plane reconstruction of the segmented mesoderm, since made, indicates that neither the first nor the last of the 10 segments is definitely segmented off from the axial mesoderm in front of, and behind, the somites. I can therefore only indicate the stage of somite formation by the statement that there are 8–10 pairs.

In Mall's embryo No. 391, reconstructed and described by Dandy (7), and also by F. T. Lewis (Keibel and Mall's *Manual*, vol. 2, fig. 232), there were 7 pairs of somites differentiated. Embryo "H 98" thus appears to be more advanced than the latter embryo, which is otherwise remarkably similar to it—to the extent of the appearance of one additional somite pair.

A feature of considerable interest in embryo "H 98" is its manifestation of a well-marked, dorsally concave body-flexure (the "dorsal kink," "dorsal flexure," or "Knickung"). This was present in almost as high degree in the Mall embryo No. 391. In Dandy's opinion it was "partly natural and partly an exaggerated post-mortem condition." He remarks (*loc. cit.*) that "we should naturally expect a dorsal concavity due to the greater development of the structures in both the anterior and posterior regions of the embryo," and then proceeds to account for the supposed post-mortem accentuation of this character. I cannot help feeling that Dandy has been influenced in his attitude towards the question of this dorsal flexure or kink by the weight of Keibel's authority against considering it as a normal feature. I therefore desire specially to emphasise the following considerations in regard to the same feature as occurring in embryo "H 98":—

(*a*) The chorionic vesicle was obtained fresh and unopened; (*b*) it was fixed in 10 per cent. isotonic formalin, in accordance with the recommendations of Mann, in order to obviate or minimise to the utmost the tendency to tissue distortion; (*c*) the photographs taken through the walls of the cleared, but as yet unopened, chorionic vesicle already showed the well-marked dorsal flexure; (*d*) a consideration of the later photograph (fig. 4–6, Pl. II. and III.) will, I think, convince the unprejudiced observer that the existence of the developmental phase of the heart and pericardium shown in the photograph must almost necessarily have determined the temporarily erect attitude of the cranial end of the body, or, more strictly speaking, of the cephalic portion of the medullary plate. And it is this erect attitude of the latter which is the main (though not the only) factor in the production of the dorsal kink. The other factor, as indeed has been already implied by Dandy, is the elevation of the tail end. And this is in turn no doubt due to the ventral attachment of the embryonic stalk.

It is, of course, open to anyone to throw doubt upon the normal character of these and similar embryos. But it will not do to base such doubts solely upon the ground of the existence of the flexure, whose validity as a normal feature is *sub judice*. And it is to be noted that the Mall-Dandy embryo, although aborted, was from a case of traumatic abortion, in which there was therefore no reason to suspect any natural or inherent abnormality of the ovum.

With regard to the normal occurrence of the flexure in question in the human embryo, Keibel has repeatedly expressed himself as sceptical. In his latest utterance on this subject (*Manual*, vol. 1, 1910, pp. 66–7) he again records his judgment that the normal occurrence of a dorsal flexure in embryos of the stage of Kollmann's "von Bulle" embryo, or later, has been disproved. But he still leaves open the question of its occurrence as a normal feature in embryos of from 6 to 12 pairs of somites. At the same time, he regards the evidence for its normal occurrence even in these stages as insufficiently based upon Eternod's 2·11 mm. embryo and Spee's embryo with 7 somites.

But, in the light of the condition met with in the Mall-Dandy embryo, and now again in my specimen "H 98," I submit that the normal existence of the dorsal flexure during stages of from 7 to 10 pairs of somites should be admitted. It is true that these two latest specimens are not by themselves wholly unimpeachable, being aborted specimens. But the traumatic character of the abortion in the one case, and the extreme care taken to avoid the possibility of distortion in the other, tend to establish the naturalness of the appearance. Each corroborates the other. And, in view of the facts as now before us, it is rather too much to ask us to set aside the positive evidence of flexure in a whole series of cases, viz. Spee's embryo with 7 somites, Eternod's embryo of 8 somites, the Unger embryo of Keibel himself with 9 somites, the Mall-Dandy embryo of 7 somites, and "H 98" with 8 to 10 somites, as each and all abnormal, whereas the fact of the matter now is that, so far as I am aware, *no* embryo of the stage of 7 to 10 somites has ever been recorded *without* the flexure in dispute.

Further, embryo "SR" No. 2, of His' *Normentafel*, is (I think unwarrantably) set aside by Keibel as probably abnormal, apparently solely on account of its possessing a dorsal flexure. Now, the dimensions of this embryo would tend to indicate that, although His does not show nor describe somites in this stage, the embryo must have possessed them. Embryo "SR," in fact, shows a tolerably close resemblance, so far as one can tell, to the stage of 7 to 12 somites, and may be confidently added to the list of embryos of this stage exhibiting the dorsal flexure.

Other features which may be noted in the figs. 4 to 6, Pl. II. and III., are (1) the differentiation of the cephalic portion of the medullary plate into fore-, mid-, and hind-brain regions. It is to be noted that what appears to be a primary cerebral flexure is at this stage intrinsic to the fore-brain region. The mid-brain shows no trace of flexure at all. One can recognise the same characteristic in the Mall-Dandy specimen and in Kollmann's "von Bulle" embryo; perhaps also, but more doubtfully, in the Kroemer-Pfannenstiel embryo "Klb." I have not seen attention drawn to this distinction, which is very striking in view of the fact that, later on, what we call the "primary cerebral flexure" lies in the region of the mid-brain.

(2) The contour of the fore-gut may be followed in the figs. 5 and 6 from its blind anterior extremity to its communication with the yolk-sac through the wide vitelline stalk. The posterior continuation of the hind-

gut from the caudal limit of the vitelline stalk into the tail region of the embryo may also be perceived. Incidentally, in connexion with the problem of the flexure, attention has been directed to the extremely prominent pericardial development. This condition represents a distinct advance on that seen in Mall's embryo No. 391, *cf.* especially F. T. Lewis' fig. 232 in the Keibel-Mall *Manual,* vol. 2. But it is an advance in the same direction as that of the progress from the stage of my "H 3" through that of embryo "Klb" to that of the Mall embryo No. 391. It is a progress which consists of a continuing process of excavation of what I have called the "pericardial plate" in embryo "H 3," and when that process of excavation has reached its limit, of a further process of bulbous expansion of the pericardial cavity.

I imagine that the condition seen in "H 98" must represent the maximum stage of this rapid expansion. When the stage of Kollmann's embryo "von Bulle" is reached, the development of the head has already overtaken the pericardium and the latter is forced ventrally by the now more or less overhanging head. The entire process seems to me a perfectly obvious and intelligible swaying in the balance of competing developmental processes. I do not even see that one is forced to believe that the equilibrium is always precisely similarly maintained at all corresponding movements in the otherwise perfectly normal course of development.

It is quite likely that another factor in the maintenance of developmental equilibrium in this region is the rate of amniotic expansion. We know perfectly well that, at least in later stages, the rate of growth and expansion of the amnion varies within tolerably wide limits without being in the least abnormal. I see little reason to deny that these may be quite normal variations in a similar sense, though of lesser degree, even at the early period now under consideration.

The carrying out of an adequate structural analysis of this embryo from the serial sections has been largely in suspense during my personal absence from Sydney. Ere I left I had done some work in the direction of reconstruction of the heart, but I do not propose now to enter upon the discussion of the sectional anatomy of this embryo. This will, I hope, form a portion of the subject-matter of Part II. of this contribution to our knowledge of early human embryos.

The sequel will also, I hope, contain a descriptive account of the third embryo of the series, viz. "H 86" in my list.

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EXPLANATION OF LETTERING OF TEXT-FIGURES.

(All sectional figures are reproduced at a magnification of 100 diameters.)

all.	allantois.
all.v.	allantoic vestibule.
am.	amnion.
ao.	dorsal aorta.
b.st.	body-stalk.
c.sw.	caudal prominences (caudal cushions).
ch.pl.	chorda-plate (?).
cl.m.	cloacal membrane.
cœl.ep.	cœlomic epithelium.
ent.	entoderm.
exoc.	exocœlom.
ht.l.	left heart-tube.
ht.r.	right heart-tube.
l.m	medullary lamina.
mes.	mesoderm.
my.	myo-epicardial mantle.
n.a.	neurenteric aperture.
p.c.l.	left pericardial cœlom.
p.c.r.	right pericardial cœlom.
p.pl.	pericardial plate.
par.r.	parietal recess (pleuropericardial).
ph.	pharynx.
ph.m.	primary pharyngeal (oral) membrane.
pr.str.	primitive-streak tissue.
s.p.p.	septum proprium interpericardiacum.
spl.	splanchnopleure.
thy.	thyreoid rudiment (median).
v.p.g.	ventral pharyngeal groove (Grosser).
vit.st.	orifice of vitelline stalk ("Darmpforte").
y.s.	yolk-sac.
yk.ent.	yolk entoderm.

EXPLANATION OF TEXT-FIG. 18.

Photomicrograph (× 100) of section No. 149 of human embryo "H 3," at the level of the cranial limit of the 1st right primary pharyngeal pouch.

The section is rather obliquely cut. It passes through the cephalic portion of the medullary plate, whose edges are well defined. In contact with the median ectoderm of the floor of the medullary groove may be seen the adherent strip of pharyngeal entoderm which represents the chorda-plate. The pharynx shows its medio-ventral keel immediately dorsal and corresponding to the *septum proprium interpericardiacum* (see text). The latter nearly completely separates right and left pericardial chambers, which show a very definite cœlomic epithelial lining. The right chamber contains portions of tissue from tangential grazing of the cranial bulging of the right myo-epicardial tube. The dorsal aortæ are visible dorsal of the pharynx.

Note the entoderm lining the roof of the yolk-sac in the lower part of the figure, and the amnion on either side in the upper part.

EXPLANATION OF PLATES I.–III. FIGS. 1–6.

Plate I. Fig. 1.

Photomicrograph of chorionic vesicle of human embryo "H 3." ×7 (reduced from ×14).

Zeiss' 35 mm. micro-projection objective.

The photograph was taken after slight surface staining with hæmatoxylin and subsequent clearing of the entire vesicle in cedar oil.

Note the very slightly branched villi on the exterior of the vesicle. The embryo, with its more intimate appendages, amnion and yolk-sac, are visible in the interior. The yolk-sac is the larger crumpled sac mainly to the left of the embryo. The sharply defined clear outline of the more anterior portion of the amnion may be seen to the right and (in the figure) above the nearly vertically directed embryonic rudiment.

Plate I. Fig. 2.

Photomicrograph (×15·5) of human embryo "H 3," with its amnion, yolk-sac, body-stalk, and a portion of its chorion, viewed from the right dorsolateral aspect.

Zeiss' 35 mm. micro-projection objective.

The somewhat collapsed and crumpled yolk-sac is seen in the lower part of the figure. The patch of chorion giving attachment to the embryo, etc., in the upper part of the figure presents its edge, for the most part, to the observer and shows no detail. Descending from this towards the embryo is the body-stalk and tail-half of the amnion. This latter appears as if separated from the anterior portion of the amnion by a deep crease of the membrane. The body-stalk is evidently directed dorsally and cranially from the caudal end of the embryonic rudiment. The medullary folds of the embryo are visible within the amnion anteriorly, and the leaf-like area traversed by the primitive streak posteriorly.

Plate II. Fig. 3.

Stereo-photomicrograph of chorionic vesicle of human embryo "H 98." The photograph was taken from the specimen in cedar oil by transmitted light, under the Braus-Drüner camera, Zeiss' stereo-objectives α°, magnification ×2·8.

The vesicle is translucent, and shows the embryo and yolk-sac in its interior.

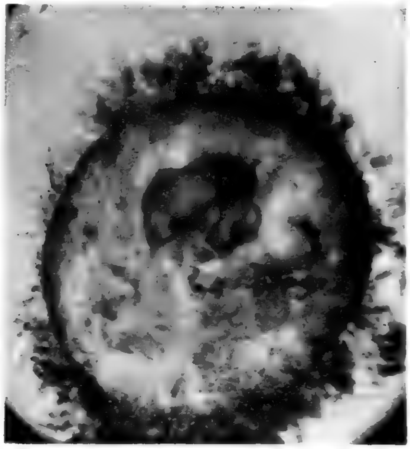

Fig. 1.

Fig. 2.

FIG. 1.—Chorionic vesicle of embryo "H 3." ×7.
FIG. 2.—Embryo of "H 3." ×15.

Professor J. T. WILSON.

Fig. 3.

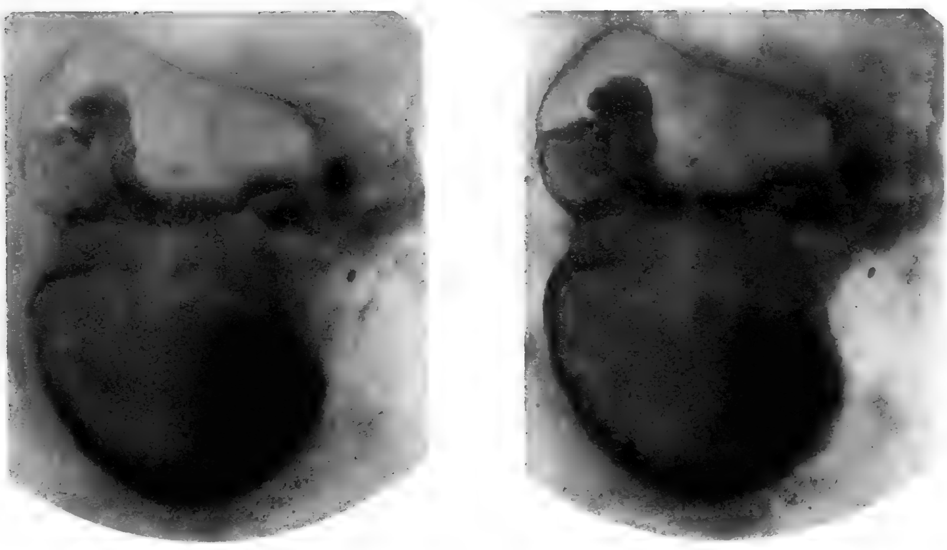

Fig. 4.

FIG. 3.—Stereo-microphotograph of the chorionic vesicle of embryo "H 98."
FIG. 4.—Stereo-microphotograph of the embryo of "H 98."

Professor J. T. WILSON.

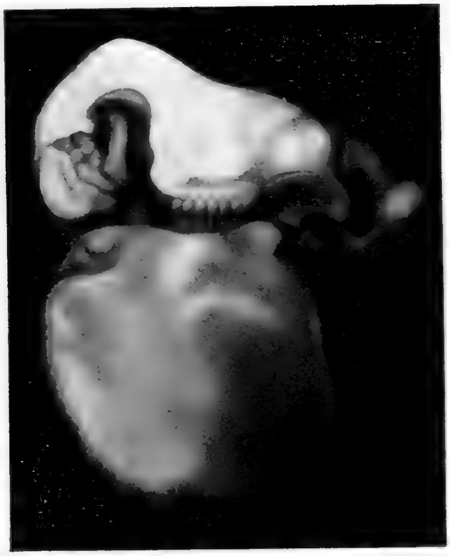

Fig. 6.

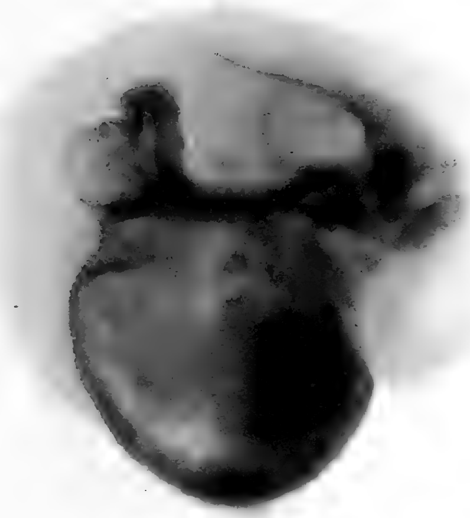

Fig. 5.

FIG. 5.—Microphotograph of the embryo of "H 98."

FIG. 6.—Composite drawing of embryo "H 98" made by Mr Beecroft from a series of photographs.

Plate II. Fig. 4.

Stereo-photomicrograph (× 16) of human embryo "H 98," with amnion, body-stalk, and yolk-sac. Enlarged from negative taken with Zeiss' stereo-objective a^2 at four diameters.

The specimen was photographed in cedar oil by transmitted light.

Compare with figs. 5 and 6, Pl. III.

The body-stalk is practically complete, although the portion of chorion which had been left in connexion with it became detached whilst in the cedar oil. The dark patches in the body-stalk represent the blood content of vessels.

The pericardium and heart form a prominent bulging mass ventrally to the head, which is, in consequence, erect in attitude.

The amnion and yolk-sac are both almost wholly free from folds, and there is no evidence of shrinkage.

Plate III. Fig. 5.

Photomicrograph (× 28) of human embryo "H 98," with amnion, body-stalk, and yolk-sac.

See description of fig. 4 and text, and compare with figs. 4 and 6, Pl. II. and III.

Plate III. Fig. 6.

Human embryo "H 98," with amnion, body-stalk, and yolk-sac.

Drawn from photographs and stereo-photographs by Mr Herbert Beecroft, Sydney.

See description of fig. 4 and text, and compare with figs. 4 and 5, Pl. II. and III.

REVIEW.

Innere Sekretion: ihre physiologische Grundlagen und ihre Bedeutung für die Pathologie. Professor A. Biedl, Vienna. Second edition. Part I. pp. 534. 8 plates and 131 figures in text. Part II. pp. 692.

The subject of "internal secretion" is one of the very highest importance, and the amount of research work which has been carried out recently in this one subject is enormous. So great is the output of work that it is impossible for the average reader to peruse all the original publications. A book which contains the essentials of these numerous papers is therefore very welcome, particularly when it has been compiled by so eminent an authority as Professor Biedl.

Part I. of the new edition, which we have had the pleasure of reading, differs considerably from the original work. The inclusion of the results of recent investigations necessitated an increase in the size of the book and the recasting of the whole. The book has, in fact, been practically rewritten.

The first volume deals with the parathyroids, thyroids, thymus, and includes a large section on the adrenal system. These various internal secretory organs are dealt with in turn in considerable detail. Their development, structure, and comparative morphology are described, and what is known concerning their physiological function is set out by condensed accounts of the numerous original researches dealing with this aspect of the subject. Experiments on the effect of complete and partial excision of these glands in various species of animals are quoted, and the views of different experimenters are included. The chemistry of the glands and their products also receives attention, though in this particular direction the available knowledge is not great.

After this review the pathological aspect of the subject is considered and the rôle of internal secretion in morbid processes is indicated. The results of feeding experiments with the several glands and the effects of grafting them in man and animals are given in detail.

It is a feature of the book that experimenters are quoted even when their results and views are divergent or directly contradictory. This is unavoidable in a subject where so much is uncertain and in which bedrock facts are few. But amid the mass of divergent views the reader is apt to become bewildered. It has been said that physiology always progresses, but that it often progresses sideways. Amid the numerous pathways set out before us here we are often unable to determine which is probably the true path of progress. We feel that the value of Professor Biedl's work would be enhanced if he had, after a critical summary of the conflicting experiments, indicated which pathway was the best to follow. It must not be thought that the book is devoid of criticism—far from it,—but we feel that there is not enough of it. Professor Biedl, who has devoted his life to this subject, could have supplied effective criticism even where he had not himself worked at the particular point in question.

As is unavoidable in a book of this size, a few mistakes are noticeable. Some of the chemical formulæ are inaccurate, and the nature of ergotoxine appears to have been misunderstood. These errors are, however, few and small, and we cordially recommend the book to those interested in the fascinating subject of internal secretion. They will find in it brief accounts of nearly all the original work which has been done on the subject, and from these they will gain not only a knowledge of the subject as it stands to-day, but the possibilities of to-morrow, which may lure them on to further investigation.

The second and concluding volume of Professor Biedl's book has appeared recently. The first seventy pages are devoted to the completion of that section of the work dealing with the adrenal system, after which the remaining three hundred pages treat of the internal secretions of the intercarotic and coccygeal bodies, the pituitary body, the pineal gland, the generative organs, the pancreas, the alimentary canal, and the kidneys. The subject is dealt with in the same thorough manner as in the first volume, and very full references to original work are included. The mass of original papers which have been abstracted for our benefit in this work may be realised when it is pointed out that the index to the literature occupies over 250 pages.

It may be doubted whether the plan, which has been adopted, of reserving the references and index for the end of the second volume is the best possible. Both volumes must be to hand in order to obtain a reference to an original paper. We feel that literature references at the foot of each page would render the referring to original papers much easier, and that the general index might with advantage be duplicated in the first volume.

We feel sure that this book will meet with the great success which it deserves. If we take exception here and there to the manner of its compilation and to the lack of illuminating criticism, we must remember that Professor Biedl has given us exhaustive references, and that by referring to the original papers which he quotes we may form our own opinions.

P. P. L.

JOURNAL OF ANATOMY AND PHYSIOLOGY

A CONTRIBUTION TO THE EMBRYOLOGY OF THE FORE-LIMB SKELETON. By N. C. Rutherford, M.B., F.R.C.S.

Introductory.

The concise account of the development of the human skeleton recently published in the Keibel and Mall *Text-book of Human Embryology* forms the standpoint of present knowledge of and opinion on the subject. Regarded from this standpoint, certain observations of some importance resulting from a study of the development of the shoulder girdle and fore-limb skeleton in man, recently undertaken by the writer, seem worthy of publication as supplementing the account of the cardinal features in the growth of these cartilages and giving an account of the early phenomena of the ossification of the scapula. In considering the observations made on the development of the skeletal arch which overhangs and strengthens the shoulder-joint, its origin from one of a smaller perimeter will be the chief subject of discussion.

The embryonic material employed consists of human embryos and fœtuses of from 10 to 30 mm. in greatest length, reconstructions of the fore-quarter skeletons being made in two cases, one a 20-millimetre and the other a 30-millimetre specimen. The specimens cited in comparison are in the Museum of the Royal College of Surgeons. As it is on the reconstructions that the initial observations were made and round them that the whole work centres, a short description of them forms the first part of this paper.

Technical Note.—In making the drawings of the cartilaginous skeleton, care was taken to indicate exactly the margins of the fully differentiated cartilage as contrasted with the transitional perichondrial layers in all cases except that of the clavicle in which the easily followed enveloping layer was shown.

Descriptive.

Model of the Fore-quarter Skeleton of a 20 mm. Human Embryo (figs. 1 and 2).

This model includes:—Twelve vertebræ of which the upper two are cervical, nine complete and two incomplete ribs, one lateral half of the sternum, all the elements of the limb and girdle skeleton.

The vertebræ are represented by their bodies, and continuous with these are the neural arches of the right side; cartilaginous continuity around the

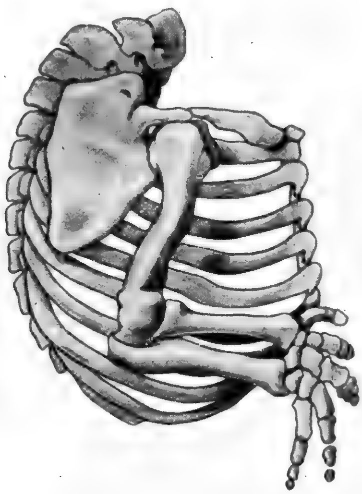

Fig. 1.—Wax-plate reconstruction from human embryo 20 mm. greatest length. Magnification in figure about × 8·5.

notochord exists between the bodies. They form a markedly arched series, the dorsal convexity being so great as to bring the two upper ones each rather ventral to the succeeding member of the series than on top of it; these two cervical vertebræ have procœlous bodies of approximately tetrahedral form, apex directed caudo-ventrally. The neural arches, imbricated above and in linear series below, show small lateral projections at their dorsal extremities representing demispines; the seventh cervical vertebra shows a separate chondral element, its costal process, which is in close articulation with the body.

The disproportionate length of the ribs and the approximately horizontal position each occupies give to the whole thoracic skeleton an appearance of marked inspiration. In general the cross-section of each rib is circular, but in front there is dorso-ventral flattening, whilst behind the flattening is from above downwards; the anterior extremities of ribs I. to V. articulate with a delicate sternal bar of cartilage which merges above partly in the cellular nonchondral interclavicular mass; VI. and VII. meet and support each other caudal to the other extremity of this bar; all turn slightly dorsally, and I. to V. then acutely caudally in contact with the sternal bar. Like VI. and VII., VIII. IX. X. and XI. bend forward and so are disposed as in the adult.

The *clavicle* is represented in its inner four-fifths by a very stout bar prolonged as to its outer fifth in the form of a flattened plate by bevelling at the expense of its costal aspect. The curve of the lateral part of the adult bone is practically absent. The cellular constitution can be well

Fig. 2.—Wax-plate reconstruction from human embryo 20 mm. Schematic representation of scapula and limb skeleton. Magnification in figure × 7·14.

seen in fig. 6; it is made up of two ossific centres on the point of coalescence within a matrix of young cartilage cells, the whole being surrounded by a very dense cellular periosteum; this last is prolonged into (1) a cellular mass surrounding the tip of the acromion, (2) a similar mass at the opposite end, the inter-clavicle, and (3) a tract or band connecting behind the coracoid with the pre-scapula in which there is an appearance of early chondrification. The wedge of cartilage described by Professor Fawcett and assumed by him to be associated with the formation of the deltoid tubercle is well shown in fig. 6. In this figure the deltoid is not associated with it.

The *scapula* is as yet incompletely merged with the coracoid, as indicated by the width of the scapular notch and by a line of division across the glenoid cavity rather below its middle. The blade is irregularly diamond-shaped; its upper limit lies opposite the caudal extremity of the body of the sixth cervical vertebra, and its surfaces are parasagittal.

The *coracoid* is a bulbous mass of cartilage joined with the scapula by a narrow neck and having a short cornuate process projecting upwards above the greater tuberosity of the humerus and a long one directed caudo-ventrally in the neighbourhood of the lesser tuberosity, considerably below the clavicle.

The *acromion* is a delicate bar showing an approximately right angle bend just above its root and a gentle curve beyond that to its tip, which projects slightly beyond the lateral extremity of the clavicle. Its root is immediately behind the edge of the scapular part of the glenoid cavity.

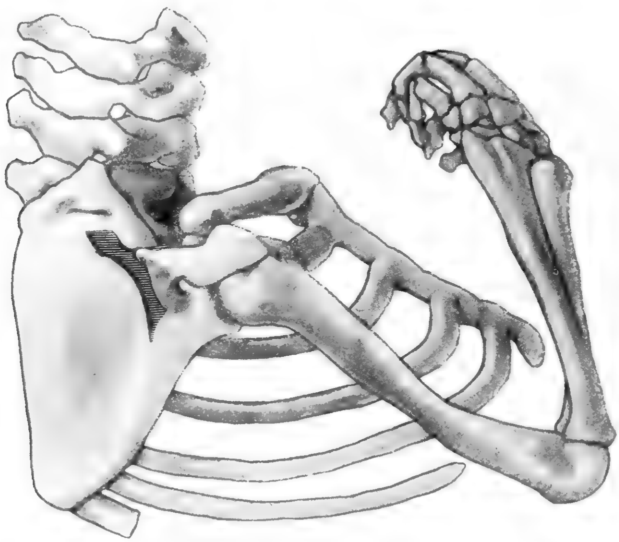

Fig. 3.—Wax-plate reconstruction from human embryo about 30 mm. greatest length. Magnification about ×8·5. Ossific plate shaded.

There is complete absence of the spine, but, on the other hand, there is present a distinct supraspinous element (which for reasons which will appear I will call the "prescapula"), separated by a slight interval near the middle of its length from the main part of the blade or "postscapula" and by a junctional zone dorsally to this. This prescapula is inclined at a slight angle to and occupies a more medial plane than the postscapula, as in fig. 5; a prominent ridge which lies on the superficial surface of the post-scapula, caudal to the interval between the two elements of the blade, indicates the future basis of support for the spine. By reason of this arrangement there exist two notches in this region, one which for my present purpose may be called coraco-prescapular, and becomes the future incisura scapularis, and the other which I will call acromio-postscapular, a temporary feature later filled up by the growth of the spine. Between these two notches is the narrow area of origin of the supraspinatus muscle which occludes on one aspect the interval between the two parts of the blade.

The roots of the acromion and coracoid, and most markedly that of the prescapula, are invested by a thick layer of cells which surrounds the origin of supraspinatus and forms the scapular extremity of the previously

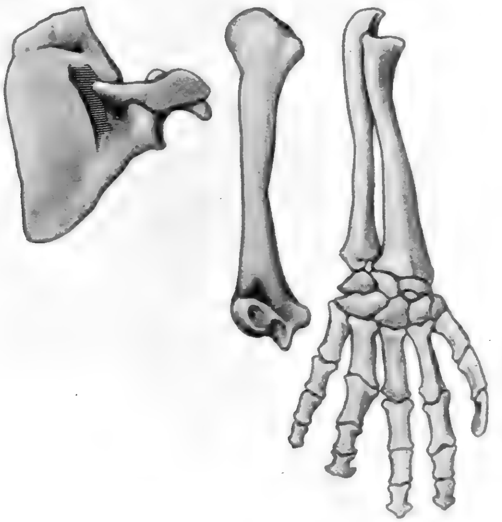

FIG. 4.—Wax-plate reconstruction from human embryo about 30 mm. Schematic representation of scapula and limb skeleton. Magnification about × 6.

mentioned band or cellular condensation which reaches behind the main mass of the coracoid to be continuous with the periosteum of the outer segment of the clavicle (fig. 6).

The *humerus* has a very remarkable shape. The shaft is bent outwards and forwards so as to form a salient angle opposite the deltoid insertion; its proximal half is arched outwards and its distal half backwards. Neither extremity in its relation to the axis of the shaft occupies a position corresponding to that of the adult bone; the proximal end is rotated somewhat outwards, and its articular surface is divided by a groove into two flattened condyles corresponding with the coracoid and scapular segments to which it is applied; the distal end occupies a plane such as might result from a great exaggeration of that angle between the axis of the trochlea and the long axis of the shaft which is characteristic of the adult. By reason of this the inner lip of the trochlea forms the distal extremity of the humerus, and the capitulum lies on the lateral aspect at a higher level. A delicate outgrowth from the perichondrium of the shaft near its lower end ventro-lateral to the median nerve indicates the position of the entepicondylic spine (fig. 7).

What has been said of the distal articular surfaces of the humerus

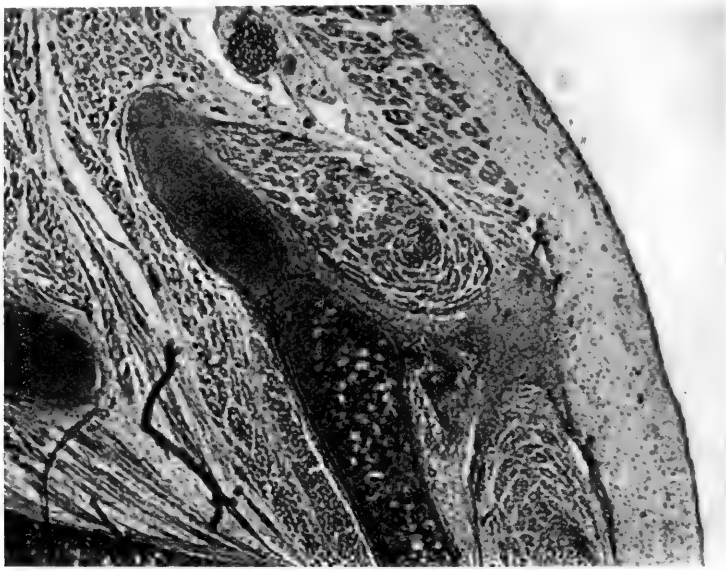

FIG 5.—Coronal section, human embryo about 30 mm. Prescapula and postscapula, ossifying spine of scapula and trapezio-deltoid intersection.

conveys equally the relative position of the contiguous extremities of the *radius* and *ulna*. These two cartilages lie parallel, one above the other, but not quite in the same plane, owing to what may be described as a very slight degree of pronation. There is present between their distal ends an independent cartilaginous nodule embedded in a thickly crowded mass of cells. This may represent the intermedium.

Of the *carpal cartilages* those on the postaxial side are far in advance of those on the pre-axial side of the wrist; the same is true of the *metacarpals* and *phalanges*, the three digits of the ulnar side being almost equal in length and slightly longer than the index. End plates to the terminal phalanges are just recognisable by their dark staining and plexiform character.

Model of Fore-quarter Skeleton of 30 *mm. Human Fœtus* (figs. 3 and 4).

This reconstruction shows ten half-vertebræ, of which three are cervical, four complete, and three incomplete costal arches, the manubrium sterni, and representatives of three sternebræ and all the elements of the limb-girdle and free limb.

The position of the *vertebræ* has altered owing to the decrease of the

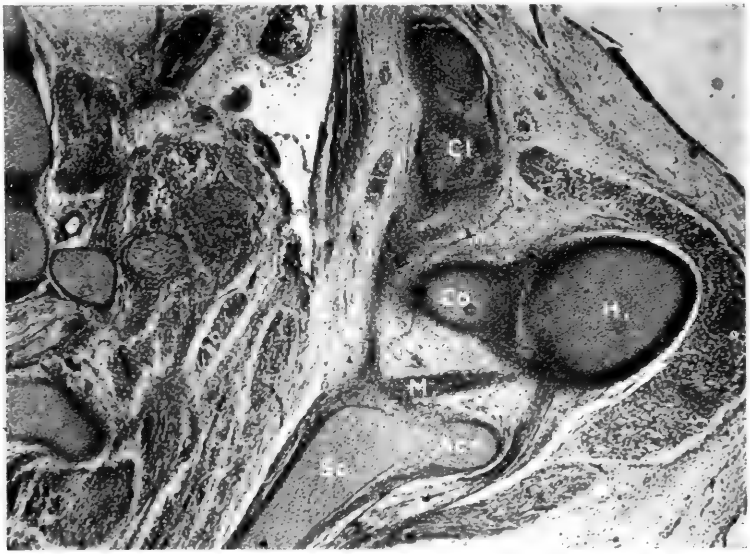

FIG. 6.—Horizontal section through shoulder of 20-mm. embryo.

Sc., scapula; Acr., acromion; H., humerus; Co., coracoid; Cl., clavicle; M., supraspinatus; and P., pre-scapulo-clavicular band shown attached dorsally where scapula is covered by thick cellular layer.

spinal curve, and the demispines on the extremities of the neural arches are now more marked. The *ribs* are now much more slender, except dorsally, where they are very massive and show commencing angulation.

The *manubrial cartilage* is pierced by a small hole, and there is a median cleft in the third sternebra.

The *clavicle* has developed rapidly, and has now almost the adult form with two curvatures; the outer extremity is, however, not so flattened as in the adult.

The *scapula* reaches headwards to the level of the caudal border of the seventh cervical vertebra; its diamond shape is still preserved, but the length of that border which runs from the coracoid to the upper angle has increased disproportionately; it follows that the "prescapular" bar is greatly increased in size, the slit separating it from the postscapula has lengthened, and there is quite a marked groove indicating the boundary between the two elements and extending from the slit to the dorsal border, which it notches. The growth of the prescapula has greatly exceeded that of the postscapula in the 20–30 mm. period, and it now bears a greater proportion to the whole blade than does the resulting supraspinous part of the blade in the adult.

Fig. 7.—Horizontal section, human embryo 20 mm., to show:

H., humerus; R., radius in cartilaginous continuity; Med., median nerve with entepicondylic process of perichondrium on its lateral aspect (*).

The *coracoid* is little changed, being only rather smaller relatively.

The *glenoid surface* is now concave and undivided; it seems to have increased relatively in its lower blade part.

The *acromion* has grown considerably and become flattened and spatula-like, so that the acromial angle of the adult is now recognisable. The tip of the process projects considerably ventral to the outer end of the clavicle. The right-angle bend near the root described in the previous stage is now a sharp projecting elbow or spur of cartilage connecting with a tract of young, actively growing cells which passes backwards over the dorsum scapulæ, under cover of the small-celled fibrous intersection between trapezius and deltoid, nearly to the vertebral border. This tract represents the developing spine, and in it, especially near the acromial elbow, ossification is well advanced (fig. 8). The ossifying region is shaded in the figures of the model, and it can be seen to extend into a projection at the scapular notch, over the edge of which it is continued on to the medial surface of the blade. The cells in which the ossification takes place are

Fig. 8.—Coronal section, human embryo 30 mm. Shows elbow of acromion and ossification of spine (*).

derived from the mass which in the 20-mm. stage clothed the roots of the postscapula, coracoid, and acromion.

The *humerus* is constricted in the region of spreading ossification, and is gently curved convex backwards. The two curvatures seen in the earlier stage are much less prominent in this later one owing to the great increase in length of the humerus, but both are easily identifiable still. The upper end is now only slightly out-turned as compared with that of the adult bone, and the lower end has assumed, in the inclination of its axis to that of the shaft, a position intermediate between that in the earlier model and that representing the average of the two sexes in adult bones.

The *radius* and *ulna* likewise show constrictions in the ossifying zones. They are now very decidedly crossed. The ulnar styloid seems to be prolonged into the chondrifying discus articularis, and the same is true of the ulnar side of the lower extremity of the radius: between the two prolongations is a dense, unchondrified cell-mass. The contrast between this condition and that described for the 20-mm. stage is remarkable.

FIG. 9.—Coronal section, human embryo 30 mm.
C., centrale continuous through faintly staining zone with N., navicular.

The *carpal elements*, especially those of the distal row, are well forward in development, and there is visible, both on the palmar and dorsal aspects of the wrist, a distinct centrale; on that side it lies between navicular, lunar, and trapezoid, and on this between navicular, capitatum, and trapezoid; its surface isolation does not correspond with the conditions in the depth of the articulation, where it is continuous, through a faintly staining transitional zone, with the navicular (fig. 9). The navicular is in only narrow contact with the trapezium, which seems isolated at the radial end of the distal row and is slightly smaller than the trapezoid still.

The *metacarpals* and *phalanges* of the free digits are so disposed as to suggest that the hand is grasping a globe of small diameter. The end plates of the terminal phalanges are very broad.

Comparative.

In discussing the features of the models described, the opportunity of reference to other human embryos in the collection at the London Hospital will be made use of. These embryos comprise 8-mm., 10-mm., 15·5-mm., 24·5-mm., and 25-mm. stages, the measurements being in all cases those of greatest length.

The Vertebræ.—The position and the curious form of the cervical vertebræ in Model I. led me to seek in earlier stages for an explanation of the pointed caudal projection of their bodies. It is only in the cervical vertebræ that this condition is very marked, and at first it was thought to be purely a positional moulding. Naturally shape and position are related features in ontogeny, a fact which in this instance is confirmed by the

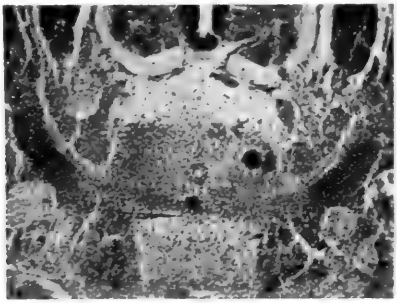

Fig. 10.—Human embryo 10 mm. Trans. section costo-hypochordal part of vertebral blastema shown stretching between the ventro-lateral myotome buds in front of chorda.

further observation that a much less and rapidly diminishing degree of the same moulding is visible in the upper thoracic bodies. Still, it seemed only reasonable to expect that the shape of the cervical and upper thoracic bodies in the adult, with their prominent ventro-caudal lips, would require for its production something more than a process of purely adaptive growth of the scleroblastema of what may be called the typical centrum. It remains to explain the two correlated features by means of some material organic addition to these vertebræ during their development: such an organic addition is provided for in the 10-mm. stage when there is present connecting the costal elements of all the upper vertebræ a hypochordal bar of condensed cellular tissue (fig. 10) into which the chondrification of the body can extend in a caudo-ventral direction. This extension will be facilitated by the positional relations of the upper vertebræ, which here form a more sharply curved arch than those lower in the series, where the hypochordal element is less easily identifiable. Lewis, in touching upon the hypochordal element, limits it to the upper three cervical vertebræ and connects it, not with the costal, but with the neural arches. Bardeen notes its presence as low as the thoracic region.

The Ribs.—Apart from the excessive length of the ribs in relation to their average cross-section, the curve of the costal arches and the shape of the thoracic cavity resulting are noteworthy, since, in both models, the proportion between the depth and breadth of this is reversed as compared with the adult form; further, the cylindrical form of the earlier stage is seen to be transformed into a truncated cone in the later, the profile view of which shows it to be much blunter than after completion of its full growth and expansion. In Model I. the ventral ends of the ribs are free, with the exception of the first, which is fused with the sternal bar, whilst the second, third, fourth, and fifth turn caudally alongside it, being accommodated in fossæ on its lateral aspect; in Model II. these have fused with the side of the sternum. The cartilaginous sternal bar ends, in the 20-mm. stage, opposite the fifth rib, and the ventral extremities of the lower ribs turn headwards, the sixth and seventh ending in a condensed blastema continuous with the cartilaginous sternum. It would thus appear that the thoracic skeleton is furthest advanced in development at its inlet, and that the fusion between rib and sternal cartilages is a secondary process, like the fusion of the sternebral halves, as seen occurring in the third body sternebra of the 30-mm. stage. The use of the term "sternebra" in blastemal and cartilaginous stages is of course unjustifiable, but it has been employed for convenience sake to designate those parts of the continuous bar or bars which correspond to the bony segments of later stages.

The Clavicle.—The form of the clavicle in Model I. is very striking by reason of the absence of that curvature which characterises its outer segment in Model II. and in the adult. In the 10-mm. stage, which may be taken as the equivalent of that, *i.e.* 10·5 mm., described by Lewis, the blastematous clavicle extends inwards only one-third of the distance to the ventral end of the first rib, which it reaches in the 15·5-mm. stage. Arrived at this stage in its growth, the clavicle is therefore represented only by that part which, if form be any criterion, is the equivalent, in the adult, of its inner two-thirds at most; at this stage it seems to halt until a short time before that represented in Model I.; then begins a further and distinct stage in growth coincident with the onset of ossification, one in which the lateral third of the clavicle of the adult is evolved from the cellular mass at the distal end (fig. 11). In this way the clavicle achieves its full development, arriving at the condition seen in Model II. The striking difference in the two stages of the development of a bone whose two parts are just as strikingly different in the adult, separated as those stages are by a considerable period of time, seems to warrant that any theory of the growth of the clavicle should take full cognisance of the causal facts that in the first stage the growth is axipetal, in the second, axifugal. It may be contended that the axifugal growth of the outer segment here emphasised is undeserving of emphasis, since it is equalled

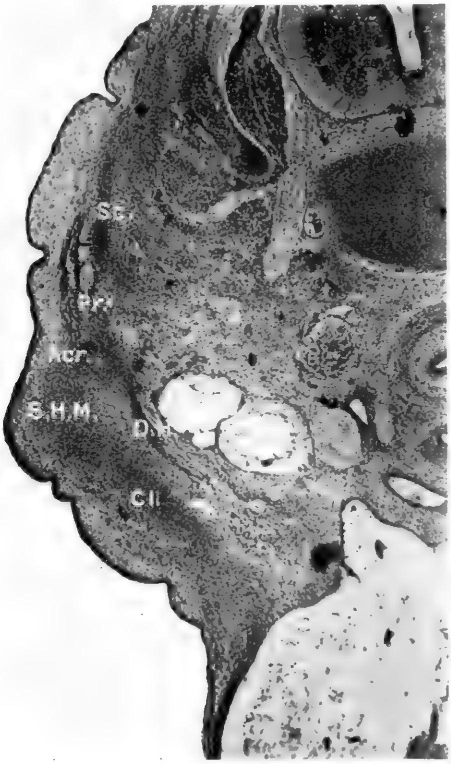

FIG. 11.—Horizontal section, human embryo 15·5 mm.
Cl., clavicle continuous laterally with suprahumeral cell mass (S.H.M.); Pr., prescapula; Sc., postscapula; Acr., acromion; O.H., omohyoid.

by contemporary axipetal growth of the inner segment; but it must be remembered, on the contrary, that the proportionate increase of the two growing ends differs widely and remains in favour of the outer, otherwise no such change in shape as occurs between that in Model I. and that in Model II. would take place.

The Scapula.—The most striking features of the growth of the scapula, as brought out by the two models, are the development of the supraspinous portion of the blade and the late appearance and mode of origin of the spine. The partial separation of the growing cartilage which represents the supraspinous part of the blade, to which the name prescapula has been given, especially excites curiosity. This separation is first fully recognisable in the 15·5-mm. embryo (fig. 11), and reaches its greatest differentiation in that represented by Model II.; it is the more remarkable in that the slit seen in the two models between pre- and postscapula is occupied only by cells of the limiting membranes or perichondria of the two parts (fig. 5), and is not a passage for vessels or nerve filaments. For this reason it is to be considered a truly morphological separation, and not merely a casual fenestration, such as is a noticeable feature of the cartilages of certain amphibian and reptilian shoulder girdles. It is further especially to be remarked that the prescapular segment is fully continuous with the rest of the blade laterally, where it bounds the scapular notch, and that, at its other extremity, it is marked off from the blade in both models by a distinct groove and projects somewhat from the vertebral border, where it forms a part of this; in the former situation also it has a decided ventral projection clothed by a distinct cell-mass, among the surface layers of which the fibres of origin of supraspinatus are interspersed. A comparable condition is found in the scapula of the dolphin, *Delphinus delphis* (fig. 12 (III.)), a condition made the more noteworthy by the absence of anything resembling a true acromion process. In the toothed whale, on the other hand, an acromion process is seemingly present, but the prescapular equivalent is absent to all appearances (fig. 12 (I.)), whilst in *Mesoplodon Grayii* a condition is present which can be regarded as an intermediate stage between the two; in it, to adopt the accepted terminology, the acromium is bent backwards into a prescapular position, without, however, becoming continuous with the blade at its vertebral extremity (fig. 12 (II.)). Here, seemingly, are three stages in the formation of a prescapular element out of what has been previously considered an acromion process—an assumption which, in the absence of the clavicle and the scapular spine among Cetacea must, for the moment, remain a doubtful quantity. There is, then, in the development of the human scapula an element, the true morphological importance of which has hitherto been disregarded, and which I have called the prescapula, whilst in the scapula of the adult dolphin a similar element is separable which, in its turn, is to be compared with the so-called acromion of *Mesoplodon Grayii* and of the toothed whale.

Turning to the development of the spine of the scapula, we find that appearances indicate an origin for it in a cellular proliferation connecting with the elbow or spur of the developing acromion process (as distinct from the adult acromial angle); this undergoes a precocious ossification (fig. 8) as it spreads dorsally under the trapezius-deltoid intersection from the region of the scapular notch. The nature of the cells is, from their appearance alone, not easy to discern, but such characteristics as they

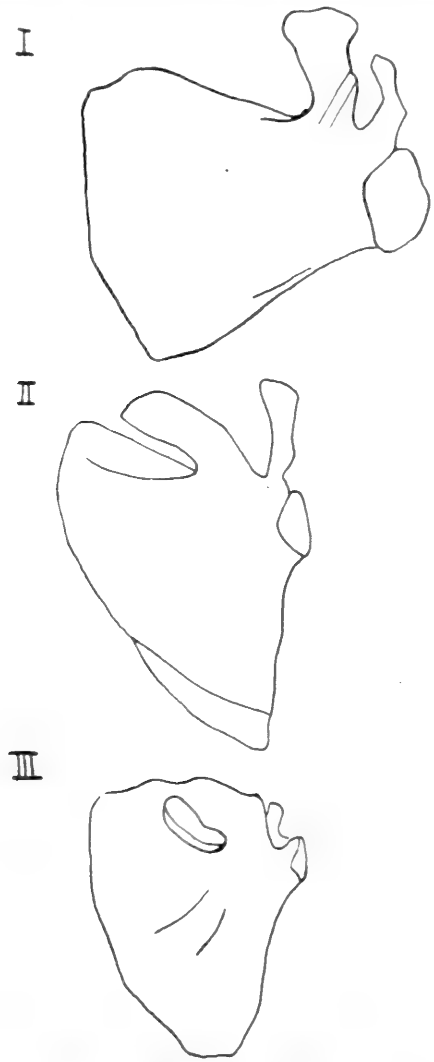

FIG. 12.—I., Scapula of *Physeter Macrocephalus*; II., Scapula of *Mesoplodon Grayii*; III., Scapula of *Delphinus delphis.*

possess, coupled with their secondary continuity with the fully differentiated cartilage of the acromial elbow, places them as derivatives of cartilage cells. Perhaps the most striking fact brought out by the second model is the formation of a bony dorsal boundary to the scapular notch through the agency of cells which in the 30-mm. stage are continuous with those ossifying under the acromion, and which are only represented in the 20-mm. stage by the mass lying most thickly at the root of the prescapula. The position and relations of this cellular proliferation are very suggestive, especially in view of the ossific process which takes place in it so early after its assumption of rapid growth. Firstly, it overlies the junctional zone between coracoid and scapula; secondly, it lies at the dorsal extremity of a band of thickly crowded cells which passes medial to the coracoid (figs. 6 and 11) to divide into three well-marked strands merging with the periosteal layer of the outer segment of the clavicle; thirdly, this connexion is identifiable in the 15·5-mm. embryo as a dense strand forming the mesial boundary of a cell-mass which includes more laterally the prechondral representatives of acromion and clavicle, the middle of which is less condensed than its mesial and lateral margins. The mesial margin is well seen in fig. 11, and can be traced dorsally to the nucleus of chondrification representing the prescapular element and ventrally to the clavicle, whilst the middle third of it gives origin to the omohyoid, just lateral to the subclavian vein. The ossification of the scapula commencing at a junctional zone is remarkable as a parallel phenomenon to that described by Professor Fawcett in the ossification of the clavicle; closer examination may show even greater resemblance in the details of the process; whilst further, in view of the importance of junctional zones as centres of growth, brought out by the work of Professor Geddes on the Vertebrate Limb, an even more widely generalised significance may be attributable to this fact in the growth of the scapula. The cell strand connecting prescapula and clavicle is so far differentiated in fig. 6 that it represents the typical position of those ligamentous fibres which in many adults pass along the upper part of the conoid ligament into the transverse ligament; in this figure the omohyoid origin is not connected with these fibres, a fact which is referable to the dorsal migration of the origin towards the scapula.

The explanation of the observed facts bases itself mainly upon the presence of the large cell-mass in the upper shoulder region in the 15·5-mm. stage. This mass is continuous with the acromion laterally, with the prescapula dorsally, and with the outer extremity of the chondrifying clavicular bar ventrally. It is in this mass that the specialisation of the clavicle-acromion arch so closely related to the evolution of a freely movable shoulder-joint must occur, and, since this specialisation is especially important in man, the steps of its development may be expected to abound in matter for comparison with the vertebrate girdles down even to those of the reptilia. Taking into consideration the variety of forms among the mammalia assumed by these portions of the skeleton, the cell-masses which are their precursors in ontogeny must be regarded as possessing a remarkable degree of lability, and, for this very reason, as being likely to preserve in the stages of their early development certain main features of their common and very early precursors in phylogeny. The earliest form of the human shoulder girdle, as figured by Lewis for a 10·5-mm. embryo, is a rectangular mass of crowded cells representing a scapula and situated high in the cervical region, to all appearance a plate-like headward prolongation of the axial condensation of the free limb. In it, again, according to Lewis's figure, there is a shallow furrow which may or may not be the first indication of the slit found in the cartilaginous scapula of later stages; if it be not, I am inclined strongly to the view that this rectangular mass of cells represents rather the prescapula of the cartilage stages than the postscapula, and from its caudo-lateral angle the postscapula may grow out; this view would be little more than speculation if it were not that the prescapula of a 15·5-mm. embryo shows a more advanced stage of differentiation than does the rest of the scapula. This is, however, a point on which the material at my disposal does not provide any further evidence of conclusive value, and which is of minor importance for the further development of the deductions made from the other facts observed in order to elucidate the connexion of prescapula and clavicle. This connexion has been fully described and figured, as has also the evolution of the so-called acromion in the Cetacea, through which it becomes converted in *Delphinus delphis* into a remarkable semblance of the human cartilaginous prescapula; and it only remains, in the first place, to emphasise that the connexion of the human prescapula with the clavicle is made at the mesial extremity of the lateral segment of the clavicle, and, in the second place, to postulate that the Cetacean so-called acromion connected with the clavicle of Cetacean progenitors, in order to reach the conclusion that the labile substance of the shoulder region can produce under evolution a mesial and a lateral arch; that one prescapulo-palæoclavicular — possibly identifiable in Cetacean ontogeny—this one acromio-neoclavicular in nature. In support of this conclusion and of the one postulate furthering it are a number of indisputable facts:—

1. That the ingrowth of the clavicle in stages from 10 mm. onwards occurs, not from the region of the tip of the acromion (*sensu stricto* as here applied), but from the ventral extremity of the strand of cells which forms the mesial limit of the suprahumeral arch mass, the outer periphery of which will later give rise to the outer segment of the clavicle ventrally and to the acromion dorsally. This is beautifully demonstrated in fig. 11,

15·5, which, it will be remembered, comes from a stage 15·5 mm., in which the clavicle has reached to the ventral extremity of the first rib.

2. That the variations in origin of the posterior belly of the omohyoid muscle almost never follow the lateral or acromio-clavicular, but nearly always the mesial or prescapulo-precoracoid arch.

3. That in the two-toed sloth, *Cholœpus Hoffmannii*, the prescapula and acromion are synostosed, and with the complete arch thus constituted from the periphery of the suprahumeral mass the clavicle articulates, which clavicle, to judge by its sole curvature, a ventral convexity, represents only the precoracoid portion of that bone (fig. 13). By reason of the primitive scale of general mammalian organisation found in the Edentata, and also by reason of the habits of the sloth, this fact supports both the conclusion I

Fig. 13.—Scapula. Clavicle of two-toed sloth, *Cholœpus Hoffmannii*, showing acromio-prescapular arch.

have come to and the postulate regarding the Cetacean clavicle necessary to its validity in the comparative sense.

To summarise, the shoulder arch in man shows in its development a fair epitome of the phylogenetic steps in its specialisation from a type which would be fairly represented by the shoulder girdle of the toothed whale, did this possess a clavicle, a type extant in both Ornithorhynchus and Echidna. With advancing specialisation the original arch becomes converted to other uses; the primitive acromion becomes the supraspinous plate, and a new acromion is evolved, whose earliest trace is possibly identifiable in Echidna and whose intermediate form is exemplified in the sloth, this new acromion having a wider sweep and necessitating an addition to the primitive clavicle. Meanwhile the intermediate portion of the original arch merges in, or specialises as the transverse and part of the conoid ligaments of man.

This theory of the development of two arches in the mammalian shoulder girdle deserves a reference to the conditions in lower vertebrates. In the reptiles the so-called clavicle often reaches far on to the dorsum of the scapula, whilst as yet no acromion can be said to exist, indeed the dorsal portion of the clavicle occupies a position on the reptilian scapula which is only comparable with that of the scapular spine in man, or in other mammals in which a truly homologous spine is developed. Such an extension of the clavicle may reasonably be supposed, I think, to follow the line of our prescapulo-precoracoid arch, and thus leads on to the hypothesis that that cellular covering of the root of the prescapula (fig. 6) which ossifies to form a bony spicule, the definitive dorsal edge of the scapular notch, and which further extends to the root of the acromion and under the trapezius-deltoid intersection to form the spine of the scapula, ossifying as it goes, is the homologue of part of the original reptilian clavicle. This is only, however, a hypothesis, but it has so many favourable features that it seems worthy of the more exhaustive examination of embryonic and comparative material necessary for its proof and acceptance as a well-grounded theory.

The secondary coalescence of spine and acromion would well account for the proliferation which forms a spur on the acromial elbow in Model II., and a similar but more marked outgrowth in this junctional zone doubtless results in the formation of a metacromion as found in certain rodents, and markedly in the elephant. For particularly directing my attention to this structure, I am indebted to Professor Wright.

The *humerus* in the forms in which it appears in Models I. and II. is a very interesting object. Its curvatures are striking, and the torsion and angulation of its upper and lower extremities are brought out in a way which previously figured reconstructions have failed to indicate. This is to be attributed to the method I have adopted of drawing only the limits of the cartilage and avoiding the perichondrium, at stages in development when the differentiation of that tissue has reached or slightly overstepped its "optimum." The seeming contrast between the two forms is dispelled on close examination of the second model, and the change is attributable only to the enormously increased length of the shaft and its relatively decreased girth in the region of the primary ossification. Distortions of the shafts of long bones have been noted in embryo by Holl, Schomberg, and others, and attributed to disproportionately rapid growth in length; these are especially marked in hardened specimens and are therefore probably artificial. Of such artificiality I see no trace in the developing humerus, either in Lewis's figures or my own material, and I consider that both the described curvatures of the shaft are a phenomenon of correlated growth during development of humerus and musculo-spiral nerve in the first place, somewhat exaggerated by the shortness of the shaft and the form of the unspecialised articular ends, and, possibly, later, by the related deltoid insertion in the second place. That the spiral groove of the adult humerus is so much broader than the structures lying in it is merely an indication of the early date of its production, when the girth of the nerve relative to the length of the bone was much greater and separated the origin of the two humeral heads of the triceps at the time when they were acquiring a firm attachment to the ossifying tissue of the shaft; for muscles never attach themselves to cartilage, but only to the perichondrial membrane, which is later incorporated with the periphery of the bone. The causation of the spiral groove of the humerus has no relation to the torsions about to be considered.

The changes of torsion and angulation of the articular ends which take place between the 20-mm. and the 30-mm. stages are attributable in the case of the upper extremity to the pre- and postnatal alteration of position of the scapula, relative both to the axis of the humerus and to the curve of the chest wall; in the one case the change is an approach of the axillary border of the scapula to the humerus, and in the other it is a change due to the increase in length and curvature of the ribs, causing the scapula to migrate towards the vertebræ and the head of the humerus to rotate inwards to accommodate itself to the altered aspect of the glenoid. The alteration in the inclination of the distal articular surfaces to the axis of the shaft is productive of the specialisation of the elbow-joint for pronation and supination of the forearm bones. Lewis, in Keibel and Mall's *Text-book*, p. 380, states that in an 11-mm. embryo, the forearm is midway between pronation and supination. This statement is incorrect, in principle and in detail, for, almost up to the 20-mm. stage, pronation and supination as movements or as postures are out of the question, owing to the form of the distal extremity of the humerus, the details of the skeleton showing that the forearm bones are parallel and the hand apparently fully supine if the plane of the hand be projected upon the plane of the lower end of the humerus; the right-angled elbow, parallel forearm bones, and paddle-postured hand make an exact reproduction of the palæo-reptilian fore-limb. The sex difference which is characteristic of the limb in the adult would seem to rest upon a less degree of specialisation of the upper extremity in the female than in the male, resulting in the greater "carrying angle" of the female. The correlation (if it be one) of this inferior grade of specialisation in the female upper limb with a higher grade of specialisation in the female pelvis is an interesting paradox.

The radius and ulna have been almost sufficiently discussed in connexion with the distal extremity of the humerus; it only remains to add that, if the inclination of forearm to arm be a true sex characteristic, the differential torsion of the two extremities of the ulna and the relative aspects of the articular surfaces of the radius should, if made capable of convenient measurement, prove a valuable means for determination of sex in osteology and anthropology.

The Carpus and Hand.—The presence of a centrale in Model II. and the mode of its inclusion are not in agreement with the observations of Graefenberg. Graefenberg's material seemingly did not include a stage as early as that of Model I., in which no centrale is to be found, for he states that it is among those carpal elements earliest differentiated, and, further, that it is probably broken up by the appearance of the lunar, and finally disappears, leaving no trace. As against these statements I have to place the facts that the centrale is unrepresented in my 20-mm. stage, yet in my 30-mm. stage it is visible on both ventral and dorsal aspects of the carpus, where it is entirely separated from all other elements by a distinct perichondrium, and that in the depth of the massed elements it is structurally continuous with the naviculare through a faintly staining cartilaginous layer (fig. 9). This further confirms Owen's and Mivart's views on the fate of the centrale, whilst opposing those of Rosenberg and Thilenius, and partially also those of Leboucq. The isolation of the trapezium on the radial side of the carpus has been noted in description of Model I.; its position confirms the observation of Hagen, one which Graefenberg professes to be unable to understand, in that it is practically confined to the ventral aspect of the wrist.

The question of the relation of intermedium and discus articularis cannot be fully entered into here because of the limited amount of material under discussion, but the appearance of a separate cartilaginous nodule in the 20-mm. stage, embedded in a mass of thickly crowded cells, and the absence of such an element in the later stage, which shows chondrification of the cell-mass in continuity, on the one side, with the ulnar styloid, and, on the other, with the inner edge of the extremity of the radius, both seem to indicate early differentiation of an intermedium, followed by its disappearance and replacement by the discus.

Summary of Conclusions.

Technical.

1. The first and perhaps the most critical matter, in its bearing upon the technical results of this work, is the imperative necessity, in preparing a reconstruction of the cartilaginous skeleton, to adhere slavishly, in the drawings made, to the periphery of the fully differentiated cartilage and to exclude all the surrounding transitional perichondrial tissue.

2. The second conclusion of a technical kind follows from the first, and is, that reconstructions of the developing skeleton, at stages earlier than the

"optimum" of cartilaginous development, must necessarily be ambiguous since the zones of transition are much wider and more difficult of limitation, whilst the shape of the growing chondral nuclei signifies nothing of a more than ontogenetic importance. It is not desired to convey by this that the form of the condensed blastemal skeleton suffers under the same disability for comparative purposes, quite the contrary; the blastematous stage, also, has an "optimum" development, only one which is more difficult to assess than is that of the cartilage; it probably lies in or around the immediately prechondral period. It is further desirable to emphasise that nothing in these conclusions can apply to elements which manifest anything in the nature of direct ossification, that is to say, which, among vertebrates, may ossify otherwise than through the intermediation of cartilage; for example, a drawing and reconstruction of such an element as the chondral clavicle will convey nothing of value, because the chondrification of the clavicle never reaches an "optimum" in the accepted sense.

3. The blastema stage of the shoulder skeleton represents in its massive cell agglomeration two arches, one mesial, consisting of the precursors of the supraspinous portion of the scapula and the cell-strand connecting this with the clavicle at the junction of its sternal and acromial segments, and one lateral, representing the acromion and acromial segment of the clavicle, both having comparable though simpler bony representatives in the Edentate *Cholœpus Hoffmannii.* In the absence of the clavicle of their progenitors the Cetacea show a conversion of the dorsal pillar of the medial arch into prescapula.

4. The supraspinous portion of the scapula may possibly be the original scapula of phylogeny; it certainly is a separate morphological constituent of the scapula, as evidenced by the course of its development in man and by the various forms of its equivalent in the Cetaceans cited.

5. The formation and precocious ossification of the spine of the scapula begins in cells which, appearing at the root of the prescapula, grow on to the dorsum along the coraco-scapular junction and under the trapezius-deltoid intersection, cells which are therefore intimately related to the mesial arch, and may be, like this, representative of the reptilian clavicle. Spine and acromion are joined up through the intermediation of these cells, and the junctional proliferation may be so marked as to result, under ossification, in the production of a metacromion, as in certain rodents, and markedly in the elephant.

6. The spiral groove of the humerus is due to the impress of the musculo-spiral nerve and is not due to torsion, which, however, is not absent during the growth of the cartilage, but affects only the proximal end.

7. The specialisation of the distal articular surfaces of the humerus takes place within the stages examined, and its degree is different in the two sexes.

8. The carpal centrale is most fully developed in cartilage about the "optimum" period for the other carpal cartilages. It fuses with the navicular.

9. The intermedium is present in the 20-mm. stage, and disappears before the 30-mm. stage to make way for the chondrification of the articular disc from its ulnar and radial extremities.

Acknowledgments.

I desire to record my thanks to Professor W. Wright for the kindly interest with which he has followed the completion of this work; to Professor A. C. Geddes, firstly, for the use of apparatus for reconstruction, which was his private property, and, secondly, for the advice which, when in any difficulty, I could always fall back upon with benefit.

The publication has been carried out with the help of a grant from the Research Fund of the London Hospital Medical College; the drawings are by Mr W. Thornton Shiells; in the photography I have been much assisted by Mr T. Collyer Summers.

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Geddes, A. C., "The Origin of the Vertebrate Limb," *Journ. of Anat. and Phys.*, vol. xlvi. p. 350.

ON THE TOPOGRAPHY OF THE INTRA-CARDIAC GANGLIA OF THE RAT'S HEART.

By JEAN MEIKLEJOHN, *John Lucas Walker Student (Cambridge). (From the Royal College of Physicians' Laboratory, Edinburgh.)*[1]

INTRODUCTORY.

LARGE numbers of ganglion cells and of ganglia have been described in close relation with the sino-auricular node and the auriculo-ventricular node and bundle.

I have tried to work out more fully the relations and grouping of these ganglion cells in the rat's heart. While adding little to actual facts already observed, this paper is an attempt to show these facts more definitely and to point out their relation to experimental observations.

The figures are from a single rat's heart, but the results shown by them may be taken as generally representative—they have been confirmed in the main in a large number of hearts, both rats' hearts and those of guinea-pigs, cats, and monkeys, and in the human heart.

HISTORICAL.

In 1899, Schwartz (1) published an account of the distribution of the cardiac ganglia, based chiefly on observations on the rat's heart. He describes the ganglia as lying chiefly in an area in the posterior auricular wall, bounded on the sides by the auricular appendices, and below by the sulcus coronarius transversus, in which the lowermost ganglia lie. He describes the characters of the ganglia and of individual cells, but does not show any relation with the auriculo-ventricular node which had been previously described by Kent and His.

In 1909, Aschoff (2) stated that the ganglia in the human heart lie chiefly in the posterior coronary groove, the posterior walls of both auricles, chiefly the left, sub-epicardially in a region corresponding to the original cross part of the sinus, further in the septum atriorum as far as the atrio-ventricular node, and in the heart muscle covering the

[1] This work was done during the tenure of a Carnegie Fellowship, and I have also to acknowledge a grant from the Carnegie Trust towards the expenses of publishing.

end part of the vena cava superior, and in the neighbourhood of the sino-auricular node.

Fahr (3) in 1910, in a paper on the topography of the ganglia of the human heart, states that the ganglia are most numerous where the heart nerves enter the auricular septum, round the entrance of both venæ cavæ, especially near the sino-auricular node; that a mass lies in the inter-auricular septum from which chains extend to the right auricular appendix, and downwards in the posterior coronary sulcus to the junction of the upper and middle thirds of the ventricle. The ganglia are sub-epicardial, except in the upper part of the inter-auricular septum and at the coronary sinus where they approach the atrio-ventricular node. He states that there is another chain extending downwards from between the aorta and pulmonary artery to the anterior coronary sulcus. He points out the connexion between the ganglia and the sino-auricular and auricular nodes.

In 1911, Eiger (4) published a monograph on the topography of the intra-cardiac ganglia. I have not been able to consult this paper at first hand, and rely on an abstract in the *Zentr. für Herz. u. Gefäss. Erkrankheiten,* 1912. The observations were made on human hearts and on those of guinea-pigs and mice. The ganglia in all were found chiefly in the posterior wall of the right auricle, less numerous in the inter-auricular septum and the sulcus circularis and at the junction of both venæ cavæ. No ganglia were found in the ventricles in mouse or guinea-pig. The upper part of the ventricle of the human heart contained ganglia, variable as to number and distribution. All ganglia were found sub-epicardially, none in the myocardium.

Methods and General Description of Figures.

The figures are all outlines taken from sections of a single rat's heart. The sections were cut in paraffin, serially, 5μ thick, and between each section figured there is an interval of 20 such sections. The stain used was Van Gieson's hæmotoxylin and picro-fuchsin stain, which shows the nerve cells very clearly, as well as their relation to muscle of different types. The larger nerve bundles were also well shown and could be traced through the series.

The outlines were made by means of a mirror projection with a low power. The smaller ganglia and the nerves were filled in from direct observations with Leitz oc. 1, obj. 3. No attempt has been made to figure more than the position and relative size of ganglia, and the position and direction of nerve strands.

RESULTS.

The ganglia divide themselves chiefly into two groups.

(1) A right-sided group, which lies high up and round the superior vena cava and in close relation with the sino-auricular node. This group appears in figs. 1–11. It is a small group, densest at figs. 8 and 9. It is entirely confined to the right side of the heart, although at figs. 8, 9, 10, and 11 it is seen to communicate with the ganglia of the left side. It extends from a little distance above the sino-auricular node to a little below it, and sends fibres into it.[1]

(2) A left-sided group. This is a much larger and more scattered group, but it also is quite definite in its relations. It is shown in figs. 6–17. It is a long chain of ganglia, densest at the level of figs. 14 and 15, and surrounds the left auricle, lying in its external walls and in the inter-auricular septum. It is not continuous, but the cell groups are linked together by strands of fibres. It extends through the greater part of the auricular wall, beginning above at the level of the sino-auricular node and extending nearly to the level of the upper part of the auriculo-ventricular node. It is clearly seen to receive fibres from the cardiac nerves (figs. 10, 11, and 15). Although these entering nerves have not been traced to their source, they correspond in position to the point of entrance of the left vagus. From the ganglionic chain large strands of fibres pass downwards, which, running in the inter-auricular septum, enter the auriculo-ventricular node or run alongside of the bundle (figs. 17–33). Many of these strands contain nerve cells (figs. 18, 19, 20, and 22).

There are also several small scattered groups of nerve cells. First, a number of small ganglia, usually 2- or 3-celled, round the pulmonary artery and high up in the roof of the left auricle, which do not seem to belong to either of the groups described above nor to have any continuity with one another (figs. 1–5). Secondly, there are a few ganglion cells around the entrance of the vena cava inferior (figs. 17 and 19). No ganglia were found in the ventricles in the rat.

The ganglia therefore fall into two main groups: one high up, on the right side, and closely connected with the sino-auricular node. The other rather lower, on the left side, and connected by means of nerve strands with the auriculo-ventricular node. The experimental work of Cohn (5) showed that the right vagus acts chiefly on the auricles, while the left acts chiefly on the ventricles and through the auriculo-ventricular system. In his experiments on the dog, stimulation of the right vagus pro-

[1] These nerves break up in the node and form fine plexuses round the muscle fibres. The fine terminations are not shown here (7).

duced stoppage of the whole heart with no disturbance of the normal sequence, while stimulation of the left vagus caused less effect on auricular rate, but resulted in various degrees of block. Gauter and Zahn (6) have recently confirmed Cohn's observations, and have further defined the points of vagus action as in the nodes, for they found that vagus inhibition could be abolished by heating the node which had been affected by vagus stimulation.

The fact that there is a distinct right- and left-sided distribution of ganglia, that the right is in relation with the sino-auricular node, while the left is in relation with the auriculo-ventricular node, gives an anatomical basis for the experimental findings, since these ganglia are most probably, at least in part, terminal ganglia on the course of vagus fibres, and controlling centres for the sino-auricular and auriculo-ventricular nodes. The subject requires fuller investigation, and further observations are being made.

In conclusion, I wish to express my indebtedness to Professor Jas. Ritchie, under whose supervision this work was done, as well as to the Carnegie Trust for a grant towards the expenses of publishing.

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[Plates.

In all figures :—

P.A. = pulmonary artery.
Ao. = aorta.
P.V. = pulmonary veins.
S.V.C. = superior vena cava.
I.V.C. = inferior vena cava.
L.A. = left auricle.
R.A. = right auricle.
L.V. = left ventricle.
R.V. = right ventricle.
C.A. = conus arteriosus.
v. = ventricular muscle (the limits indicated by dotted line).

The nodal tissue (sino-auricular node and auriculo-ventricular node and bundle) is indicated in red.

Ganglia shown thus

Nerves in cross section thus

Nerves in longitudinal section thus

All the figures are projection outline drawings at a low power of sections from a single rat's heart. The position of nodal tissue and nerve elements has been filled in under a rather higher power. It is intended to represent only the position, relations, and relative size of the ganglia and nerve strands. The drawings are partially diagrammatic, but are exact within the limits stated.

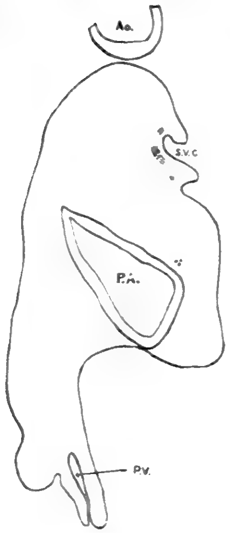


FIG. 1.

FIG. 2.

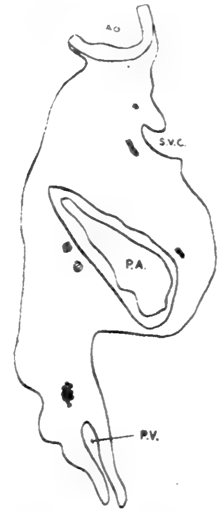
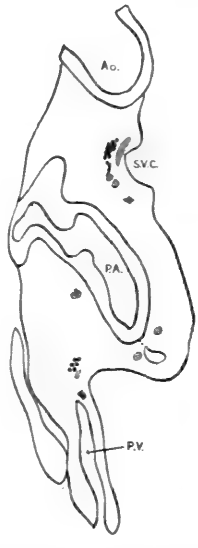


FIG. 3.

FIG. 4.



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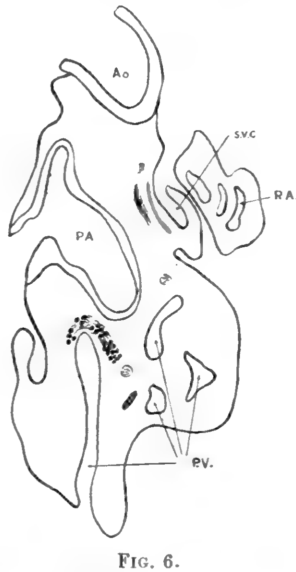


FIG. 6.

FIG. 1.—Section through pulmonary artery, aorta, and terminations of superior vena cava, and of one of pulmonary veins ; commencement of small right-sided ganglionic chain.

FIG. 2.—Section just above roof of left auricle ; right chain as above ; scattered ganglia round pulmonary artery and on roof of left auricle.

FIG. 3.—Section just above sino-auricular node ; right chain ; ganglia in roof of left auricle ; nerves round pulmonary artery.

FIG. 4.—Section through upper part of sino-auricular node ; small ganglion lying beside the node ; scattered ganglia round pulmonary artery and in roof of left auricle.

FIG. 5.—Section a little lower than fig. 4 ; nerves as in fig. 4.

FIG. 6.—Section through roof of left auricle ; sino-auricular node and upper part of right auricular appendix ; right-sided chain ; commencement of larger left-sided chain round bases of pulmonary veins.

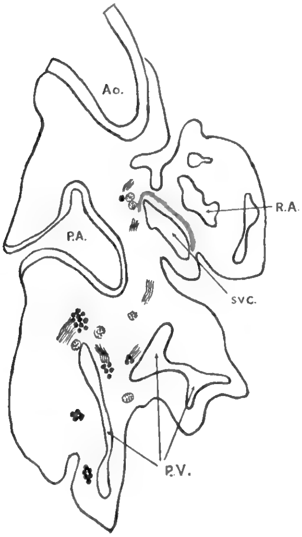
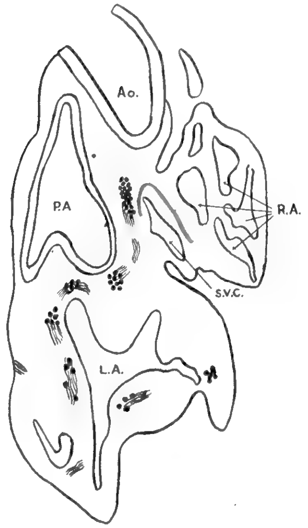


FIG. 7.



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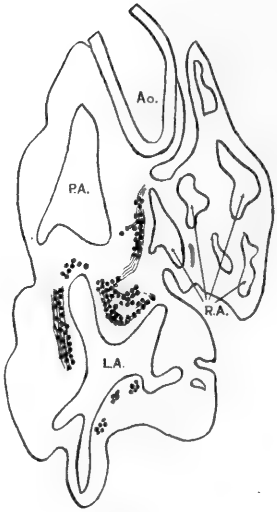

FIG. 9.

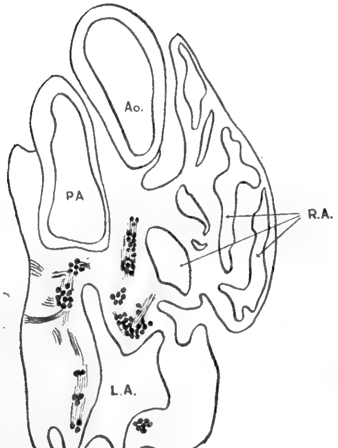

FIG. 10.

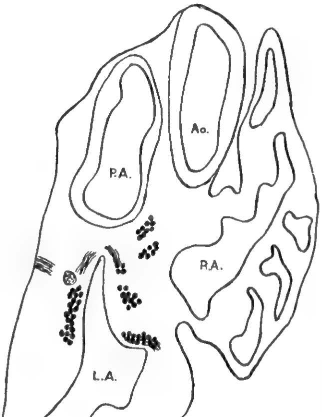

FIG. 11.

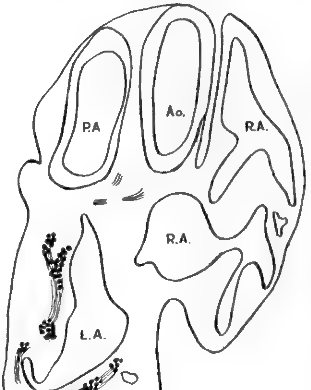

FIG. 12.

FIG. 7.—Nerve chain between ganglia near sino-auricular node; scattered ganglia of left chain round openings of pulmonary veins.

FIG. 8.—Large ganglion of right side lying beside sino-auricular node, showing connexions with ganglia of left side in wall of left auricle.

FIG. 9.—Lowest part of sino-auricular node and large ganglion of right side connected with the large ganglionic collection of left side lying between right and left auricles.

FIG. 10.—Level of entrance of left cardiac nerves; fibres seen entering on left of diagram to join left chain; lowest part of right chain below sino-auricular node.

FIG. 11.—A few nerve fibres entering on left to join left chain; the left chain is passing posteriorly round left auricle; the ganglia between right auricle and pulmonary artery belong to right chain.

FIG. 12.—The left chain has passed still further to the back.

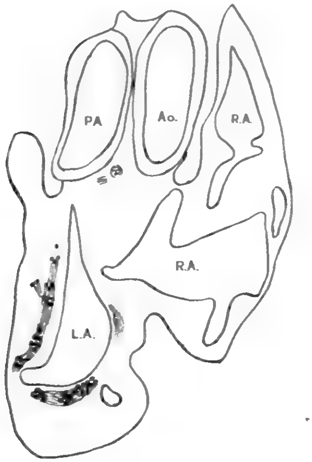

Fig. 13.

Fig. 14.

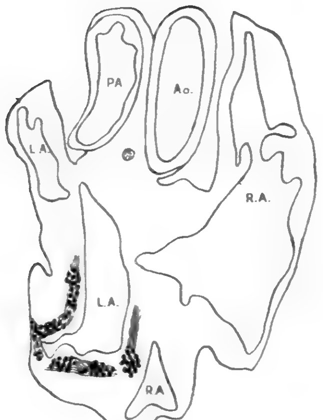

Fig. 15.

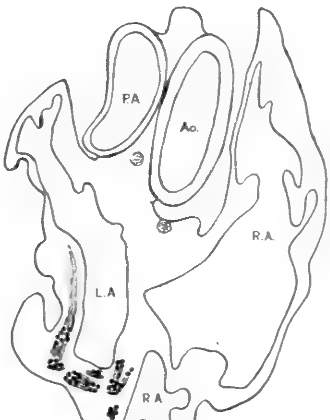

Fig. 16.

Fig. 13.—Left-sided chain passing round the back of left auricle to reach the inter-auricular septum.

Fig. 14.—Left-sided chain lying towards the back of the heart, and sending fibres into the inter-auricular septum and to the left auricular appendix.

Fig. 15.—Ganglia of left side as in fig. 14, passing down in inter-auricular septum (the nerve between pulmonary artery and aorta passes down into the ventricles in the anterior coronary groove).

Fig. 16.—Ganglia of left chain as in figs. 14 and 15.

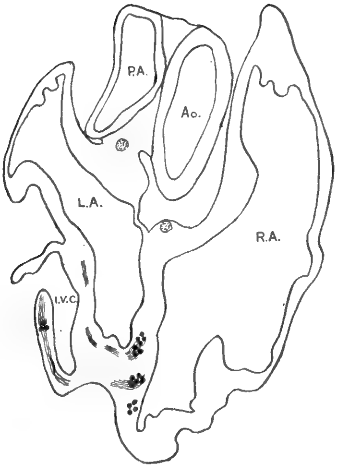

Fig. 17.

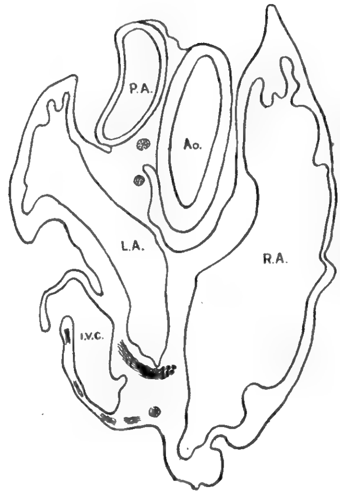

Fig. 18.

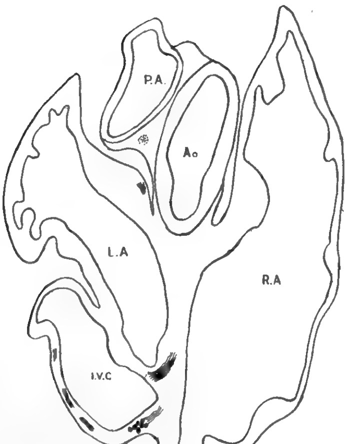

Fig. 19.

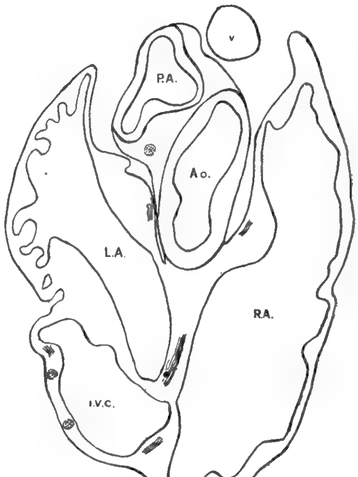

Fig. 20.

Fig. 17.—Left-sided chain passing down in inter-auricular septum ; the inferior vena cava is shown with a ganglion and fibres in its wall.

Fig. 18.—Ganglia and nerves as in fig. 17.

Fig. 19.—Nerve strand containing cells passing downward in inter-auricular septum ; nerve strands and ganglia round inferior vena cava.

Fig. 20.—Nerves as in fig. 19 (small v. in this and succeeding figures indicates ventricular muscle, the limits of which are mapped out by dotted lines).

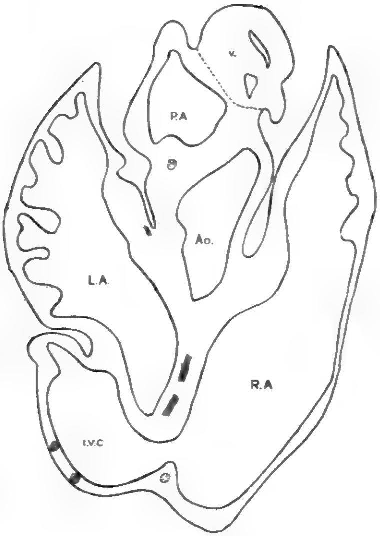

FIG. 21.

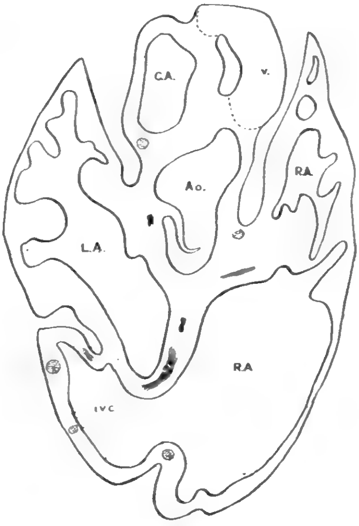

FIG. 22.

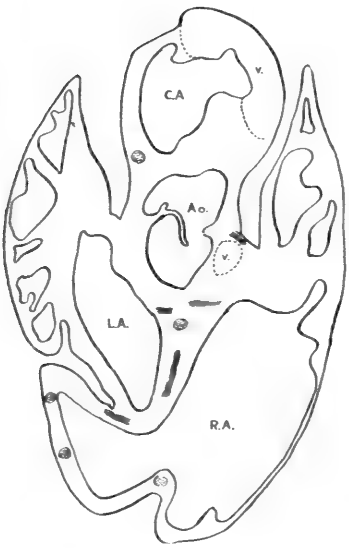

FIG. 23.

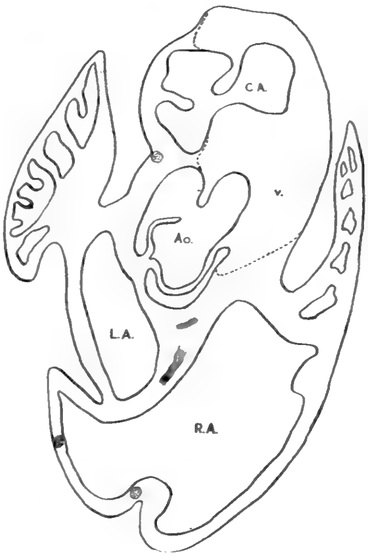

FIG. 24.

FIG. 21.—Just above level of auriculo-ventricular node; fibres from left-sided chain passing down in inter-auricular septum and right auricular wall (some of the latter pass lower to auriculo-ventricular bundle; some pass to ventricles in the posterior coronary groove).

FIG. 22.—Upper part of auriculo-ventricular node; nerve with cells passing to the node.

FIG. 23.—Level of auriculo-ventricular node; fibres passing to the node and downwards in right auricular wall from left chain.

FIG. 24.—Level of auriculo-ventricular node; nerve fibres as in fig. 23.

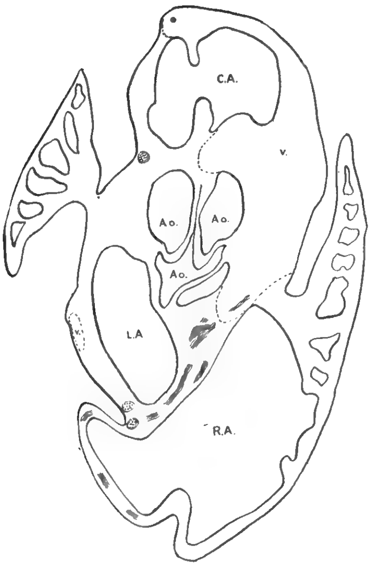

Fig. 25.

Fig. 26.

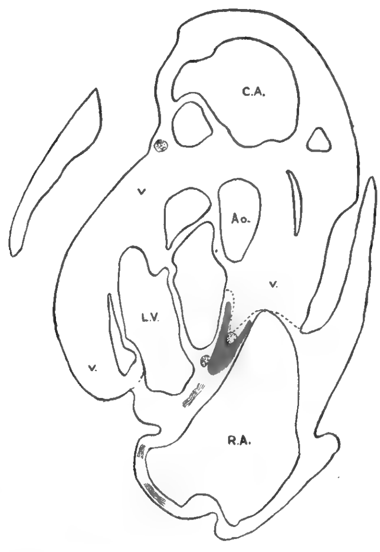

Fig. 27.

Fig. 25.—Level of auriculo-ventricular bundle ; numerous nerves passing forward to the bundle in the inter-auricular septum.

Fig. 26.—Level of auriculo-ventricular bundle ; nerves running forward to the bundle and accompanying it (these nerves enter and break up in the bundle).

Fig. 27.—Bifurcation of the bundle ; nerves accompanying it shown in cross section.

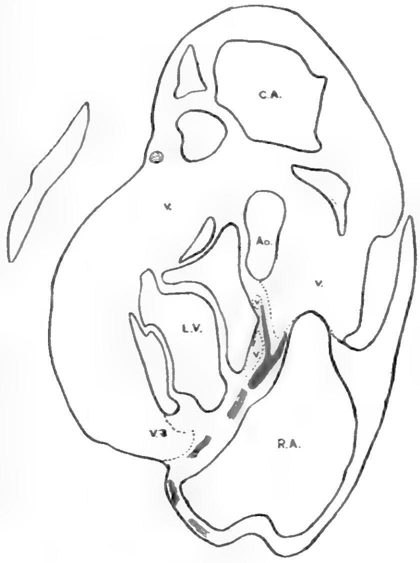

FIG. 28.

FIG. 29.

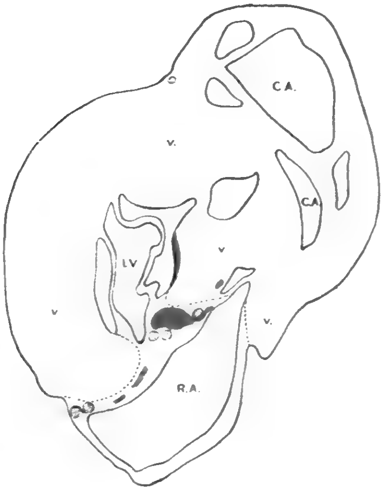

FIG. 30.

FIG. 28.—Bifurcation of the bundle ; nerves running in inter-auricular septum to join it.
FIG. 29.—The bundle has divided into right and left branches, but main stem still shown owing to sections being oblique to its course ; nerves accompanying it ; one shown with right branch.
FIG. 30.—Main stem and branches of bundle and nerves accompanying the bundle.

FIG. 31.

FIG. 32.

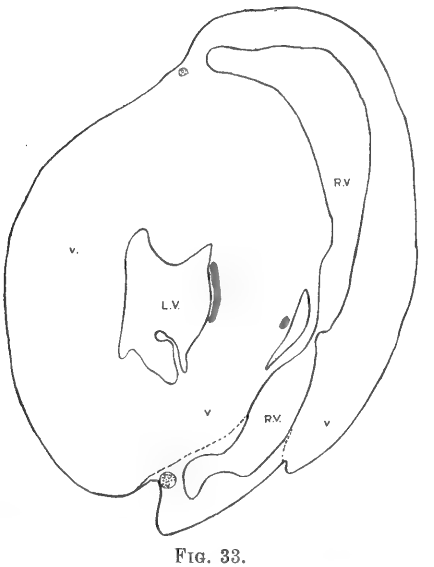

FIG. 33.

FIG. 31.—Main stem and branches of bundle ; the branches have passed well to the right and left of the septum, and their nerves have broken up in them ; two larger nerve strands shown with main bundle.

FIG. 32.—Right and left branches of bundle and main stem accompanied by nerve strand.

FIG. 33.—Right and left branches of auriculo-ventricular bundle ; no nerves shown accompanying the branches, as they have entered and broken up in them ; nerve in anterior coronary groove is derived from right-sided chain ; that in posterior groove from left chain.

THE SECOND VISCERAL ARCH AND GROOVE IN THE TUBO-TYMPANIC REGION. By J. Ernest Frazer, *Lecturer on Anatomy in the Medical School of St Mary's Hospital.*

In 1910 I brought the results of an investigation into the development of the naso-pharynx before the Anatomical Section of the British Medical Association, calling attention at the same time to the fact that the tubo-tympanic recess has in its floor the outer ends of the first two arches and grooves, and that consequently its posterior margin or wall is formed by tissues owning a third arch value: further, I showed that the first and second lateral pouches persisted and were recognisable throughout the second and third months, with the outer ends of the arches, whereas the inner portion of the second arch disappeared in the tubal region, the wall of the cavity in its neighbourhood undergoing what I called—in default of a better term—a process of atrophy. The description which I published at that time (*B.M.J.*, 15th October) was rather of the nature of a side-issue in the work on which I was engaged, and no subsequent reference was made by me to it; but in the present paper I hope to give a more complete account of the modifications which occur in this region and affect the second arch in particular, and to indicate the rearrangement of the parts that leads to the ultimate formation of the tubo-tympanic cavity.

Before entering on such a description, it is perhaps advisable to lay a little stress on the general characters and relations of the tubo-tympanic recess. The early pharynx is a cavity that is very wide from side to side in front, and narrows rapidly and considerably as it is traced back towards the stomach; it is flattened dorso-ventrally, so that the floor and roof are almost in contact, perhaps quite in contact in the living embryo. It has no proper side wall, the lateral limits of the cavity being made by the junctions of floor and roof, and the visceral arches and grooves are only found in the floor; the grooves terminate in lateral pouches (whose sub-divisions do not affect the general arrangement), and these lie therefore in the region of the lateral parts of the cavity, where they form depressions deeper than the remainders of their corresponding grooves. Towards the end of the first month the narrowing of the cavity from side to side is seen to take place less gradually than in the earlier stages, and the region of the third arch is the level at which this more sudden decrease in width is placed, so that in front of this arch there remains a wide area, and the part of the cavity that extends out in front of the arch, beyond the general lateral limits of the cavity, constitutes the tubo-tympanic recess that will subsequently be moulded into the cavity of the middle ear and Eustachian tube.

Fig. 1 gives in outline the shape of the pharyngeal cavity in a 12-mm. embryo, and illustrates this description, showing how each broad and open recess is floored by the outer parts of the first two arches, how their grooves lie behind them and end externally in deeper lateral pouches, and how the third arch, lying between the second and third pouches, necessarily forms the short posterior boundary of the recess.

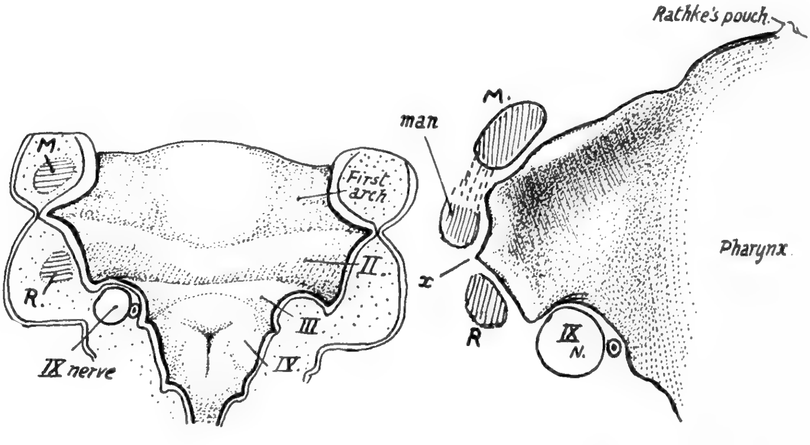

FIG. 1.—From models to show (A) floor of 12-mm. pharynx, (B) view from above of left tubo-tympanic recess in 16-mm. embryo. Somewhat diagrammatic.

M., R., condensations forming Meckel's and Reichert's bars respectively; *man.*, position of manubrial extension from first arch. This causes depression of the neighbouring wall, with a secondary projection, *x*, behind it

Later, as the recess elongates obliquely and develops, it is rotated on its longitudinal axis so that its original floor becomes its front and outer wall, and the periotic capsule that primarily lies on its roof assumes an inner and posterior relationship to it.

It follows from the foregoing statements that an account of the arches utilised in the formation of the recess must concern itself mainly with the floor, and that, as development proceeds, the arch-structures which persist will be found in association with what is described as the outer wall in the anatomy of the adult.

The second drawing in fig. 1 is an outline of the cavity seen from above in the 16-mm. embryo, and the projections of the first and second lateral pouches are easily recognised and compared with those in the 12-mm.

specimen. In the older one, however, the wall of the cavity has been pushed in immediately behind the first pouch by the extension of a mass of condensed mesenchyme from the upper part of the first arch, concerned in forming the handle of the malleus, etc. This incursion is associated

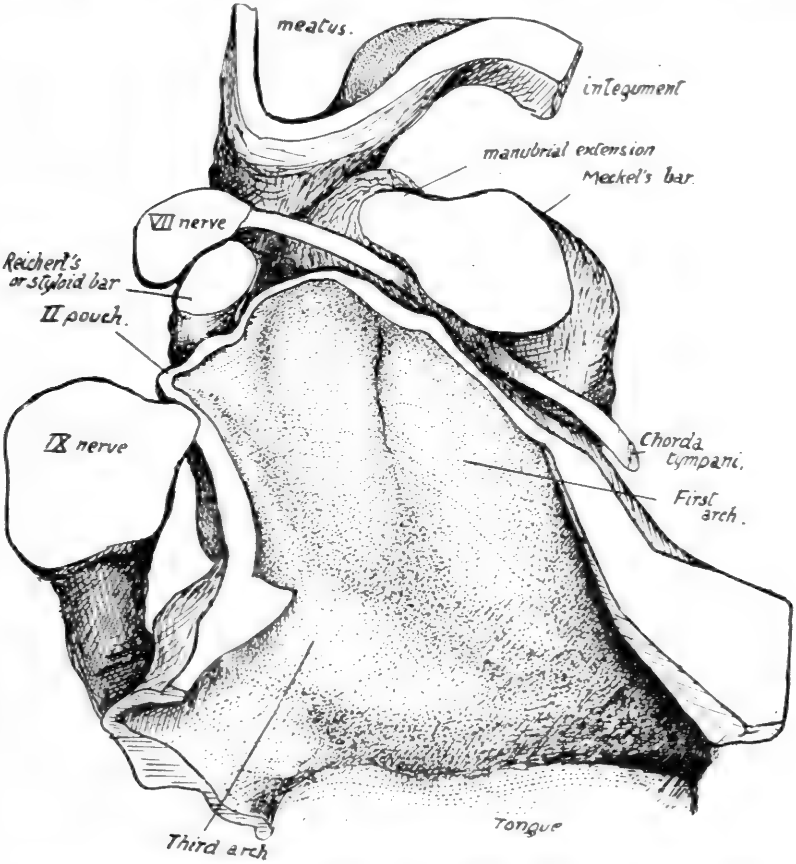

Fig. 2.—Floor of left recess, roof removed. From model (magn. 100 × $\frac{5}{6}$). A portion of the margin of the tongue is seen below. 16 mm.

with temporary separation of the pouch from the ectoderm (see figure), and also with the formation of a secondary projection in the margin of the cavity just behind the portion pushed in by the manubrial condensation.

On removing the roof of the recess and thus exposing the floor, the disposition of the arches becomes apparent. Fig. 2 is a drawing of the floor of the left recess in an embryo of 16 mm. exposed in this way, and is of interest because the key to subsequent changes is to be found in the conditions present at this stage.

The front part of the field is formed by structures of the first arch, among them Meckel's bar passing downwards and inwards, and behind this a deep but narrow sulcus marks the situation of the first visceral groove ending externally in the first lateral pouch, just above which the chorda tympani runs forward. The second lateral pouch is apparent behind the styloid bar (Reichert's bar), between this and the glosso-pharyngeal, which is closely applied to the wall of the recess here: this is the definite position of the second pouch, shown also in fig. 1 in the 12-mm. specimen, and is the position maintained by it until the growth of the cartilaginous auditory capsule effects a separation between it and the nerve.

The area of the second arch lies between the first and second pouches, and is plainly subdivided into two districts, an anterior one showing the prominence caused by the underlying manubrial condensation, and a posterior one exhibiting a convexity which is evidently caused by the styloid bar against which this part of the floor rests; the sulcus between these two districts corresponds, of course, with the secondary projection seen externally in fig. 1.

But, if we follow the complete second arch area inwards, it becomes clear that there is already a difference apparent between the arrangement of structures in the floor here and that in the 12-mm. embryo, and this difference is due to growth of the third arch tissues. The region of the third arch, where it forms the hinder boundary of the recess, has become more prominent, and an extension forward from it has taken place, spreading across the inner part of the floor towards the first arch, and, in doing so, covering over the tissues of the second arch in this situation, so that this latter is not represented in this part of the floor. The extension of the third arch is evident in the figure, and it is seen to be separated from the first arch region by a shallow gutter towards which the limiting sulci of the second arch are directed: they reach a broader hollow from which the first-mentioned shallow gutter is directed forwards and inwards. The floor of the gutter and broader hollow, as seen in the model and the drawing, is composed of much-thickened epithelium, and a reconstruction of the regions with the epithelium removed allows the surface appearance of the second arch to be followed a little lower than in the complete condition; but the general result is the same—the outer part of the arch is concerned in the formation of the floor of the cavity and is divisible there into its two districts, but the inner part has dropped out of the floor, and is separated from the cavity by a forward growth of the arch immediately succeeding it.

It may be pointed out here that the floor of the recess shows a general and well-marked concavity from before backwards as well as from without inwards, a condition that is not brought out in the drawing owing to the necessity for a clear presentation of the arches, etc. In other words, the growth of the first arch has turned up the related floor, the same effect has been produced on the manubrial district of the second arch by the mesenchymal extension underlying it, the styloid bar is directed downwards as well as inwards, so that the posterior district of the arch is correspondingly disposed, and the third arch is raising the hinder part of the floor as a result of its increasing size: the part that remains unaffected by these several factors is the broad hollow toward which the other surfaces slope, and the narrower gutter leading away from it which marks the place where the first and third arches have not yet met, but where such meeting is about to occur.

The further development of the region up to the third month is a simple progression of the changes seen in their early stages in fig. 2. The first arch area stands up more, the manubrial district of the second arch is more prominent and defined, and the second pouch is recognisable between the styloid bar and the glosso-pharyngeal nerve. But a distinct change is visible when attention is directed to the third arch region; the arch, presumably as a result of its growth, is encroaching on the lumen of the inner portion of the cavity from behind, so that already some indication of a division into tubal and tympanic parts is foreshadowed. A drawing of one of the models showing this stage is seen in fig. 3, and it is interesting to compare it with the earlier condition: recognition of the first and second arch region is easy, and the districts into which the latter is subdivided are evident and unmistakable.

But equally evident and unmistakable is the change that is apparent in the back and inner boundary of the recess. The third arch has grown and has carried this part of the hinder wall in a forward direction, tending to lessen the size of the opening of the recess from behind forwards: this can be graphically demonstrated and appreciated by superimposing a tracing of the later upon the earlier stage, when the first and second arch areas will be found practically to correspond and occupy their proper positions, whereas the increased obliquity forward of the hinder wall shows at once how much this part has extended in a forward direction relative to the other parts. Such growth, moreover, is most marked at the inner or pharyngeal end of the hinder wall, so that the corresponding portion of the recess exhibits some narrowing compared with the remainder.

The chief growth appears to be in the prominent part of the arch from which (fig. 2) the forward extension takes place, and in this extension itself. As a result of growth in the first-mentioned region, the depth and abruptness of the postero-internal wall of the broad hollow in the floor is increased and the hollow thus accentuated, while the growth of the forward extension has enabled this to reach the mandibular arch and to obliterate in doing so the gutter that separated the two in the earlier stage. The whole process is a continuation of that seen in its early stages at 16 mm.,

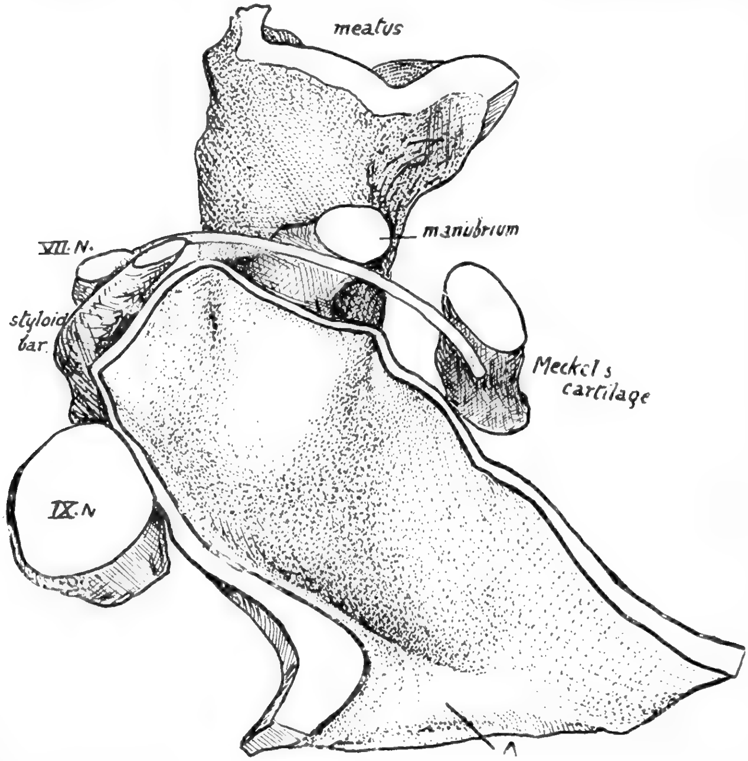

Fig. 3.—Left recess, from a model. 27 mm. Observe that the forward extension, A, from third arch along the floor is much more marked and prominent than in the last figure, and has reached the first arch.

and indicates the results of growth forward of the third toward the first arch across those tissues of the second arch which should be in the inner part of the floor of the recess, but still leaving the outer parts of the second arch exposed in the corresponding portion of the floor.

The two districts into which the outer part of the second arch is divided are more definite at this stage, principally because of the greater prominence and definition of the manubrial swelling, which not only stands out into the cavity, but has a deeper sulcus between it and the styloid district; at one place this sulcus shows an extension deeply round the back of the manubrium, which is apparently an early indication of the posterior recess of Tröltsch. The styloid district is if anything relatively smaller, depending on the thickness of the bar on which it is moulded. The second pouch is seen behind, and a little internal to, the styloid district, between the styloid bar and the glosso-pharyngeal nerve.

The first arch region, like the manubrial mass, stands up more than in the early stages; in other words, the front and outer part of the floor is being lifted up by underlying growth, and thus being brought more into the position of an outer and front wall, as mentioned in the beginning of

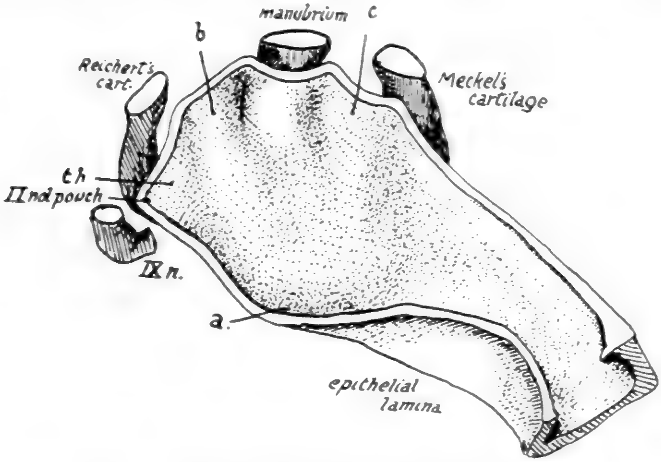

FIG. 4.—Left recess, simplified, from model. 35 mm.

a, bottom of tympanum practically corresponding with lower extremity of meatal plate and tympanic ring; *b*, *c*, prominences made by back and front edges of meatal plate growing in round the manubrium; *th.*, tympano-hyal area.

this paper. It follows as a result that the growth of these parts assists in accentuating the hollow that lies at the bottom of their declivities.

It is about this time that the process begins, the effects of which are so strikingly seen in specimens of about 35 mm. length: apparently the mass of the third arch advances toward the area of the first arch with greater rapidity, along the floor, so that one is heaped up, so to speak, against the other, with an epithelial septum lying between them composed of the cells which at the time cover their meeting surfaces.

Fig. 4 is from a model of a 35-mm. embryo, and shows how greatly the third arch has extended forward; comparison with the earlier stages makes this evident. The recess as a whole is slightly longer, and the growth of the third arch particularly affects the inner part and narrows it, thus definitely indicating the distinction between tube and tympanum. But it is equally plain that this narrowing has not been obtained by a raising up of the epithelial floor as a result of growth under it, but by a fusion of the surfaces of the first and third arches where they have come into contact; for an epithelial lamina is present below the newly made "floor" in this region which is continuous with the epithelial lining of the cavity along its length from the hinder boundary of the pharyngeal opening to the hollow situated at the foot of the anterior district of the second arch in the tympanic region. Such a lamina can be nothing but the covering of the prominent arches caught between them as they meet. The lamina, as shown in the model, consists only of a solid and continuous epithelial septum; but under the microscope broken layers and masses of cells can be found which are not suitable for modelling, but indicate that the fusion is more extensive behind and below than is suggested by the model. What is probably the beginning of this process is found in the 29-mm. embryo, in which an epithelial mass can be seen lying above the front part of the forward extension of the third arch, between the thicker posterior part of this extension and the first arch eminence.

The lower part of the tympanic region is now (fig. 4) more definitely limited in front, by the fusion that narrows the cavity, and it becomes necessary to see how far back the fusion would extend if it were marked out on the earlier recess shown in fig. 3. At that stage there is a large and well-marked hollow to be seen; it lies along the lower margin of the first arch area and extends back to the foot of the manubrial swelling and forward to the forward-growing process of the third arch, which separates it from the opening of the recess. In the stage shown in fig. 2 its narrower inner part forms the gutter which is interrupted by the process of the third arch, so that the hollow seen in fig. 3 includes the commencement of the gutter. This hollow, as seen in fig. 3, is obliterated by the adhesion and fusion of its postero-internal with its antero-external wall, *with the exception of the part which lies at the foot of the manubrial swelling*; this part is seen at *a* in fig. 4, the remainder of the hollow in front of this being obliterated and its adherent walls forming the epithelial lamina, which increases in depth as the area of adhesion increases. The convexity of the first arch which forms the antero-external wall of the hollow is preserved in the adherent state, and can be appreciated in the 35-mm. model, in which the epithelial lamina is concave forward and continuous with the curve of what is left of the first arch region above the area of fusion.

The growth and fusion which goes on at the inner part of the recess does not affect the outer portion of the second arch directly, but leaves it exposed in the wider part of the cavity where no fusion has occurred.

Remembering that the floor of the recess becomes the outer wall of the ultimate tympanum, it is easy to follow the changes which are apparent in the surface view of the arch that is obtained here: the changes are evident in the figures of the various stages.

In this connexion it is necessary to inquire first into the nature of the structures which are in relation with the deep or outer side of the arch seen in the floor of the recess. In the 12-mm. stage the first and second lateral pouches are in contact relation with the ectoderm of the corresponding external grooves, but after this they are separated by the increasing thickness of the mesoderm which interposes itself between the outer and inner grooves. In the case of the second pouch the separation causes at first an elongation of the epithelial connexion, drawing it out into a narrow *ductus branchialis* connected with the lining of the precervical sinus; this soon atrophies and disappears, and no trace of the structure can be found subsequently. With the first pouch, however, the case is different so far as the sequel is concerned. Possibly the mesoderm which effects the separation is the condensed mass which extends back from the upper part of the first arch to the outer side of the chorda tympani, and constitutes what I have termed the "manubrial mass" or extension in this paper. This forms a thick mass which is continuous in the sixth week with the condensation of the anlage of Meckel's bar, the continuity lying above and outside the first pouch. The mass formed in this way has therefore extended from the first arch into the second, pushes in the anterior part of this last arch to form the anterior district visible in the 16-mm. stage, and is placed between this part of the second arch in the floor of the recess and the epithelium-lined recess or bay of the external groove which represents the early state of the external meatus at this stage.

The position of the developing meatus and the shape it assumes appear to be factors of some importance in the production of modifications in the aspect of that part of the wall of the tympanum which is under consideration, and, without entering into the whole question of the formation of the meatus, it may be of some little use to give a brief account of the structures as they concern the tympanum.

The external meatus, at the stage shown in fig. 2, is represented by a broad groove directed downwards and inwards, and ending below in a pit which is placed below the level of the outer part of the tubo-tympanic recess: the structure as a whole can be described as situated obliquely below and outside the recess, and separated from it by the "manubrial mass" of cells. In fig. 2 the upper and outer part of the groove is seen cut through at the top of the drawing, and from this the floor of the groove can be followed down and in, separated from the floor of the recess by the manubrial extension, until it is lost to sight under the floor of the recess. The upper part of the manubrial mass is thick, but it thins away below, so that the pit in which the meatal groove terminates below is nearer the floor of the tubo-tympanic recess than is the upper part of the groove, and the part of the floor with which the pit is in nearest relation is near the lower end of the anterior district of the second arch. In later stages the relative length of the open groove has decreased, while that of the pit has much increased, so that this latter is now in relation with the floor of the recess —the manubrial mass intervening—so far in as almost to reach the level of the bottom of the hollow in the floor seen in fig. 3; in other words, the

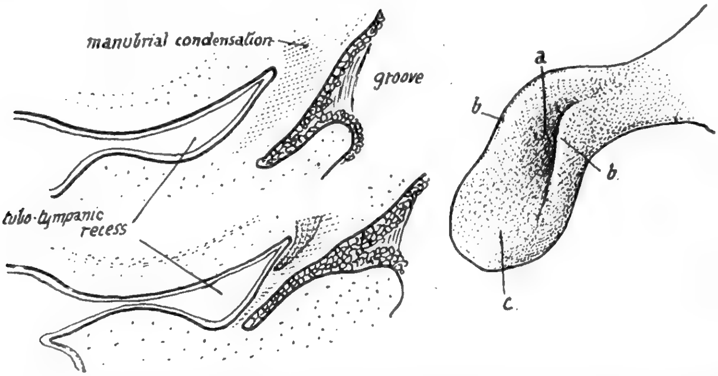

FIG. 5.—On the left, two schemes to show the relations between the recess and the meatal extension (meatal plate). Represented in transverse section. In the upper figure the plate is separated from the recess by thick condensation, but in lower figure the meatal extension is longer and more nearly in contact with the recess, with thinned out mesenchyme intervening. Note the correspondence between the extremity of plate and bottom of tympanum. The right-hand figure represents the separated meatal plate.

a, concavity receiving manubrium; *b b*, edges passing round manubrium to reach wall of recess; *c*, flat lower part applied to wall of recess below level of manubrium.

inner part of the pit-like meatal extension is now applied to the outer wall of the hollow in the recess and to the lower part of the anterior district of the arch above this, and here is separated from them only by the attenuated lower part of the "manubrial" condensation, and is consequently plate-like in form, whereas the outer and upper part of the meatal growth is further away, separated from the recess by the greater thickness of the condensation where the handle of the malleus is developing, and the edges of the meatal extension are growing out toward the recess on each side of the handle, thus limiting the condensation and fitting in between the handle and the styloid bar behind and Meckel's bar in front.

Fig. 5 shows schematically the application of the meatal extension to the floor of the recess, and in the same figure is given a sketch of the extension to exhibit its general shape. Its inner part is a solid plate of epithelial cells—the *meatal plate*—and is practically flat at its extremity, but higher up it is concave where it receives the manubrial mass which separates it from the floor of the recess; it is at the edges of this concave portion that the growth inwards takes place towards the floor.

We can now appreciate the appearance of the floor seen in the ninth week (fig. 4). The lower end of the meatal plate is applied to the floor just above the point *a*—with, of course, a thin mesenchymal layer intervening—and above this it is applied to the floor as far up as the definite prominence caused by the handle of the malleus. Here the plate becomes separated from the floor by the thicker mass of structures, but its edges have grown forward on each side of these and have produced a decided bulging of the floor on each side of the manubrial swelling, marked in the figure as *b* and *c*. Of these, the anterior one, *c*, is evidently produced in the first arch region in front of the remains of the first groove, while the posterior one, *b*, is situated behind the secondary post-manubrial sulcus (posterior recess of Tröltsch), and therefore in the posterior district of the arch. A glance at fig. 2 will show that this posterior district is in its early state practically altogether in relation with the styloid bar, but in fig. 3 the bar is proportionately smaller; it has not kept pace in its growth with the general enlargement of the recess, and thus is only occupying a part of the field of the posterior district. It is the unoccupied area antero-external to the bar which is reached by the posterior edge of the meatal plate and is pushed in by it, and thus the part of the floor which covers the styloid bar is again and more definitely mapped out, and can now be termed the "tympano-hyal" area (*th*, fig. 4). At this stage, therefore, we can recognise the situation of many definite structures in relation with the outer wall of the tympanum. The area over which the meatal plate comes into relation with the floor of the recess determines the extent of the tympanic membrane, and this area is apparent in fig. 4; the definite swellings produced by the edges of the plate at *b* and *c* are continuous below with the indefinite convexity which covers the flatter lower end of the plate, and the whole forms a horseshoe-shaped area round the manubrial swelling that marks the position of the tympanic membrane. This area has the bony tympanic ring round its periphery; the ring does not produce any visible impression on the floor, but its lowest part comes down practically to the level of the point *a*. The chorda tympani is not shown in the drawing, but would be as in the other figures; and we can thus see that the outer wall of the tympanum, nearly if not quite up to the level of the chorda, is formed from the floor of the recess, and has both first and second arch elements in it, the share taken by the first arch being limited to the part in front of the handle of the malleus.

The area of the second arch includes the outer wall behind this, and turns on to the back wall to take in the tympano-hyal region.

The second pouch is evident between the styloid bar and the ninth nerve, which still approaches the wall of the recess here, although the growing auditory capsule is carrying it as a whole further away. Observe the position of the pouch: it is no longer behind the styloid bar as in fig. 1, but is now definitely internal to it, a position which has been gradually assumed as the recess has developed; that is to say, that the original relation, which was postero-internal, has now lost its posterior character and remains only internal. The relationship is still, of course, morphologically posterior in the sense that if we follow the side-limits of the pharynx in an aboral direction we come to the pouch after passing the arch and bar.

The outer wall of the tympanum, so far as it has been seen, appears to be fixed in its position as a result of its relations and connexions with the structures lying deep to it, and it would seem probable that, if this is so, that part of the outer wall which lies above the chorda tympani must be formed as a secondary derivative of the roof of the recess.

The limitation of the area of fusion as shown in fig. 4 strongly suggests that there is some connexion between the persistence of the non-fused tympanic region and the close relation of the ectodermal meatal plate, but what this connexion may be, if it exists directly at all, there appears to be no evidence to show. I hope to get some light on the question by examination of other forms, but in the meantime can only say that the advance and fusion with anterior structures of the third arch does not take place where the meatal plate is in relation with the floor of the recess, that the size of the cavity is consequently greater in this area, and that here the second arch remains in the floor and is not covered in, as in the more internal parts, by the forward advance of the arch-structures which lie behind it in a morphological sense.

The growth of the third arch tissues and the consequent covering over of those of the second arch where it occurs is a phenomenon which has its parallel in the external growth of the second arch that hides the third and other arches and even extends forward over the mandibular derivatives. It is interesting to observe that the second arch begins to drop out of the floor of the recess about the time that it commences to extend its muscle cells more externally away from its own special region. Before this it lies (see fig. 1) as a complete visceral bar across the pharyngeal floor, passing to the region of the future back part of the tongue; but after it has commenced its external growth the central portion apparently ceases to grow proportionately and seems to be only responsible for the formation of the fibres of the stylo-hyoid and digastric. This comparative atrophy of the greater part of the original arch leaves it poorly represented in the general floor, and it is in fact seemingly completely covered by the increased internal growth of the third arch; the only part of the arch persisting in the floor is that outer portion which I have shown in this paper to remain as part of the floor of the recess or outer wall of the tympanum, and the stapedius is developed here from the muscle cells of the original arch-tissue. While examining sections I have found some reason to think that the attenuated second arch can be followed in its proper situation—though covered by third arch tissues—during the second month, and that the true nerve of the arch is to be found in the remnant: this must form the subject of a future investigation, but it may be mentioned here that the nerve in question appears to be the connexion running from the facial to the glosso-pharyngeal, which, in the embryo, makes its junction deeply in the basal portion of the tongue.

The increase in the pharyngeal aspect and extent of the third arch fills the deficiency resulting from the comparative atrophy of the second arch in the pharyngeal floor. This growth of the tissues of the third arch in the neighbourhood of the opening of the tubo-tympanic recess is associated with the formation of the palate. When investigating the development of the naso-pharynx and nose it was necessary to work out the development of the palate, and in 1910 I called attention to the fact that a forward growth takes place from the region of the third arch to join the (maxillary) palate-fold, and is, in fact, the basis of the pharyngeal extension of the fold. I also pointed out that the maxillary fold is really an outgrowth of the floor of the pharynx, and it can be understood, without entering further into the formation of the palate, that if the fold extends back on the floor to the hinder limit of the first arch, at the junction of the recess with the pharynx, the forward growth of the third arch will reach it when it extends across the buried remnants of the second arch. So far as I am aware, this observation and suggestion of the formation of the palate from two distinct elements was a novel one, and it interested me to find that Michio Inouyé (*Anat. Hefte*, 1912) described and figured the palate in moles and mice as developing in separated parts which coalesce later: in the human embryo, however, the two parts have always met before they produce any appreciable "backward extension" that can be seen on the pharyngeal wall.

The relative position of these extensions of the third arch can be understood by referring to the stage shown in fig. 2: the palate fold will be placed along the outer side of the sulcus beside the tongue, just internal to the forward extension from the third arch, and the palatal growth from this arch will meet it in this line. Thus, when the compound ridge becomes apparent on the surface, it stands out as a fold between the opening of the recess and the sulcus beside the tongue, dividing the original floor of the pharynx in this situation into an inner and outer portion; the former is depressed with the tongue and makes the posterior part of the wall of the mouth, but the latter is raised up, supported on the mass of mandibular mesenchyme, and becomes the antero-external wall of the tube and tympanum. We have seen that the tissues of the third arch by their extension make the "floor" of the tubal opening, and this extension is continuous with the palatal growth, so that structures developed between the opening and the palate are also formed in this extension, which covers the more central parts of the second arch; in fact, it may be shortly stated that all the structures which lie in the plane of the wall of the pharynx between the floor of the Eustachian tube and the stylo-hyoid level are derived from the secondary growth of the tissues of the third arch.

Internal to (*i.e.* below) the palatal growth the mesenchyme of the third arch extends on to the tongue, covering over the remains of the second arch and forming a new posterior part for that organ.

At the end of the second and early part of the third month there appears to be a rapid increase of the third arch growths, so that we find about this time that the inner part of the tubo-tympanic recess is narrowed by growth of the tissues there, the palate fold becomes more prominent preliminary to closure, and the tongue extension forms a prominent mass *in sitû* which makes with its fellow an angular depression that marks the future foramen cæcum. In this way the partial fusion which brings the tubal division of the recess into evidence can be said to be associated with the later stages of formation of the palate, not as cause or effect, but as a result of the same factor, the rapid growth of the tissues of the extension forward from the third arch which has buried under it those of the inner and larger part of the second arch.

In this account of the formation of the tubo-tympanic region I have, *inter alia*, dealt rather fully with the question of the closure of part of the recess to produce the tubal portion of the cavity, because my later and more detailed investigations have led to results which call for a certain amount of modification as well as extension of the views outlined in my previous paper. In that account I termed the process an "atrophy," and in one sense the term is a true one, for there is, without doubt, an atrophy of the layer immediately lining the cavity, and a failure of development of the true second arch where it lies below this part of the cavity; but, although I had made certain observations on the palate growth, I had failed to appreciate the wide extent of the forward movement of the third arch, and was thus at a loss to account for the occurrence of the narrowing, even though I described the appearances as probably indicating that it had been preceded by epithelial adhesion between the walls. It was therefore suggested that the second arch atrophies, leaving it to be understood that when it disappears the third and first arches must of necessity come together. The present investigation, aided by a series of reconstructions of the floor of the cavity, show that that suggestion rather placed the cart before the horse—that the disappearance of the second is a result and not the cause of the changes affecting the third arch, depending, like the fusion with the first arch, on the growth of the tissues of the third arch.

This correction of a suggestion by a truer conception of the conditions involves as a corollary the modification of another and smaller point in the original description. This concerns the presence of a shallow groove emerging from the opening of the recess and situated in front of what is evidently part of the third arch: such a groove, without a right conception of the extent of growth of the third arch, suggests itself at once as a portion of the second groove, and falls into line thus with the idea of a partial atrophy of the arch in the tubal region and its reappearance further in. But although it is in front of third arch structures it is really only a groove secondarily made between these and other tissues of the same arch, part of the forward growth, and cannot therefore be properly described as a portion of the second groove.

The second groove, however, may be said to reappear below the main mass of the growth of the third arch. This mass has been described as showing three principal processes or parts—an upper forward extension in the tubal region, a palatine part, and an extension to the tongue: the last of these is separated from the pharyngo-epiglottic fold, which is the proper third arch in the floor of the pharynx, by the deep groove in which the tonsil develops and which is part of the second visceral groove. It is true that the second arch structures in front of it are covered by those of the third arch, but the groove itself appears to remain unaltered from the 12-mm. stage, and really marks the position of the second groove. The groove first described, at the opening of the recess, may possibly mark the place where the third arch growth crosses the original situation of the second groove, but as it is on a third arch basis it ought not to be classed with the second groove, which would properly be described as reappearing below (and not above) the level of the palate-fold.

The second pouch remains in its position between the upper part of the styloid bar and the glosso-pharyngeal nerve up to the stage to which we have so far followed the development, but the fate of the second groove between the pouch and the lower part of the tympanum is not so clear. Examination of the earlier stages shows that the lower portion of the groove in this fraction of its extent is filled by proliferated epithelium, and the condition in later stages suggests that the lower portion may be obliterated: probably it would be safe to say that only the upper or outer extremity of the groove remains, along the postero-internal edge of the tympano-hyal area (fig. 4), while the lower part, extending to the bottom of the tympanum, only shows the partly obliterated remnants of the groove remaining in their proper position between structures of the second and third arches.

The second pouch is affected in the direction it assumes by the relationship of the auditory capsule to the developing recess. The capsule grows very rapidly, and, being situated above the roof of the recess, produces a concavity on the upper aspect of the roof. The pouch is at the outer and posterior part of the roof and concavity, and thus is on the whole turned somewhat upwards with reference to the general level of the roof. The condition may perhaps be rendered clearer by fig. 6, from a model of the parts in a fœtus of 50 mm.: the roof of the tubo-tympanic cavity is seen from above and behind, exhibiting the depression caused by the cartilaginous (cochlear) capsule with the second pouch turned slightly up at its outer and posterior part. The cartilaginous structure is shown separated in part and reversed, so that the hollow into which the pouch fits is seen on it: this is the fossula rotunda. At this time there is no part that could be termed the tympanic sinus, the locality in which one would expect *a priori* to find the pouch, and if the sinus is related to the pouch it is

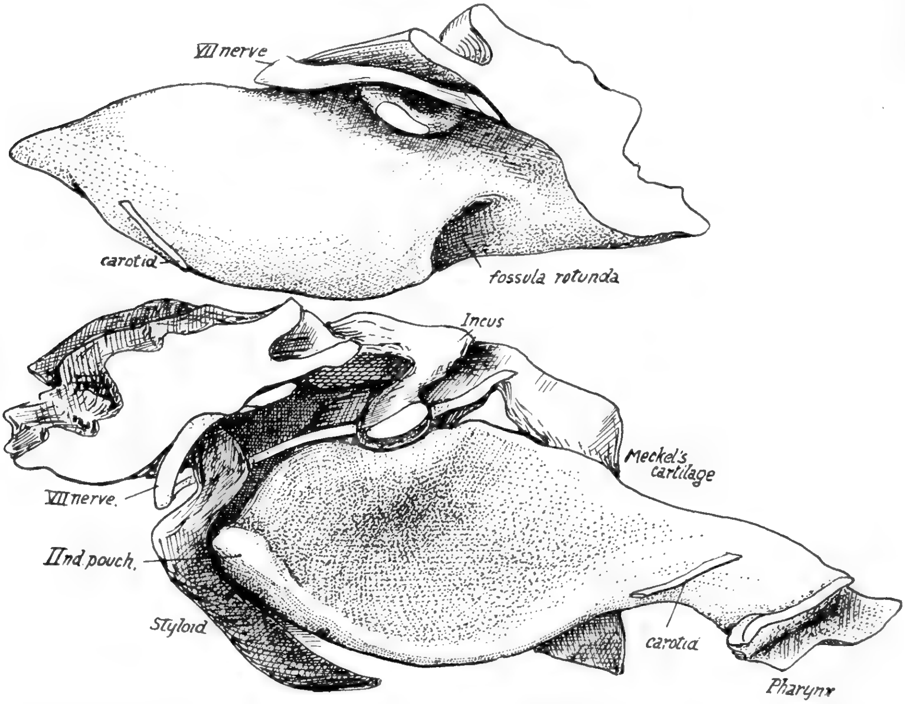

FIG. 6.—From model of left middle ear region in 50-mm. specimen. Somewhat simplified. Lower figure shows superficial view of recess seen from above and behind. Note position of 2nd pouch and its relation to the concavity, visible on the roof, which lodges the auditory capsule. The upper figure shows the cochlear portion of capsule cut away from the rest and turned round to exhibit the fossula rotunda which lies over the pouch. Above this the facial nerve and stapes are seen cut, their other parts remaining on the other portion of the model. The thickness of the walls, of course, makes the pouch appear more prominent than it would be if the region were exposed as in the previous figures.

probably as a secondary extension: on this matter, however, I cannot make any positive statement, and must be content with the account already given—that it corresponds with the fossula rotunda in the later third-month stages. Both the fossula and the sinus are internal to the tympano-hyal, so that one or other—or both—might mark the situation of the remains of the pouch.

The secondary sulci in relation with the outer wall of the tympanum developed from the floor of the recess may be briefly mentioned here. The posterior recess of Tröltsch has already been noticed forming immediately behind the developing manubrium; it deepens somewhat rapidly, and by the third month shows a tendency to extend up to the outer side of the chorda tympani. In this rate of extension it differs from the sulcus in front of the handle which marks apparently the remnant of the first groove; this is deep in the 16-mm. embryo, and later becomes partly filled up and shallower, so that its presence in the third month appears to owe its evidence as much to the prominences at each side of it as to any inherent depth it may possess. Probably the anterior recess of Tröltsch is secondarily derived from it, but even in the fourth month there is only a very slight increase in the relative depth of the groove. The different powers of extension which are exhibited by the two sulci may have something to do with the fact that the posterior recess is said to communicate with the pouch (Prussak's) above it, but that this never occurs with the anterior recess.

The consideration of the nerve supply of the walls of the tympanic cavity would seem to belong more appropriately to the account of the formation of the roof of the tubo-tympanic recess and its subsequent development, but, as the second arch is represented in the floor or outer wall, one might expect to find an area over which the nerve of the second arch distributes filaments. Such an area is quite unknown—at least, I am not aware of a description of a sensory supply of this sort ever having been given, and I have failed to find any indication of its existence in sections at the fourth month. If such an area did exist, one would expect it to be very small, limited to the mucous membrane over the tympano-hyal, for the remainder of the second arch has been invaded by extension from the first arch, and this has carried its nerves and vessels with it.

The condensation of this manubrial extension is placed between the meatus and the floor of the recess, and is much thicker above than below. The thick upper and outer part can again be divided into an inner part in which the handle is formed, and an outer which is continued into the thinner layers of the lower and inner portion: these two by their subsequent thinning out make the membrane, which is therefore on the outer side of the handle of the malleus. Thus the manubrial mass is not only concerned with the manubrium but also with the membrane, this portion of it being thinned out apparently by the pressure of the meatal plate growing toward the cavity: perhaps the thicker and looser and more vascular tissues of the membrane of Shrapnell may represent the upper and less compressed part of the condensation. The nerves of the condensation are carried backwards and downwards with it. They thus belong to the auriculo-temporal group of the mandibular, and one of them (the superior meatal of auriculo-temporal) runs back over the top of the meatal plate and turns down in the condensation with the handle of the malleus; it lies outside and behind the handle, running parallel to it, and gives off filaments which pass radially to the whole periphery of the membrane, round which they turn to be distributed to the region of the meatus. I cannot help thinking that these branches are also supplied to the tympanic aspect of the structure. Todd describes connexions between this nerve and the chorda tympani: I have not been able to find these certainly, nor any indication of other nerve supply. It seems to me that a supply from the auriculo-temporal might be expected over the tympanic aspect of the membrane as far up as the chorda, but my observations made with bearing on the question have been very unsatisfactory in their results, and I have been unable to reach definite conclusions on the matter.

While on the subject of nerves related to the tympanum, it is not out of place to call attention to the position of the chorda as seen in the models and figures given in this paper. It is a common—though not perhaps a general—teaching that the facial nerve does not possess a representative of the pretrematic branch of the typical branchial nerve, but that the ninth nerve shows an example of it in its tympanic branch. The conditions as found in the embryo appear to be quite clearly against this view. The chorda passes from the region of the second arch over the first pouch into the first arch, and is thus strictly comparable with a pretrematic branch: although the subsequent secondary evolution of the cavity leaves the nerve along the outer wall, this is owing to its maintenance of its original and fixed pretrematic course. The ninth nerve, on the other hand, has no branch that passes over the second pouch, at any time in the development, to reach the second arch, and the ramus tympanicus is a branch which seems to be confined to the roof of the recess and to have none of the characters of a pretrematic branch.

In endeavouring to present a picture of the conditions ruling in the developing tympanum, I have been constrained to deal with certain matters only indirectly connected with the proper subject of this communication; but at the conclusion of the whole account I would like to call attention to some points in it on which I wish to lay particular stress. These are:—

1. The original position of the second arch and groove in the floor of the tubo-tympanic recess.

2. Its exclusion from the floor of the inner part of the recess as a result of the growing forward of the third arch over it.

3. The persistence of the arch and groove in that part of the recess which subsequently becomes the tympanum. The partial invasion of it here by the structures associated with the membrane, but its existence purely as second arch in the tympano-hyal region.

4. The formation of the narrow tubal region from the wider inner part of the recess by a direct fusion of the masses of the first and third arches as a sequel to the great forward growth of the latter.

5. The position of the second pouch at the fossula rotunda or sinus tympani, or both, and of the first pouch in the situation of the anterior recess of Tröltsch.

INVESTIGATIONS IN THE ANATOMY OF THE PALATE. By

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The present paper has to do with certain points in the musculature and arterial supply of the palate. The illustrations are taken from a series of dissections which were made during an inquiry into the operative treatment of cleft palate. The observations made differ in a number of particulars from the generally accepted views, and are recorded on that account.

In the case of the muscles of the palate, the conditions represented in the figures have been found in a considerable number of dissections, so that they may be regarded as normal; as regards the arteries, however, the statements are made with more reserve, because neither time nor material sufficed for the making of such a large number of dissections as would be necessary before dogmatic assertions could be made.

Fig. 1 shows the region of the sinus of Morgagni of the right side. Attention is called particularly to the tensor and levator palati, and to the Eustachian tube.

The *tensor palati* is easily recognised in any dissection in which it is displayed, from its breadth, and from the large number of tendinous fibres which it contains (see fig. 5). It arises in five situations: (1) from the inner aspect of the spine of the sphenoid, or from the great wing immediately in front of this; (2) from the scaphoid fossa; (3) between these two points, the muscle does not arise from bone, but from the lateral lamina of the cartilage of the Eustachian tube; (4) by its deep aspect, from the membranous part of the tube; (5) from the posterior border of the internal pterygoid plate. The tendon of the muscle, having passed superficial to the upper fibres of the superior pharyngeal constrictor, and turned inwards round the hamular process, at once expands so as to occupy the anterior third of the soft palate; in this manner is formed the *palatal aponeurosis*, which is not a separate structure, but is actually the expanded tendon of the tensor palati. The posterior border of this aponeurosis gives origin to certain other muscles of the palate, especially the palato-pharyngeus (see fig. 3); while the anterior border is attached partly to the posterior border of the horizontal plate of the palate bone, and partly, passing forward beyond this, to the transverse ridge upon the oral aspect of that bone.

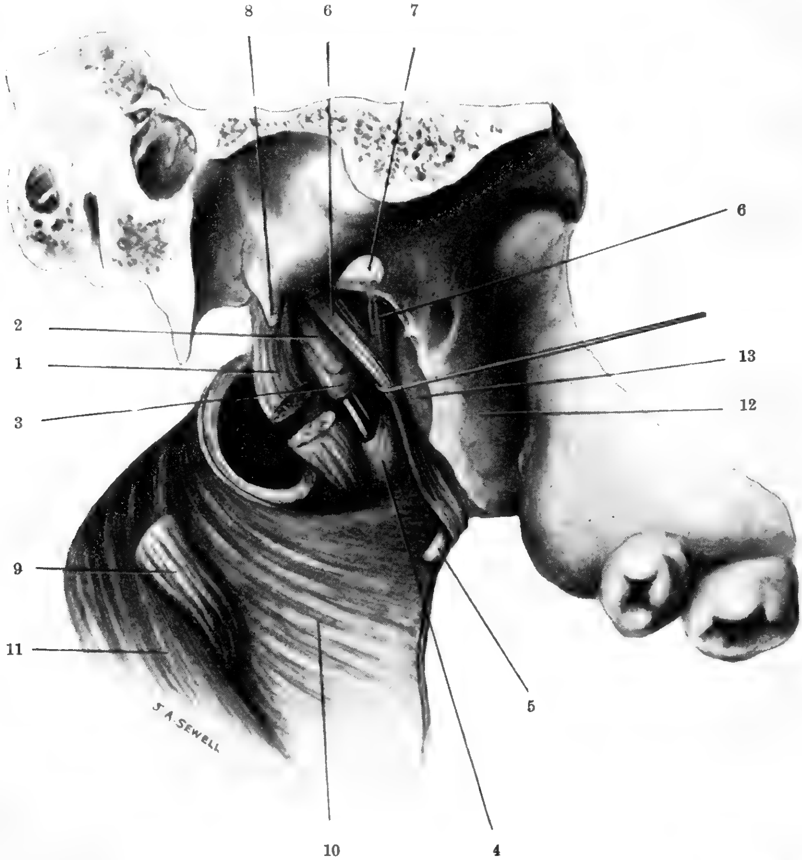

Fig. 1.—A dissection of some of the muscles of the soft palate. The levator palati has been divided, and its proximal half drawn backwards: the posterior border of the tensor palati is seen hooked forwards. A glass rod has been passed along the Eustachian tube, and an opening made into the latter close to its pharyngeal extremity.

1, levator palati; 2, cartilage of Eustachian tube; 3, membranous lamina of Eustachian tube; 4, wall of naso-pharynx at point of entry of tube; 5, hamular process; 6, the bony origins of the tensor palati: between them is seen a part of the cartilage of the tube; 7, foramen ovale; 8, spine of sphenoid; 9, stylo-pharyngeus; 10, superior constrictor; 11, middle constrictor; 12, external; and 13, internal pterygoid plate.

Although the tensor palati undoubtedly acts to some extent as a tensor of the soft palate, yet this action is greatly limited, first by its extensive insertion into bone, and secondly by the fact that its aponeurosis is confined to the anterior third of the soft palate.

The action of the muscle as a dilator of the tube, if such action exist, can only be very slight, owing to the nearly vertical direction of its thin sheet of muscular fibres (see fig. 6). The Eustachian tube is seen in a transverse section as a narrow, vertically placed slit. The outer boundary

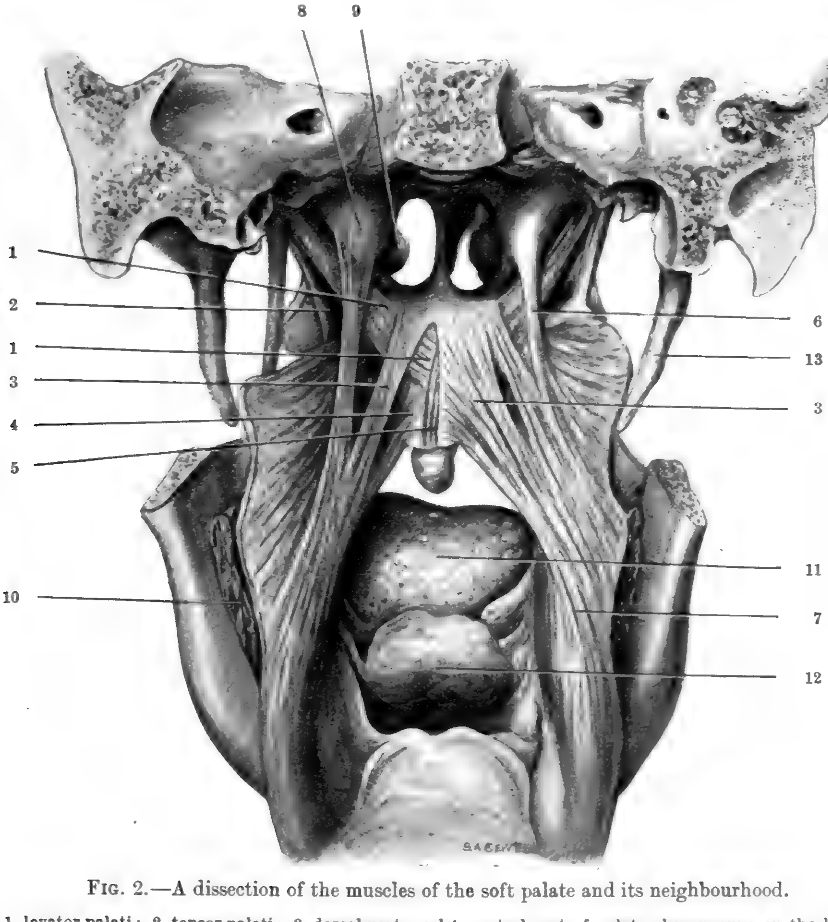

FIG. 2.—A dissection of the muscles of the soft palate and its neighbourhood.

1, 1, levator palati; 2, tensor palati; 3, dorsal part, and 4, ventral part of palato-pharyngeus: on the left side a part of the dorsal division has been removed, in order to show the levator palati, and 5, the azygos uvulæ; 6, salpingo-pharyngeus; 7, insertion of palato-pharyngeus into pharyngeal aponeurosis; 8, Eustachian tube; 9, inferior turbinate; 10, cut edge of mylo-hyoid muscle; 11, tongue; 12, epiglottis; 13, styloid process.

of this slit is formed for the most part by the membranous lamina of the tube, in contact with which, and partly arising from it, is the tensor palati; contraction of this muscle is much more likely to press together the sides of the slit, so as to produce closure, than to bring about opening of the tube.

The anatomy of the *levator palati* is shown in figs. 1, 2, 3, and 6. The thick, rounded belly of the muscle is in marked contrast to the flattened tensor. It has quite a small origin, from a rough area of the petrous bone immediately in front of the inferior aperture of the carotid canal; the quadrate area upon the inferior aspect of the apex of the petrous bone does not give origin to the muscle; nor does the latter arise, by more than a very few insignificant fibres, from the medial lamina of the cartilage of the Eustachian tube. The relation of the muscle to the tube is also worthy

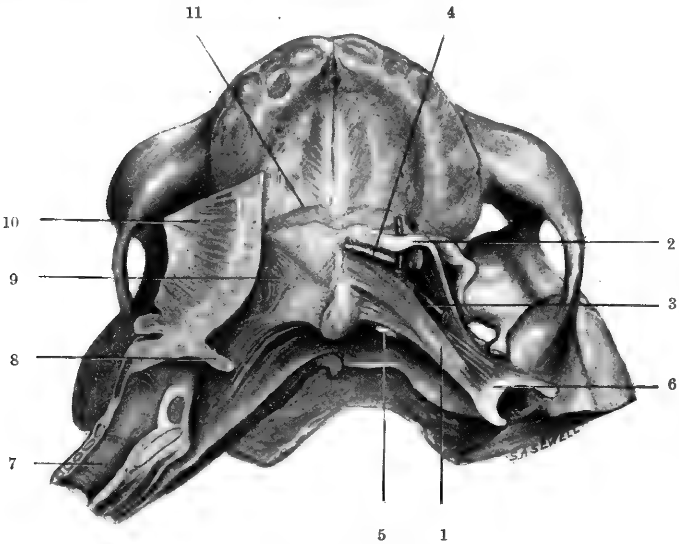

Fig. 3.—A dissection of some of the muscles of the palate of a full-term fœtus. The base of the tongue and the larynx have been split in the middle line, the left half removed, and the right half turned to the right side.

1, levator palati; 2, tendon of tensor palati turning round hamular process: a glass rod has been placed under the tendon; 3, rod in Eustachian tube; 4, 5, the two parts of the palato-pharyngeus, cut short; 6, tympanic bone; 7, trachea; 8, epiglottis; 9, palato-glossus; 10, tongue; 11, suture between palatal processes of maxilla and palate bone.

of note; it lies along, and is closely applied to, the posterior or inferior border of the tube, and rather to the outer side of the latter, not at all upon the inner side, where it is usually described as lying (see fig. 2).

The muscle passes downwards and inwards to the soft palate, above the upper border of the superior constrictor; the upper fibres of the latter muscle here separate the levator and tensor palati from each other. Entering the soft palate immediately in front of the salpingo-pharyngeus muscle, and between the two layers of the palato-pharyngeus, the muscle extends inwards to the middle line, its fibres running as much inwards as downwards. A dissection such as that shown in fig. 2 makes it plain that this muscle must have nearly, if not quite, as much action as a tensor as as a levator of the palate. Without doubt, it, more than any other muscle, tends by its contractions to separate the sutured edges after the operation for cleft palate, unless it has been divided or in some other way put out of action.

As regards the action of the levator palati upon the Eustachian tube,

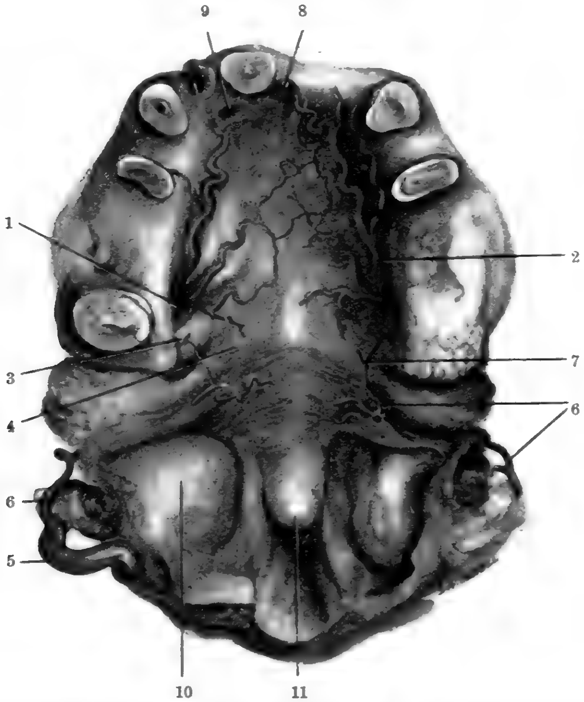

Fig. 4.—A dissection to show the arterial supply of the palate. On the right side the descending palatine artery becomes obliterated before reaching the anterior palatine canal, probably as the result of some inflammatory process connected with the root of a carious right lateral incisor tooth.

1, posterior palatine canal; 2, descending palatine artery; 3, accessory palatine foramen; 4, aponeurosis of tensor palati; 5, facial artery; 6, 6, ascending palatine artery; 7, anastomosis between accessory and ascending palatine arteries; 8, terminal branch of descending palatine artery at anterior palatine canal; 9, old abscess cavity, resulting from carious tooth; 10, tonsil; 11, uvula.

its contraction can exercise no direct pull upon the tube, since none of the fibres of the muscle arise therefrom; but the intimate relation of the muscle belly to the inferior border of the tube suggests other possibilities (see figs. 2 and 6). It has been suggested that the contracting muscle belly might bulge upwards to such an extent as to obliterate by its pressure the lumen of the tube; such an action can scarcely be possible, even at the pharyngeal orifice of the tube, where under ordinary circumstances the levator palati produces something of a swelling upon the floor; for even here it is difficult to close the lumen of the tube, even by forcibly pushing the muscle upwards towards it. It is much more probable that the muscular contraction opens the tube, in one or both of two ways:

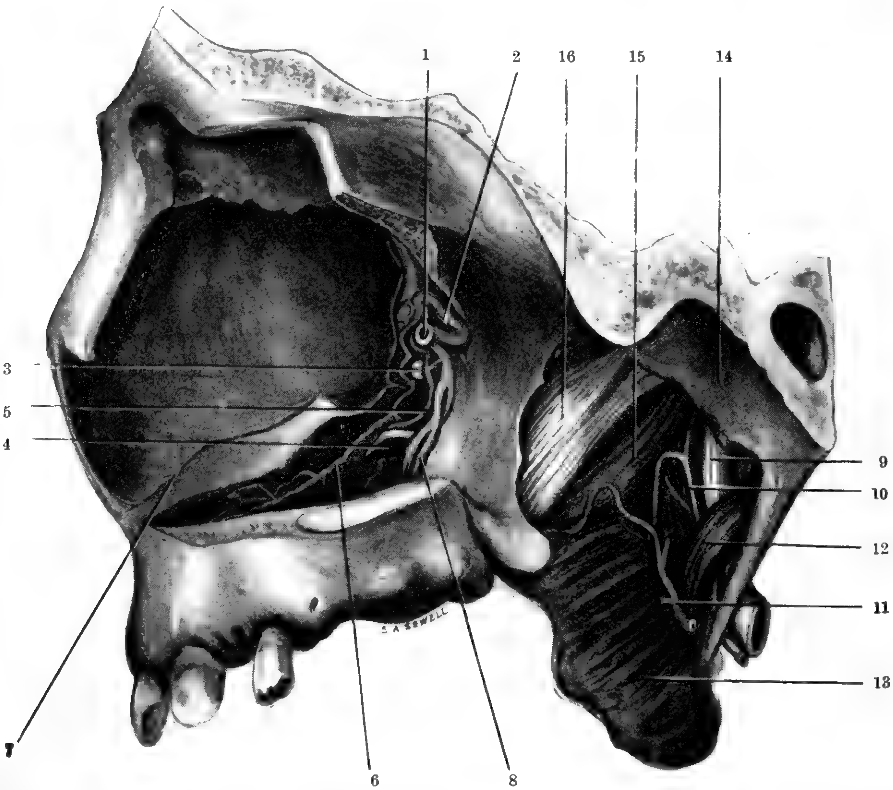

FIG. 5.—A dissection to show the arterial supply of the palate. The bones forming the outer wall of the left nasal fossa have been removed to show the course of the naso-palatine artery.

1, termination of internal maxillary artery; 2, spheno-palatine artery; 3, stump of middle turbinate; 4, stump of inferior turbinate; 5, lateral nasal branch, and 6, naso-palatine branch, of spheno-palatine artery; 7, cut edge of mucous membrane covering septum nasi; 8, descending palatine artery; 9, internal carotid artery; 10, ascending pharyngeal artery; 11, ascending palatine artery; 12, stylo-pharyngeus; 13, superior constrictor; 14, tympanic bone; 15, levator palati; 16, tensor palati.

(1) by pressing upon the inferior border of the tube so as to cause its lumen to open in a transverse direction; (2) by tilting the whole of the cartilaginous part of the tube, so as to bring it more into line with the bony portion.

The *palato-pharyngeus* is shown in figs. 2 and 3. The observations made agree with the published descriptions, except in two particulars: (1) the posterior lamina arises not only from the middle line of the soft palate, but also, at its most anterior part, from the dorsal aspect of the palatal aponeurosis, immediately in front of the levator palati; (2) the anterior lamina takes origin from the horizontal plate of the palate bone not directly, but by means of the palatal aponeurosis, to the posterior border of which the muscle is attached. It also arises, behind this, from the middle line of the palate.

Figs. 4 and 5 are taken from a dissection showing the arterial supply of the palate.

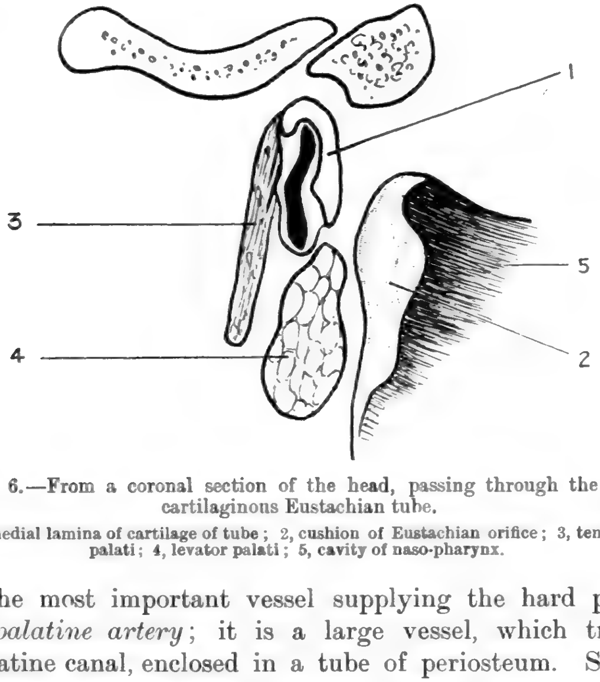

Fig. 6.—From a coronal section of the head, passing through the left cartilaginous Eustachian tube.

1, medial lamina of cartilage of tube; 2, cushion of Eustachian orifice; 3, tensor palati; 4, levator palati; 5, cavity of naso-pharynx.

By far the most important vessel supplying the hard palate is the *descending palatine artery*; it is a large vessel, which traverses the posterior palatine canal, enclosed in a tube of periosteum. Still lying in the periosteum, the artery takes a tortuous course forwards towards the anterior palatine canal, giving branches inwards to the hard palate, and outwards to the alveolar process and to the gum; the branches to the hard palate are tortuous, like the parent stem, and anastomose freely with one another, and less freely with those of the opposite side.

The accessory palatine branches, given off in the posterior palatine canal, pass through the accessory palatine foramina and turn backwards to anastomose with the ascending palatine arteries. The terminal branch of the descending palatine artery turns upwards through the anterior palatine canal, and, on the nasal septum, anastomoses with the *naso-palatine branch of the spheno-palatine artery.* Should the descending palatine artery be obstructed or divided, this anastomosis would not as a rule bring any large amount of blood to the hard palate, owing to the small size of the naso-palatine artery; the parent trunk of the latter, the spheno-palatine artery, is large as it arises from the internal maxillary, but is much diminished in size by giving off lateral nasal branches to the turbinate bones, so that only a small branch remains to carry blood to the palate.

It becomes of importance, therefore, in operating for cleft of the hard palate, to place the lateral incision (through which is introduced the elevator used to separate the muco-periosteal flap from the bone) as far externally as possible, in order to include the descending palatine artery in the flap, and thus to secure the vitality of the latter. The incision should be directed outwards against the alveolar process, rather than upwards against the palate, as otherwise the artery may suffer injury or its branches be divided.

Just as the descending palatine artery is of chief importance in the supply of the hard palate, the main artery to the soft palate, in the dissection shown, is the *ascending palatine* (branch of the facial). It is seen in figs. 4 and 5, arising from the facial artery, passing upwards superficial to the stylo-pharyngeus and superior constrictor, and then turning inwards above the upper border of the last-named muscle to reach the soft palate along with the levator palati. It is seen to give off the tonsillar artery, which reaches the tonsil by piercing the superior constrictor.

Summary.

1. The palatal aponeurosis is actually the expanded tendon of the tensor palati.

2. The levator palati has only a small origin from the petrous portion of the temporal bone, immediately anterior to the inferior aperture of the carotid canal.

3. The levator palati is the most powerful tensor of the soft palate.

4. Contraction of the tensor palati probably closes the Eustachian tube, while contraction of the levator palati probably opens it.

5. The dissections tend to show that the most important arteries of the palate are, to the soft palate, the ascending palatine branch of the facial; and to the hard palate, the descending palatine branch of the internal maxillary. The naso-palatine artery, as far as the blood supply of the palate is concerned, is small and relatively insignificant.

PARIETAL PERFORATION ACCOMPANIED WITH FLATTENING OF THE SKULL IN AN ANCIENT EGYPTIAN.

By DOUGLAS E. DERRY, M.B., Ch.B., *Lecturer in Physical Anthropology, University College, London.*

ALTHOUGH cases of perforation of the parietal bones have been recorded in this Journal and elsewhere on several occasions, the condition is sufficiently rare to justify the publication of the present example, especially as this case differs in certain important particulars from those already described.

The skull, a photograph of which is shown in fig. 1, was found by Mr R. Engelbach at Shurafa, Lower Egypt, in a cemetery of Roman date, which he was excavating for the British School of Archæology, and I am indebted to him for preserving it and bringing it to this country, and to Professor Flinders Petrie for his permission to publish this account.

The skull is in perfect condition, only a few teeth having dropped out since removal from the grave, and from its general characters is probably that of a young woman of about twenty-one years of age. All the cranial sutures are open, and the basilar synchondrosis is becoming ossified. In the mandible the wisdom teeth are fully erupted and level with the rest; and although in the maxilla they appear to be still not perfectly on a level with the other teeth, this is probably due to the natural upward curve of the posterior ends of the alveolar arch, as they are in perfect apposition with the lower third molars when the mandible is articulated. In this connexion it may be noted that the teeth appear to be practically unworn, a condition which, in an Egyptian of this age, is, in my experience, unparalleled. The possible significance of this will be referred to later on.

External Aspect.—Except for the condition now to be described the skull appears to be quite normal. In the *right* parietal bone, close to and involving the sagittal suture, and situated exactly opposite the obelion, or, in other words, near the site of the right parietal foramen, is a large hole, measuring 24 mm. in the diameter parallel to the sagittal suture and 26 mm. at the widest part of the hole, at right angles to the antero-posterior diameter. As may be seen from the photograph (fig. 2), the hole is irregularly circular, and is incomplete at its inner margin where it breaks into the sagittal suture. Its edges are perfectly smooth and bevelled externally, and about 8 mm. from the margin of the hole there is a faint suggestion of a bony elevation running concentrically round the opening. The bone here and over both parietals, especially near the middle line, is very finely pitted. This pitting is not visible below the temporal lines. Except for these manifestations there are no signs of inflammatory reaction. From the hole downwards as far as the superior angle of the occipital bone, and laterally involving the posterior-superior angles of both parietals, as well as an area adjacent to these angles, the skull is markedly flattened (fig. 1). The depression of the bone, exclusive of the hole itself, is greatest immediately below the opening and exactly over the posterior end of the

FIG. 1.—Profile view, showing flattening in posterior parietal region.

sagittal suture; but below the lambda the flattening has affected the right side of the skull more than the left, so that the left side of the occipital bone seems to bulge when compared with the corresponding part to the right. From this it would appear that there is an association between the perforation of the bone and the flattening.

On the left side the parietal foramen is represented by a minute hole. At the anterior superior angle of the left parietal bone, and passing across the coronal suture on to the frontal, is a shallow oval depression (19 × 8·5 mm.) with a roughened floor, perhaps the result of an injury.

Internal Aspect.—All the sutures are open internally. The sulcus for the superior longitudinal sinus, which anteriorly is placed exactly in the middle line over the sagittal suture, is at the site of the perforation deflected to the left, coming again into the middle line after passing the opening in the parietal bone. The inner margins of the parietal bones at the point where the hole touches the middle line are thin and translucent. There are two depressions on the inner table of the right parietal bone behind the perforation and between it and the lambdoid suture, in one of which the bone is translucent. This depression measures not less than 3 cm. in length and 1 cm. in breadth. It lies vertically, and is deeply excavated in its upper part, but becomes shallow as it approaches the lambdoid suture. These depressions do not affect the outer table. There is a similar elongated depression on the left parietal bone in the same situation, which reaches the left lambdoid suture. The bone here is also translucent. All of these de-

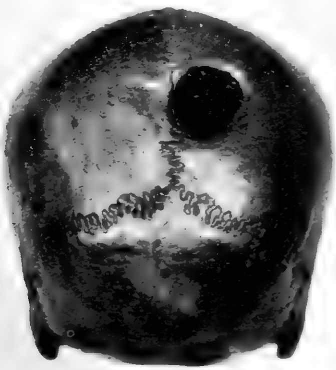

Fig. 2.—Posterior view, showing position and shape of the parietal perforation which just breaks into the sagittal suture.

pressions, as well as the great perforation itself, have large branches of the meningeal vessels running directly to them. The superior longitudinal sinus bifurcates below the lambda, the deeper and better marked of the two channels passing to the left. Just below the point of bifurcation there is a deep depression to the right of the middle line, perhaps associated with the occipital sinus. The *left* side of the occipital bone and the posterior part of the left parietal bone are translucent, but on the right side the density of the bone is greater and no light passes through in the corresponding positions.

It is necessary, before discussing the cause of this opening in the cranial wall, to eliminate the possibility of this being an ancient example of trephining, a practice which was not uncommon in neolithic times in Europe. Sir Victor Horsley, to whom I showed this skull, believed that this might be a case illustrating an old trephine wound. I had not entertained such a possibility, because the character of the opening is unlike those in neolithic skulls which have been generally attributed to surgical interference, as in the cases described and figured by M. Manouvrier (1). There is, however, some resemblance to the present instance in a case published by Manouvrier (*op. cit.*), which differs from others recorded by him in the absence of any signs of inflammatory reaction at the edges of the opening. There is also considerable thinning of the bone in the neighbourhood of the hole, which Manouvrier believes to have been caused by the removal of the periosteum by the prehistoric surgeon, or by some accident, for which subsequently the operation was performed.

An examination of old trephine wounds from cases operated upon at the National Hospital, which Dr F. E. Batten very kindly allowed me to see, shows that while extensive healing of the cut edges of the bone takes place, there is nothing in the nature of bevelling to be seen, while traces of the original inflammation are very obvious.

But from the Egyptian skull itself we can obtain the most important evidence against trephining; for the superior longitudinal sinus is, as already described, deflected to the left on reaching the opening in the right parietal bone. It skirts the margin of the hole, lying altogether, at this point, upon the left parietal, and only returns to the median line after passing the opening. Now, the position of the sinus is remarkably regular under normal circumstances. It does not slavishly follow the course of the sagittal suture, should the latter deviate from the middle line, as may be seen, for example, in a hydrocephalic skull preserved in the Anatomy Museum at University College, where the groove for the longitudinal sinus is absolutely central, while the sagittal suture takes a course obliquely across it. Such a displacement of the sinus groove as exists in the Egyptian skull can only have been brought about in early life, and must mean a pushing of the falx and with it the contained sinus to one side by something which occupied the site of this large foramen and encroached upon the middle line. Had this opening been made artificially, such a displacement would have been impossible, and it is more than likely that the sinus itself would have been opened, with probably fatal results, as in its normal median position it would have been well within the circumference of the opening. Further, the theory of trephining does not explain the flattening, unless, as Sir Victor Horsley suggests, the operation was performed on account of the deformity, which, to say the least of it, appears to me most improbable—if not, in the light of what has been said in regard to the position of the sinus, impossible. Lastly, no case of trephining has so far been recorded in any Egyptian skull, though probably more crania of this race have been examined and carefully studied than of any other people either ancient or modern.

The first case of a skull exhibiting perforation of the bones was described by Turner in 1865 (2). The skull-cap belonged to a woman aged twenty-five, who had been operated upon for the removal of a cyst of the scalp which had been present all her life, but had recently commenced to increase in size. Death took place from meningeal sepsis, and at the subsequent post-mortem examination it was found that there was an opening in the middle line of the occipital bone at the site of the cyst. There were also two further openings, one in the posterior part of each parietal bone, in the neighbourhood of the normal parietal foramina. The sagittal suture between these openings was obliterated, and the superior longitudinal sinus was deflected between the two apertures, to the right. All of the openings were closed by cribriform fibrous membranes. Turner considered the parietal openings to be exaggerated parietal foramina.

In the following year Wrany (3) described four skulls with large parietal foramina, but in only one of these were the openings of a large size, measuring respectively three-fifths and four-fifths of an inch in diameter. He believed that the large size of the opening was associated with an enlarged condition of the perforating branches of the meningeal arteries, and compared his cases with Turner's.

In 1870 Grüber (4) described two cases of the same enlarged condition of the parietal foramina, and again in 1876 (4) he published a further case of this anomaly and discussed possible causes. He appears to conclude that there is no relation between the production of the foramina and the meningeal vessels. The holes are due to a lack of ossification of the bone at this site, but the reason of such failure is obscure.

In 1892 Greig (5) published an interesting case of congenital and symmetrical perforation of both parietal bones in a soldier, then living. The openings were large, the right measuring $3{\cdot}6 \times 2{\cdot}7$ cm., the left $2{\cdot}5 \times 2{\cdot}3$ cm. Between the two unossified areas there was a narrow bridge of bone about 2 cm. wide in the course of the sagittal suture.

In 1895 Symmers (6) recorded a case of "enormous parietal foramina" in the skull of a man aged forty who died of acute pneumonia. In each parietal bone there was a large hole, the left 21×14 mm., with smooth rounded and distinctly bevelled margin; while the opening in the right bone presented the same characters but was smaller, 15×14 mm. "During life the dura mater was adherent through the foramina to the pericranium, forming a tough fibrous membrane, which effectually closed the openings." . . . "The father of this man had a similar abnormality."

In 1900 Paterson (7) published three cases of symmetrical perforations of the parietal bones, accompanied by excellent plates, which illustrate very clearly the position of the apertures and their relation to the normal parietal foramina. In some of the fœtuses which he examined similar deficiencies were present, but not in the exact situation of the parietal foramen. Paterson is inclined to associate these perforations with inequality of growth in the cranium and cerebrum, by which the latter has exerted pressure upon the ossifying bone and thus retarded its formation, and in support of this he draws attention to the microcephalic character of the cranium recorded in some of the cases, and believes that, in the case he describes, arrest of development of the base of the skull and closure of sutures may account for the existence of these great perforations.

Paterson's theory receives further support from a case published by Paul-Boncour (8). The skull-cap examined had belonged to an idiot, who was also blind and suffered from epileptic fits. Death took place at the age of thirty-three. There was complete synostosis of the skull, which was trigonocephalic owing to congenital closure of the metopic suture, and acrocephalic from the same early synostosis of both the coronal and sagittal sutures. There were symmetrical perforations at the site of the normal parietal foramina, measuring 13 mm. transversely and 5 mm. in the antero-posterior diameter.

Although, in the cases described by the observers just quoted, there are great differences in the size of the perforations and also in the accompanying conditions, they all agree in regard to the position of the apertures, which are invariably situated at or about the site of the normal parietal foramina—that is, close to the obelion; and this part of the sagittal suture is generally synostosed in association with such perforations, whatever the condition of the rest of that suture. It is generally recognised that the parietal foramina are the remains of the two clefts, one in the upper border of each parietal bone near its posterior end, which are normally present during ossification of the bone. These clefts, together with the intervening space in the line of the sagittal suture, form the sagittal fontanelle, which is usually closed before birth. At this point, according to Paul-Boncour (9), ossification takes place more slowly, and there is thus, in this part of the cranial wall, a predisposition towards perforation which may be taken advantage of by vascular, meningeal, or cerebral anomalies. That these perforations do occupy the site of the original fœtal clefts is borne out by their symmetry, the constancy of their position, and also by the fact that the long axis of the aperture is in almost every case transversely placed.

Although in some of the cases, Paterson's, Paul-Boncour's, and one of Wrany's, in which the child of three years and two months died of tubercular disease and hydrocephalus, there was deformity of the skull accompanying the perforations, this is by no means always so, for some of the best-marked instances are perfectly normal in cranial form.

Again, the somewhat natural assumption that such large apertures must have been produced by something protruding through the skull wall finds no support from those cases which have been seen with the soft parts *in situ.* Neither in Greig's case, in which the apertures had been recognised since childhood, nor in that reported by Symmers was there any sign of a cause for the perforations. But in Turner's case, although nothing apparently existed to explain the symmetrical parietal openings, there was a dermoid cyst definitely related to the hole in the occipital bone, which measured 2·5 cm. in vertical direction and 1·25 cm. transversely. It is difficult to believe that the presence of the parietal perforations in the same skull was merely a coincidence, and that in early life there had not been some similar cause at work which might account for these deficiencies. That dermoid cysts do cause lack of ossification in the underlying bone is well known. Mr Shattock has very kindly given me particulars of such a case in the museum at St Thomas's Hospital, in which in the skull of a child of eight months there is a membranous area in the middle line of the frontal bone immediately beneath a dermoid cyst. I know of another case in which a dermoid cyst was removed from the neighbourhood of the external angular process of the frontal bone. Here again an unossified area in the cranial wall was discovered by the surgeon, which prevented the complete removal of the cyst owing to its attachment to the subjacent membrane.

The question now is whether such a condition could satisfactorily explain the large hole in the Egyptian skull. It has been shown that large perforations may be present without any apparent cause, and we might consider the present case to be one of these. There are, however, two facts which differentiate the condition in this skull from all of the others recorded with which it may reasonably be compared. In the first place, the opening is unilateral. Now, in none of the crania with *large* parietal perforations is this the case. In three of Wrany's cases and two of Grüber's the perforations were quite small, evidently merely enlargements of the normal foramina, and in one or two of these only the foramen of one side was affected; but in all of the cases in which the openings are of large size they are symmetrically placed, one on either side of the sagittal suture, and there is generally a well-marked bar of bone between the two holes. In one of Paterson's cases the intervening bar is incomplete and the two apertures are thus united. Here, too, the longitudinal sinus deviated from the middle line and appeared to end in front of the left aperture.

The second point of difference in the Egyptian skull is the flattening below the aperture. It is difficult to avoid the conclusion that the parietal perforation and the accompanying deformity of the skull are causally related. When I first saw this skull I was inclined to the belief that a hernia of some sort must have been responsible for the opening and for the flattening below it. But cerebral meningocele, which seemed the most likely explanation, is, I believe, unknown in this situation.

There is, however, still a further condition exhibited by this skull which may bear strongly on the argument. It has already been said that the teeth are scarcely worn. For an Egyptian skull this is remarkable in a girl of at least twenty years of age. Two other skulls from the same cemetery and of similar age, *i.e.* below twenty-five years, both with excellent teeth, show nevertheless considerable wear, particularly, of course, of the first molars, which have been longest in use. This is not the case with the teeth of the perforated skull. The first molar is the only tooth which shows marked signs of wear, and these are comparatively small, consisting of slight facetting of the cusps where the opposing tooth has met them. The incisors are also slightly chiselled, as well as the canines, but the general appearance of the teeth suggests that the amount of mastication performed by the jaws was unusually small. But this is not all. The enamel of all the teeth, with the exception of the lower incisors (the upper central incisors have dropped out recently), is pitted and irregularly laid down (fig. 3). It is interesting to notice that the first molars are the least affected. Now, it is well known that interference with nutrition in early life, when the teeth are calcifying, tends to affect the structure of the teeth, and such interference produces the condition known as hypoplasia of the enamel. Mr Sidney Spokes (10), to whom I showed the teeth, considers that this is an instance of such a condition, though of an unusual form. From the fact that the first molar, which has commenced to calcify at birth, shows signs of this change, although to a slighter degree than the others, it is inferred that the factors responsible for this affection of the enamel had already commenced to operate even at this early date, and became progressively more effectual as time went on, for the third molars exhibit this change more clearly than any of the other teeth. Finally the lower incisors are thickly covered on the labial aspect with tartar, a condition which Mr Spokes considers was probably associated with mouth-breathing and a depressed lower lip. In this connexion it should be mentioned that the left middle turbinate bone is much swollen and reaches the middle line, pushing the septum to the right. Close to the anterior attachment of the turbinal is an opening into the left antrum.

Now, if we sum up all the evidence yielded by this skull, it seems clear that the unilateral character of the perforation in the parietal bone, accompanied by the deformity of the skull in the neighbourhood of that perforation, and more particularly on the same side as that upon which the hole is situated, differentiates this case from those quoted above in which the holes are always symmetrical and in which associated flattening of the bone is absent. At the same time, this very flattening, as well as the alteration in position of the sinus, points to the existence of the conditions responsible for these peculiarities, at a very early period of life, and this is further borne out by the changes in the enamel of the teeth, changes which could only have taken place while the enamel was being laid down, from the time of birth onwards. It is clear, therefore, that this hole in the

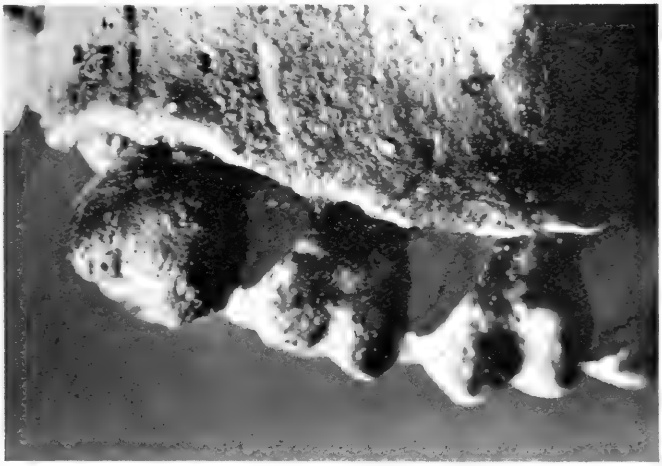

Fig. 3.—The right upper molar teeth of the perforated skull to show the condition of the enamel, particularly in the wisdom tooth.

parietal bone must be either of congenital origin or have been produced within the first few months after birth; and if it is, as I believe, related to the flattening, it seems necessary to suppose that something protruded from this aperture and depended in such a way as to flatten the bones upon which it lay, immediately beneath the foramen.

Cases of traumatic encephalhydrocele in children are well recognised. The injury to the cranial wall generally takes the form of an elongated slit, which enlarges very rapidly, and the edges are everted. Dr F. E. Batten very kindly showed me such a case, over four years after the accident, which was due to the baby being dropped and striking its head on a sharp projection. The wound in the skull is at the present time 10 cm. in length, and stretches right across the right parietal bone from the lambdoid suture towards the bregma. It was noted at the time of the accident that the injury did not involve the anterior fontanelle, and that it measured 4 inches in length, so that this diameter has not changed. The widest part of the aperture is at the posterior end of the parietal bone, and here pulsation is plainly visible. The edges of the wound are now thickened and rounded off. The mental condition of the child appears to be perfectly normal. In another case, for which I am also indebted to Dr Batten, a similar accident had occurred at about five months of age. The patient, who is now twenty-eight years old, is slightly hemiplegic, but is otherwise quite normal. At the age of nine, when she first came under Dr Batten's notice, there was marked visible pulsation over the wound, which is situated about the centre of the right parietal bone. To a large extent this has become covered in by new bone, and only a small area remains unossified. Here, again, the original injury was evidently of the nature of a split in the bone spreading from the site of the actual blow. In neither of these cases is there the least resemblance to the case under discussion either in position or in the form of the aperture. We may therefore exclude the possibility of injury, and are compelled to recognise that this large opening is congenital, but that its cause remains obscure.

It is, however, possible that such a cyst as that which caused the large opening in Turner's case was also responsible for this; and when all the facts of the present case, so far as we can ascertain them from an examination of the evidence afforded by this ancient skull, are read in the light of the following case described by Dr John W. Ogle (11), it seems not only possible but probable that the Egyptian girl suffered in a similar way and from the same cause.

Dr Ogle's case was that of a boy aged two and a half years, who had not been well for six months, and about twelve days before admission to the hospital had fallen from a chair. The next day it was observed that he squinted, and there was rolling of the eyes and some convulsive movements of the arms, while the neck was tetanically drawn to the left side. There was no insensibility or paralysis. General convulsions of the limbs and body came on before death. At the subsequent examination a cyst, which was contained in the dura mater lining the occiput, was discovered, which had projected into the brain. The cyst was 1½ inches in length and 1 inch in breadth, and corresponded to a depression in the occipital bone, which was very shallow at the lower part but deep in its upper portion, with abrupt margins. Its direction was vertical, and the lower part of the groove for the superior longitudinal sinus was considerably deflected to the left of the median line. The bone forming the hollow was remarkably thin, and at its upper part was pierced by a foramen which admitted a probe. It opened on the outer surface of the skull, having an oblique upward direction and being bevelled off at the upper margin. Except for this there was no want of union of the bony parts of the occiput. The cyst was formed in the dura nearest the bone and posterior to the sinuses terminating at the torcular. By means of the cyst the lower part of the superior longitudinal sinus and the torcular were pushed much to the left side. The termination of the right lateral sinus was also greatly pushed forwards. The cyst contained hair and sebaceous material, and a few of the hairs passed through the cyst wall to the foramen referred to above.

Now, allowing for differences of position, the conditions described on the inner surface of the occipital bone in the above case are very closely paralleled by the depressions described in the Egyptian skull on the inner surface of the parietal bones, and especially on the right side. Here we have the same thinning of the bone, in association with the depression, which is also, as in Dr Ogle's case, deep in its upper part and shallow below. The deviation of the sinus to which he twice refers has been emphasised in the Egyptian, although in the latter it is related to the aperture in the parietal bone, which is absent in Dr Ogle's case. By way of illustration, Dr Ogle showed at the same time a cyst projecting out into the scalp and obviously connected with intracranial structures.

There can be little doubt that such superficial dermoid cysts may be associated with similar cysts within the skull, and if this is granted, the conditions existing in the Egyptian skull admit of a reasonable explanation. In this case it may be supposed that a large cyst occupied the site of the aperture in the parietal bone, pushing the superior longitudinal sinus to the left, and that it was connected with smaller cysts within the skull which were the cause of the depressions in the cranial wall. The constant pressure of the cyst may account for the flattening of the bone below the aperture. In the light of Dr Ogle's case we may be permitted to suggest that this Egyptian girl from an early age suffered from the effects of cerebral pressure owing to the presence of the constantly growing cysts, and was thus mentally defective, a suggestion which receives support from the fact that the teeth have been scarcely used in mastication, and that they also exhibit definite traces of early and long-standing interference with nutrition. The girl died at about twenty-one years of age, at which time these cysts tend to enlarge more rapidly.

It is not suggested that all cases of parietal perforation are due to cysts, but the association of such perforations with another in the same skull directly due to a dermoid, as in Turner's case quoted above, is very significant, and may possibly explain their presence. It is noteworthy that in this same case Turner describes the superior longitudinal sinus as being deflected between the two parietal apertures, although there was at the time of death no apparent cause for the anatomical conditions.

I am greatly indebted to Mr Shattock for originally suggesting the possibility of dermoid cyst in this case; and to Dr F. E. Batten for the opportunity of seeing the two cases of traumatic perforation of the parietal bone which I have referred to in the paper. I also owe my thanks to Sir Victor Horsley, Mr Sidney Spokes, and Mr Percy Sargent, all of whom very kindly examined the skull and gave me their opinions upon it.

A list of measurements of the skull is appended to this paper.

MEASUREMENTS OF SKULL WITH LARGE PARIETAL PERFORATION.

Glab.-occip. length	170 mm.	Palate length	45·5 mm.
Ophryo-occip. „	169·5 „	„ breadth	36·5 „
Maximum breadth	131·5 „	Nose height	49·5 „
Frontal „	89·0 „	„ width	23·0 „
Basi. breg. height	131·5 „	Longitudinal arc	349·0 „
Auricular „	117·0 „	Frontal „	111·0 „
Bizygomatic breadth	114·0 „	Parietal „	134·5 „
Bimalar „	95·5 „	Occipital „	103·5 „
Upper facial height	64·0 „	Transverse „	290·0 „
Total „ „	107·5 „	„ „ R.	145·5 „
Basi-nasal length	95·0 „	„ „ L.	144·5 „
Basi-alveolar „	95·0 „	Circumference	487·0 „
Profile angle	80·5°	Foramen magnum, L.	37·0 „
Orbital width, R.	37·5 mm.	„ „ B.	32·5 „
„ „ L.	38·0 „	Capacity (cranial)—	
„ height, R.	33·0 „	by mustard seed	1250 c.c.
„ „ L.	33·0 „	by Pearson's formula	1277·8 „
Interorbital (interdacryal)	18·5 „		

Mandible.

Bicondylar breadth	106·5 mm.	Breadth of ramus (max.), L.	41·0 mm.
Bigonial „	87·5 „	„ „ (min.), R.	31·0 „
Height of symphysis	29·5 „	„ „ „ L.	33·0 „
„ ramus, R.	56·0 „	Mandibular angle, R.	122·5°
„ „ L.	54·5 „	„ „ L.	118·5°
Breadth of ramus (max.), R.	40·0 „		

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A NEW MYLOMETER. By DOUGLAS E. DERRY, M.B., *Lecturer in Physical Anthropology, University College, London.*

IN the Report of the Commission appointed by the Thirteenth International Congress of Prehistoric Anthropology and Archæology for the Unification of Craniometric and Cephalometric Measurements, translated by Dr W. L. H. Duckworth (Cambridge University Press, 1913), the following directions are given for measuring the length of the ascending ramus of the mandible (page 13):—

"Anatomical Landmarks:—

"1. Above: superior border of the condyle.

"2. Below: the *gonion*: but since this point is often very difficult to determine, it is recommended to take the point of intersection of the lines representing the lower and posterior surfaces respectively, prolonged till they cut each other. The measurement may be made conveniently by placing the mandible on a plane surface, and placing the bar of the callipers in contact with the posterior border of the ascending ramus."

In actual practice it was found impossible to take the measurement with the callipers as described, accurately.

For this reason the instrument illustrated was devised in consultation with Professor Thane, who suggested the employment of a millimetre scale with a sliding arm, which was to be fixed on a hinged board similar to Broca's mandibular goniometer. This was made experimentally, and proved quite satisfactory. The addition of the protractor attached to the upright board at the back, for measuring the mandibular angle, we owe to Professor Karl Pearson, who by a coincidence was engaged at the same time in constructing a mandibular goniometer.

As both sides of a mandible are seldom if ever symmetrical, it is necessary to measure each ramus independently. For this purpose both the fixed and the movable boards are provided with millimetre scales. In the illustration the mandible is in position for the measurement of the length of the *left* ramus. The line representing the lower border of the body of the jaw is given by the surface upon which the mandible is resting, and this meets the line corresponding to the surface of the hinged board, with which the posterior border of the ramus is in contact, exactly at the centre of the hinge, which at this point is cut down level with the surface of the board, to accommodate the angle of the bone. A T-square sliding against the edge of the board is brought down upon the condyle, and the length of the ramus from "the point of intersection of the lines representing the lower and posterior surfaces respectively," to the top of the condyle, can be accurately read off. The mandibular angle is read on the protractor without moving the bone. To measure the *right* side, the bone is turned over and made to rest with its right ramus on the fixed board and its body on the hinged board, the latter being readjusted as necessary. We owe the idea of the second scale for measuring the right side also to Professor Karl Pearson.

FIG. 1.—Mylometer, with mandible in position, for measuring the length of the *left* ramus, and the angle which it forms with the body of the bone.

Some difficulty was experienced at first in fixing the movable board in the required position during the taking of the measurements. This was solved in a simple and efficient way by the introduction of a clamping-nut, which is attached to the movable board and passes to the back through a slot in the upright board. Thus while the left hand holds the bone in position, the right holding the clamping-nut brings the hinged board into exact contact with the posterior border of the ramus, and by a turn of the screw fixes it in that position. This device is due to the laboratory assistant, G. J. Hancock, who also made the instrument.

Lastly, the eminently suitable name of mylometer, which we have applied to this instrument, was suggested by Professor Thane, whose ideas, coupled with those of Professor Karl Pearson, are responsible for its success.

THE GENESIS OF JACKSON'S MEMBRANE: NOTES ON THE GENITO-MESENTERIC FOLD OF PERITONEUM AND THE SUPRA-ADHESION FORAMEN.

By DOUGLAS G. REID, M.B., Ch.B. Edin., M.A. Trin. Coll. Camb., *Anatomical Department, University of Cambridge.*

(*a*) JACKSON'S MEMBRANE.

WHILST supervising the dissection of an adult I observed a strong membrane (see fig. 1) lying in front of the ascending colon. The cæcum lay in its normal position and was free from adhesions except at the upper part of its posterior wall, where it was fixed to the parietal peritoneum of the iliac fossa. Here it covered the short appendix (3·5 cm. long), which was almost completely buried in the adhesions. The terminal portion of the ileum was also "free."[1]

The transverse colon, in the first part of its course, was bound directly to the ascending colon, in the last 5 cm. of its course, by the great omentum as it passed to the right lateral abdominal wall to form a "right colic ligament."

The connexion was rendered still more secure by adhesions binding the transverse colon directly to the anterior surface of this part of the ascending colon. In this way a permanently acute kink of the bowel was produced at the hepatic flexure. Immediately below this adhesion the transverse colon became horizontal in direction; and so closely were the two portions of the colon bound together that at first there appeared to be an abnormal cæcum-like outgrowth of the bowel.[2]

Crossing in front of the ascending colon and covering the whole of its anterior surface, with the exception of the part which was bound to the transverse colon, was a strong opaque membrane, coated by endothelium. It contained a considerable amount of fat, distributed uniformly throughout, and many blood-vessels, which coursed parallel to one another and at

[1] Apart from its mesentery the terminal part of the ileum may be connected to the abdominal wall by (1) the genito-mesenteric fold of peritoneum; (2) the bloodless fold of Treves; (3) adhesions which bind the ileum directly to the parietal peritoneum (in 50 per cent. of adults).

[2] For skiagrams showing conditions resembling this, see Pilcher's paper, "Surgical Aspects of Membranous Pericolitis," *Annals of Surgery*, January 1912, vol. lv. p. 1.

right angles to the long axis of the bowel. They were visible macroscopically; and the arteries, ultimate branches of the right colic and ileo-colic vessels, crossed the bowel to reach the lateral parietal peritoneum. They gave rise to a transversely striated appearance, seen to some extent in the photograph (see fig. 1). The membrane completely obscured the anterior tænia coli of the ascending colon.

It passed directly from the colon to the lateral abdominal wall without giving rise to any peritoneal fold. Below it faded away upon the cæcum.

Fig. 1.—Case I. Jackson's membrane in an adult, ♂. A knife has been passed between the membrane and the ascending colon, and its blade rests upon the cæcum (also indicated by a hook). A hook has been stuck into the terminal part of the ileum, and another holds forwards the upper part of the membrane which was dissected up from the bowel.

Here it formed a number of strands passing downwards and to the right from the ileo-cæcal junction. It did not pass from the cæcum to the parietal peritoneum, and did not end below in a free edge.

It was a Jackson's membrane.

Above it was continuous with the right colic ligament. It did not bound a pre-colic fossa such as I have described (*Journal of Anatomy and Physiology*, vol. xlvi. p. 401); but the handle of a knife could easily be passed between the membrane and the connective element of the peritoneal coat of the bowel.

As pointed out by Eastman (*Surgery, Gynecology, and Obstetrics*, April 1913), "this would hardly be the case were it a product of membranous pericolitis alone, as suggested by Jackson, or of mechanical irritation alone, as indicated by Martin."

Jackson also draws special attention to its "apparently distinctly detachable nature."

This is illustrated by the fact that before I secured the photograph the dissectors, who were unconscious of the existence of the membrane, had dissected a part of it up from the bowel (see fig. 1).

The ascending colon was not kinked in any way, but was constricted to a remarkable degree, and flattened from before backwards. At its narrowest part it measured 32 mm. from border to border. Above it expanded quite abruptly; and the part which was bound to the transverse colon, as well as the transverse colon itself, had a width of 5 cm.

Traced downwards, the colon, after retaining a uniform diameter for some distance, gradually widened, and the cæcum was 7 cm. broad.

The colic constriction was obviously due to the membrane.

Pieces of bowel between two tæniæ coli were examined microscopically.

The muscular coat of the cæcum was normal in thickness, and all its coats were healthy. The longitudinal and circular layers of the muscular coat[1] of the ascending colon were both much thicker than usual, and on an average were four times as thick as those of the transverse colon.

The connective tissue of the membrane did not "seem to penetrate in increased amount between the muscle bundles" (Hall).

The walls of some of the arteries in the submucous coat were rather thicker, and some of the veins rather larger than normal.[2]

It will be seen that my description differs in some points from that of a membrane given by Hall in Jackson's article, "Membranous Pericolitis" (*Surgery, Gynecology, and Obstetrics*, September 1909).

The fact remains that a sheet was present such as Jackson was the first to point out might become of considerable clinical interest.

It is noteworthy that there was an acute kink of the bowel at the hepatic flexure; and the cæcum lay in its normal position and was neither hypertrophied nor dilated.[3]

[1] It is a mistake to think, as some still seem to do, that in man there is no longitudinal muscular layer between the tæniæ coli.

[2] The body was that of a man aged (?) who died partly as the result of a compound fracture got whilst in a state of alcoholic intoxication.

[3] Compare this with some of the remarks made by Gray and Anderson, University Press, Aberdeen, 1912. It is noteworthy that in none of the adults in which I found a well-marked Jackson's membrane was there "prolapse" of the cæcum such as some say is common; and in none were there angulations of the ascending colon such as are sometimes

The Genesis of Jackson's Membrane.

If we include Case II. (see fig. 2), a well-marked membrane was present in front of the ascending colon in three out of six adults (50 per cent.) whose abdomens were dissected at Cambridge this term (Lent, 1914). In two out of twenty fœtuses I found the parieto-colic fold of Jonnesco formed by a large appendix epiploica. In one it arose from the front of the ascending colon; in the other it crossed in front of the bowel, bounded a pre-colic fossa, and contained arteries, visible macroscopically, which crossed

Fig. 2.—Case II. Adult male. The fold of peritoneum referred to has been lifted up from the colon. The upper and lower parts of this appendix epiploica are not shown. It really extends downwards as far as the knife.

the colon, at right angles to its long axis, to reach the lateral parietal peritoneum. A Jackson's membrane is really nothing but a parieto-colic fold of Jonnesco in cases in which this forms an investment for a definite part of the ascending colon.[1]

found in association with the membrane (Jackson). "Recently I have operated on a great many cases of dilated and prolapsed cæca associated with a Jackson's membrane" (H. J. Stiles, personal communication).

[1] Eastman first drew attention to my pre-colic folds in relation to Jackson's "membranous pericolitis" about which I was ignorant at the time my papers were published.

In another adult male I found a fold of peritoneum (see fig. 2), 12 cm. long, and attaining a height of 3·8 cm., lying in front of the ascending colon. Its posterior surface and right border were quite free from any union with the bowel. It contained fat, distributed uniformly throughout, and blood-vessels. It was a large appendix epiploica. It extended from a point just above and internal to the ileo-cæcal junction upwards to the hepatic flexure, and had no connexion whatsoever with the right colic ligament. Below, it arose from the parietal peritoneum (formerly ascending mesocolon) immediately to the left of the colon. Above, it was attached for a distance of 5 cm. to the colon to the left of the anterior tænia coli. Just before passing on to the colon it gained some attachment to the duodenum, which in the descending part of its course was closely bound, as is not uncommon, to the left side of the ascending colon. It covered a number of smaller appendices epiploicæ.

The blood-vessels in this fold were visible macroscopically and lay parallel to one another and at right angles to the long axis of the bowel. The arteries were ultimate branches of right colic and ileo-colic vessels.

I have no doubt as to how the Jackson's membrane in Case I. (see fig. 1) arose. Had the fold in Case II. become fused down to the bowel (and apparently this had occurred to a slight extent over the upper and inner part of the ascending colon), and adherent at its free border to the parietal peritoneum, as in the two fœtuses referred to, a membrane, similar in every respect, would have been produced;[1] and the smaller appendices epiploicæ buried beneath it would have given rise to special "spots and tags of fat" (Hall).

I am not inclined to lay any stress upon the continuity of the membrane in Case I. with the right colic ligament.

In the fœtus the great omentum may adhere to the ascending colon and cæcum (completely descended), and may pass from these to the parietal peritoneum, coating the right surface of the genito-mesenteric fold, and carrying on to it blood and lymph-vessels (*Journal of Anatomy and Physiology*, January 1911).

In two adults I have seen a quite extensive pre-colic membrane formed by the laminæ of the great omentum which had fused together (as may

[1] Although the main blood-vessels in these appendices epiploicæ lay at right angles to the long axis of the bowel, it is possible, should an appendix epiploica adhere to the abdominal wall before the cæcum had completed its descent, that the blood-vessels in it might become oblique. They might then extend from "the inner lower portion of the gut" to its "outer upper peritoneal attachment" (Hall). In cases where the membrane is formed by the great omentum, the blood-vessels in it tend to take a distinctly descending course.

occur extensively in fœtuses from five to nine months old) and become adherent to the ascending colon from which they passed to the right lateral abdominal wall. In both the cæcum was in its normal position. In one the right part of the transverse colon was closely bound to the upper part of the ascending colon simply by this membrane.[1]

In several adults I have noted bands of variable width lying across the front of the ascending colon. These, doubtless, were formed by appendices epiploicæ which had become adherent to the bowel and to the parietal peritoneum.[2]

(*b*) The Genito-Mesenteric Fold of Peritoneum.

This fold was present in seven out of ten (70 per cent. of) full-time fœtuses recently examined by me.

It must be fairly common in children.[3]

In fœtus No. I. (a full-time male) there was a very interesting fold (see figs. 3 and 4).[4] Its mesenteric border (3 cm. long) was related, as normally, to the ileac branch of the ileo-colic artery. Its posterior (parietal) border descended, for a distance of 3 cm., upon the right spermatic vessels. At a

[1] Jackson (*Surgery, Gynecology, and Obstetrics*, 1909) notes that "in some instances it appears as though the membrane came on to the colon from the lateral parietal wall just above the cæcum, and courses directly upwards to disappear beneath the liver on the superior layer of the transverse mesocolon." The transverse colon may also be "drawn down" to the ascending colon by the "membrane."

[2] In some cases a membrane which invests the cæcum, appendix, or indeed the ascending colon, may be formed in other ways. Should the bloodless fold of Treves adhere to the abdominal wall, or should some other adhesion be formed between the bowel and the parietal peritoneum, it is possible that during cæcal descent and torsion, the bowel may gain an unusual peritoneal investment. Eastman has indicated this especially in relation to Treves's fold. In this connexion he gives another interpretation of C. H. Mayo's view regarding the congenital origin of Jackson's membrane. These are the various ways in which such a membrane may be formed apart from pathological causes. I have an interesting specimen showing the genito-mesenteric fold forming a partial investment for the ascending colon.

By the term "adhesion" I mean a union which was not different from those which occur elsewhere during the fusions together of peritoneal sheets in the fœtus. Moreover, I have shown that there is no "general shifting of the endothelial layers in such a manner that what was once free peritoneal surface remains free"; and have demonstrated the mechanical causes which operate in producing adhesions in different situations.

[3] In children "numerous instances of acute and chronic salpingitis, sometimes accompanied with ovaritis and pelvic peritonitis, have been recorded" (Kelly, *Operative Gynecology*, 1906, vol. ii. p. 566).

"Appendicitis occurs so frequently that it should be formally designated as a disease of childhood (Sonnenberg, Karewski, Selter)" (Pfaundler and Schlossmann, *The Diseases of Children*, vol. iii.).

[4] For other photographs of the genito-mesenteric and other folds of peritoneum, etc., see my paper in the *Proceedings of the Royal Society of Medicine*, February 1914, and Professor Eastman's paper, "Fœtal Peritoneal Folds" (*Journal of the American Medical Association*, 30th August 1913).

point 2 cm. from the internal abdominal ring (annulus inguinalis abdominalis) it deviated from this line and passed horizontally outwards for 1·2 cm. The fold thus formed a shelf (I have seen it forming a deep pocket), slightly concave upwards, upon which the appendix rested at the lowest point of its acute curve convex downwards (see fig. 3).

There was no doubt that this alteration in the line of attachment was brought about through the pressure which had been exerted upon the left

Fig. 3.—Full-time fœtus No. I. The specimen is viewed from the right side. An opening (above which lies the ileo-cæcal orifice) has been made into the cæcum. The ileum is simply steadied by the hook, and the natural form of the loop is in no way distorted (*cf.* fig. 4). Note the large loop of pelvic colon to the left of the genito-mesenteric fold.

surface of the fold by the large intra-abdominal meconium-distended pelvic colon.

I have now noted, in a number of fœtuses, that the pelvic colon may obliterate in this way part of the genito-mesenteric fold, and thus interrupt a track by which inflammation may spread from the bowel to the ovary and Fallopian tube, or in the opposite direction. The appendix at first descended for a distance of nearly 2 cm.; and in this part of its course skirted the posterior border of the genito-mesenteric fold, and adhered firmly to the posterior abdominal wall, as did the cæcum higher up.

Below, where it became bent upon itself to form an acute flexure, it was bound directly to the right surface of the fold.

The ileum, as traced from the ileo-cæcal junction, also descended for 2 cm. and then ascended for the same distance. It thus formed a loop (see fig. 3). This was firmly bound, *throughout its entire extent*, to the right surface of the genito-mesenteric fold.

FIG. 4.—Another view of the genito-mesenteric fold in full-time fœtus No. I. Whilst this photograph was being taken, a slight traction, in an outward direction, was exerted upon the ascending limb of the loop of ileum (indicated by the thread and the strip of white paper). The exact position of the posterior (parietal) border of the fold is indicated by the end of another strip of paper.

Not only this, the mesentery of the loop also adhered to the right side of the fold, as did the whole of the meso-appendix. Therefore the appendix was connected to the terminal part of the ileum not only by the bloodless fold of Treves, also fused down, but by the meso-appendix and genito-mesenteric fold. Its lymph-vessels were thus thrown into immediate connexion with those of the ileum and genito-mesenteric fold—a connexion which is not uncommon, however, as the ileum quite frequently adheres to the fold and is then often connected with the meso-appendix, over which the ileum also frequently fuses down to the abdominal wall.

I have pointed out (*Proceedings of the Royal Society of Medicine*, February 1914) that it is necessary to distinguish between flexures of the terminal part of the ileum which are permanent and those which have no real claim to be regarded as other than temporary, and also (*Journal of Anatomy and Physiology*, 1909–13) that the ileum, appendix, cæcum, etc., may adhere to the genito-mesenteric fold. But fœtus I. (see figs. 3 and 4) was especially interesting in that the ileum and appendix *both* adhered to the fold *and formed flexures which were rendered permanent* in this remarkable manner. In another full-time fœtus there was an almost exactly similar condition.

In several fœtuses I have observed that the appendix may lie completely below the cæcum; and when retained in this position by a genito-mesenteric fold, it is noteworthy that it may become retro-colic if the cæcum is able to complete its descent.[1]

In two full-time fœtuses the appendix, besides adhering to the right surface of the genito-mesenteric sheet, was bent backwards over its sharp free edge to come into contact with the left surface of the fold. The appendix and its mesentery may be acutely kinked in this way; and if kept thus for any length of time, or should the kink become permanent, inflammation, or even strangulation, may follow upon interference with the blood supply. I have pointed out that the genito-mesenteric fold may in some cases determine strangulation of the ileum.

In fœtus II. (see fig. 5) the genito-mesenteric fold passed downwards from the mesentery, and ileac branch of the ileo-colic artery, to the Fallopian tube and ovary. Lying in the fold, some in its central part, others close to its mesenteric border, were a number of small lymph-nodes —an important point. It contained many blood-vessels, especially veins —some of these could be traced to the ovarian vein. Apart from these vessels, no muscular fibres were present in the part removed for microscopic examination.[2] The meso-appendix adhered to the right side of the fold (to a much greater extent than would appear from the photograph).

This important connexion is very common. Indeed, when there are no adhesions binding the ileum, meso-appendix, etc., to the abdominal wall, the two folds are rarely seen completely separate from one another.

The ileo-appendicular fold of Jonnesco ("bloodless" fold of Treves) was

[1] For photographs showing variations in the position and relations of the appendix at different stages of cæcal torsion, see my paper in the *Proceedings of the Royal Society of Medicine*, February 1914. Such variations must of course be interesting to the surgeon.

[2] It might be well to make further microscopic examinations of folds in fœtuses at various ages.

quite distinct from the genito-mesenteric fold, with which it should not be confused (see fig. 5).

The genito-mesenteric fold may remain well marked in the adult; but even if obliterated, through fusion with adjacent peritoneum, it must "leave behind," in the form of adhesions, many permanent results of its presence.

A remnant of the fold was present this term (Lent, 1914) in two out of six adults (33 per cent.).

In both it was attached to the peritoneum over the external iliac artery.

Fig. 5.—Full-time fœtus No. II., ♀. The genito-mesenteric fold is viewed from the right side. One strip of white paper crosses the appendix, and the others indicate the posterior border of the fold and the upper end of the Fallopian tube. Note the ileo-appendicular fold of Jonnesco ("bloodless" fold of Treves).

In one it passed from the terminal part of the ileum, at the lower limit of the adhesions (present in 50 per cent. of adults), binding this to the peritoneum of the iliac fossa. These adhesions were absent in the other case, the fold passed from the mesentery, and the meso-appendix adhered to its right surface. The root of the mesentery formed an angle the vertex of which lay at the genito-mesenteric fold, and considerably below and to the left of the ileo-colic artery (which primitively lies along the line of the root). The root descended, much more vertically than usual, to reach the fold. It then passed to the right and slightly downwards to a normally placed cæcum. Obviously *the genito-mesenteric fold had caused an abnormal displacement of the root of the mesentery downwards and to the left.*[1]

In accounting for the adhesions in the ileo-cæcal region, not only the genito-mesenteric fold, but the large intra-abdominal pelvic colon, so often seen in the fœtus, and the relatively unyielding posterior and right lateral abdominal walls must be kept in mind.

Thus, confined between the abdominal wall and the genito-mesenteric fold, and rendered relatively immobile through the anchoring of the mesentery and connexion with the large intestine, the terminal part of the ileum, as well as the mesentery on each side of the fold, may readily become adherent to adjoining peritoneum against which it is pressed.

The pressure exerted by the pelvic colon is important in determining adhesions.[2] Special attention is directed to this mechanical cause of peritoneal adhesions. The cæcum and appendix may be bound directly to the abdominal wall or, in the case of the appendix, to the under surface of the mesentery, as a result of this pressure. This gives us an explanation, apart from pathological causes, of the direct adhesion, sometimes seen in adults, of the appendix and meso-appendix, to the left (under) surface of the mesentery. The whole appendix may become "sessile" in this way and may be kinked acutely and permanently. Adhesions involving the pelvic mesocolon itself may thus be produced (see the *Journal of Anatomy and Physiology*, 1911, vol. xlv.).

I have now shown that we are further justified in believing that the genito-mesenteric fold must be of interest to the surgeon and gynecologist, not only as a track by which infection or inflammation may spread, but in relation to the formation of adhesions—adhesions which may act as ready-made barriers resisting the spread of inflammation, adhesions which the surgeon may encounter, and should carefully deal with, in operations in the ileo-cæcal region.

(*c*) The Supra-Adhesion Foramen.

I have already published figures and a photograph of this foramen (see the *Journal of Anatomy and Physiology*, July 1911 and 1912, April 1913, and the *Proceedings of the Royal Society of Medicine*, February 1914) as

[1] In association with the fold in the fœtus, whilst the cæcum still lies high up in the abdomen, I have shown that the root of the mesentery may acquire the direction it normally has in the adult.

[2] It is noteworthy that if in the fœtus a large unyielding meconium-distended pelvic colon remain with its summit at the level of the duodenum, the mesentery may fuse down over this part of the colon. I have noted this in several adults. I have a photograph showing some remarkable effects of the pressure exerted upon adjacent parts by the pelvic colon.

Fig. 6.—The supra-adhesion foramen in an adult, ♀. The liver has been pulled upwards and the gastro-hepatic omentum reflected downwards. The handle of the knife rests upon the stomach at its pyloric end, and the blade lies in the foramen. Photo by Mr Walter J. Calcott, Anatomical Museums, Cambridge.

Fig. 7.—The supra-adhesion foramen in a fœtus (♂) 19 cm. long. A large portion of the liver, and the left part of the great omentum have been removed and the greater curvature of the stomach has been pulled upwards into contact with the heart. Note how the transverse mesocolon passes from the stomach below the small foramen. Behind the foramen the "deep gastric ligament" is seen. Photo by Mr W. J. Calcott

seen in fœtuses. Fig. 6 shows the foramen as I have frequently seen it in adults.

The coronary vein lay at some distance from the free margin of the coronary (left gastric) portion of the septum bursarum omentalium (deep gastric ligament of Jonnesco, plica gastro-pancreatica).

Primitively it lies along this border. Fig. 7 shows how the foramen is determined, viz. by adhesions (appearing relatively late in intra-uterine life) which bind the postero-inferior surface of the stomach to the transverse mesocolon. These and other adhesions must be of importance both in anatomy and surgery in helping to fix and support the viscera.

THE ANATOMY OF THE HEAD END OF A 20-MM. HUMAN EMBRYO.

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THE embryo here described is in the collection of the University of Edinburgh. It was removed by operation and was fixed in a 5 per cent. aqueous solution of formaldehyde. After fixation the vertex-breech measurement was 20 mm. There are no data as to its age, but, judging from its length and general development, it may be placed at approximately a little over seven weeks. The specimen was stained in bulk with acid hæmalum and eosin, and cut in serial transverse sections of 10μ. A series of models of the head region, at a magnification of 50 diameters, was reconstructed by the wax-plate method. It is upon these models that the following description is based.

The general characteristics of the embryo are very similar to those of others of about the same age, of which records have been published and which are figured in Keibel's *Normentafeln* (1). The cervical flexure is still so well marked that the chin almost touches the chest wall. The outlines of the brain can be easily distinguished through the superficial tissues (fig. 1). The head in the region of the hind-brain is somewhat wrinkled, but its outline presents a fairly uniform curve, while in Meyer's 18·5-mm. embryo (1) the hind-brain forms a distinct projection. The external acoustic meatus is represented by a deep oval pit. Its edges are raised and thickened, but there are no longer any distinct tubercles. It is similar to embryos of 18 and 18·5 mm. in the *Normentafeln*, while in embryos of 20 and 22·5 mm. the cavity of the meatus is much diminished. The forehead is a large rounded prominence, separated from the nose by a deep transverse fronto-nasal groove, which is prolonged laterally into the upper eyelids. The eyelids are still widely separated. They are better defined than appears to be the case with some other embryos of comparatively similar age, for they are thick raised folds surrounding the eye. The other eyelid is groved by the lateral continuation of the fronto-nasal groove, which divides it into three segments, viz. a small triangular part at the medial commissure (fig. 1, A), a larger intermediate part (B), and a lateral part (C), which becomes continuous with the lower lid at the lateral commissure. The lower lid is smooth, and blends with the cheek and the upper lip at the angle of the mouth, and is continuous medially with the root of the nose. The nose is broad and upturned. The nares are widely separated and directed forwards (fig. 2). Their openings are small and partly occluded by plugs of epithelium. They are bounded laterally by thick alæ nasi. The mouth is open, exposing the tip of the tongue. The upper lip has a shallow median notch. The lower lip is a smooth rounded shelf, with no trace of its bilateral origin. There is a distinct double chin, which is seen also in an embryo figured by His (2).

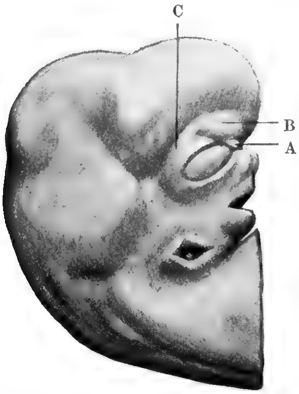

Fig. 1.—Profile view of the embryo showing general form.

Fig. 2.—Front view of embryo.

Nervous System.

Brain.—The three flexures of the brain are still well marked, the cephalic flexure forming the most acute angle of the three.

Primitive Forebrain and its Divisions.—The primitive forebrain is distinctly separated into telencephalic and diencephalic portions. The telencephalon has divided into two cerebral hemispheres, and each hemisphere, which is ovoid in form, has grown ventrally (forwards) beyond the lamina terminalis and dorsally (backwards) over the antero-superior portion of the diencephalon (fig. 3). The olfactory bulb on the ventral surface of the hemisphere is distinctly defined, and is limited medially and posteriorly by a sulcus. In sections it is seen to be definitely connected with the olfactory epithelium by nerve fibres. The eye stalk on each side is attached to the end of the forebrain, about half-way between the olfactory bulb and the hypophysis. It is very slender, and shows no trace of its originally hollow character. The eye stalk of Keibel's 18-mm. embryo (1) also is solid, but that of Meyer's 18·5-mm. embryo is still to a great extent pervious. There is as yet no chiasma. The hypophysis is situated at the ventral corner of the forebrain and is flattened dorso-ventrally. The buccal lobe is crescentic in form and partly surrounds the smaller infundibular lobe. It is hollow and still connected with the mouth by a thin cord of cells.

The lateral wall of the third ventricle is distinctly separated by a hypothalamic sulcus into a dorsal thalamic and a ventral hypothalamic region. The hypothalamic sulcus pursues a curved course from the interventricular foramen round the thalamus, and is continuous with a furrow which traverses the entire length of the mid-brain. The optic recess bounds the hypothalamus anteriorly, and intervenes between it and the corpus striatum. The corpus striatum, again, is separated from the thalamus by the anterior part of the hypothalamic sulcus, and is prolonged laterally

FIG. 3.—Lateral surface of model of brain and cranial nerves.

through the interventricular foramen of Monro to form part of the floor of the lateral ventricle. The interventricular foramen is a wide opening, through which one can see a large choroid plexus in the lateral ventricle. The hypothalamus is separated by a shallow sulcus into an anterior and a posterior portion. The anterior portion lies just dorsal to the hypophyseal recess, while the posterior part becomes continuous with the floor of the mid-brain. The posterior part of the floor of the diencephalon forms a projection outwards, representing the mammillary protuberance. The thalamus is crossed by a ridge which separates it into dorsal and ventral portions. The posterior or caudal end of this ridge is lost on the lateral wall of the ventricle on a level with a recess in the roof, which probably represents the pineal recess. The anterior end of this ridge is joined by a prominent fold attached to the roof of the diencephalon. Its anterior end blends with the thalamus, and its surface is continuous through the interventricular foramen with the choroid plexus of the lateral ventricle. This fold is seen in several of His's specimens (3), and is most probably the commencement of the choroid plexus of the third ventricle, since, according to Elliot Smith (4), that structure is developed from the roof of the fore-brain. This choroid ridge extends posteriorly along the roof of the forebrain to a point opposite to where the floor becomes invaginated just posterior to the mammillary eminence. Immediately caudal to its posterior extremity the roof is thickened, and in this thickened portion of its wall are two recesses, which may represent the pineal and prepineal recesses. The anterior commissure is represented by a thickening of the lamina terminalis about its middle.

Mid-brain.—The mid-brain or mesencephalon is tubular and curves on itself to join the isthmus. Viewed from the lateral aspect it is some-what indistinctly separated into a lamina quadrigemina and a peduncular

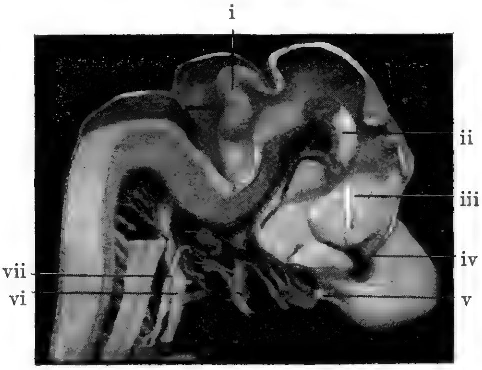

FIG. 4.—Shows medial aspect of model of brain.

i, Cerebellum ; ii, tegmentum ; iii, thalamus ; iv, inter-ventricular foramen ; v, olfactory bulb ; vi, vagus ; vii, sympathetic.

portion. The dorsal part of lamina quadrigemina projects posteriorly over the isthmus so as almost to touch the roof of the fourth ventricle. The cavity of the mid-brain is much smaller than that of the forebrain. Its roof shows several irregularities, probably artificial, as this region of the brain was somewhat damaged. The floor of the mid-brain is thickened on each side of the middle line, this thickening represents the tegmentum of the adult, and is bounded laterally by the continuation of the sulcus hypo-thalamicus. At the isthmus a small deep pit is seen in the lateral wall.

Hind-brain.—The hind-brain has still distinct pontine and cervical flexures. Its walls vary considerably in thickness in different portions. The thin roof of the fourth ventricle bulges upwards and also laterally, and forms a very prominent feature of the brain in this region. Near the cervical flexure the choroid plexus forms a deep transverse invagination of the roof, and divides it into anterior and posterior portions. The anterior portion of the roof overlaps the alar lamina of the anterior limb of the pontine flexure, so that a deep sulcus appears on the outer surface running parallel with the anterior limb of the pontine part of the brain. The posterior part of the roof of the fourth ventricle is not nearly so prominent as the anterior part, and blends with the medulla oblongata, which tapers off rapidly into the spinal medulla. The diameter of the spinal medulla is fairly uniform, but opposite the origin of the brachial nerves it increases somewhat in thickness. The spinal medulla in the cervical and upper thoracic regions is nearly straight, there being only a slight ventral convexity. The appearance of the hind-brain, as seen from inside, is very striking. The cavity of the fourth ventricle communicates with the mid-brain by means of a narrow isthmus rhombencephali. Immediately posterior to this the cavity widens out in all its diameters. Its floor is very thick, especially in the posterior limb of the pontine flexure and in the region of the medulla oblongata It has a longitudinal ridge on each side of the middle line which traverses the whole length of the hind-brain. The alar lamina is distinctly separated from the basal lamina in the anterior part of the pons by a furrow. It forms a thick rolled edge and has three bends on it. It begins on the lateral wall of the isthmus near its roof and runs laterally and dorsally a short distance. It then bends at an acute angle and runs ventrally a short distance. Soon it bends slightly laterally, and then again resumes its ventral direction till it reaches the pontine flexure, where it ends. It is much thicker at its pontine end than at the isthmus. Lateral to it the roof forms a very deep recess. The part of the ventricle posterior or caudal to the choroid plexus is comparatively shallow. It is broad at its anterior end, but narrows rapidly into the central canal of the spinal medulla. The cervical flexure occurs in this part of the brain, hence the floor of the cavity is convex in the sagittal plane.

The Spinal Medulla.—The spinal medulla has a large central canal, narrow from side to side, but wide in the sagittal plane. The ventral wall is much thicker than the dorsal wall. Its ventral surface shows a shallow median groove. Transverse sections show that the greater part of the spinal medulla is composed of grey matter with a surrounding zone of white matter.

Cranial Nerves.

I. The olfactory bulb on each side is represented by a short, thick process from the ventral surface of the cerebral hemisphere, extending between it and the epithelium of the dorsal part of the olfactory cavity.

It is composed of a more or less homogeneous mass of cells with round or oval nuclei.

The optic nerve on each side is fairly slender and springs from the corresponding angle of the diencephalon. It consists largely of cells, but mixed with them are a number of longitudinal fibres, which can be traced as far as the junction of the optic stalk with the diencephalon. There is as yet no indication of any fibres crossing the middle line to form a chiasma. There is now no cavity in the interior of the optic stalk. Keibel's 18-mm. embryo also has a solid optic nerve, while the nerve of Meyer's 18·5-mm. embryo is still hollow.

III. The oculomotor nerve is very long. It arises from the floor of the mid-brain by a bunch of five or six fine rootlets, and passes ventrally between the forebrain and the hind-brain till it comes into relation with the semilunar ganglion, when it curves laterally between the ophthalmic and maxillary divisions of the trigeminal nerve to end in the neighbourhood of the eye.

IV. The trochlear nerve springs from the root of the isthmus by a single root. It arches round the mid-brain and passes forwards a little lateral to the oculomotor nerve. Near the eye it curves forward in intimate relation to branches of the trigeminal nerve, and ends near the olfactory bulb.

V. The trigeminal nerve arises as a very thick trunk a little anterior to the apex of the pontine flexure and some distance from the median plane. Soon after leaving the brain it expands into the large semilunar ganglion, which at this stage is somewhat triangular in shape. At its central or proximal end the nerve consists mainly of fibres, with which a few cells are intermingled; but as the triangular enlargement which represents the semilunar ganglion is approached, the cells increase in number, more especially round the periphery of the bundle of fibres. As the more distant part of the ganglionic mass is approached, the cells increase in number until they almost entirely replace or conceal the fibres. Along the medial side of the ganglion a small bundle of fibres remains distinct, and can be traced into the mandibular division of the nerve. This bundle represents the motor root.

The ophthalmic division springs from the extreme frontal end of the ganglion and runs obliquely downwards and forwards. It soon divides into two branches, one passing medial to the eyeball to end near its medial commissure, the other ending near the optic nerve.

The maxillary division consists of a single trunk, passing downwards and forwards just under the eye to end in the cheek.

The mandibular division (fig. 5), the largest branch of the trigeminal, springs as a short thick trunk from the posterior angle of the semilunar ganglion. It passes downwards (caudally) for a short distance before breaking up into its various branches. Of these, the most medial is the lingual nerve, which passes in a medial direction as a flattened band to reach the side of the tongue, where it enlarges into a ganglion just lateral to the submaxillary gland. The auriculo-temporal is the most posterior branch, and is much smaller than the lingual nerve. It has a short course, curving laterally to reach the skin round the external acoustic meatus. The inferior alveolar nerve lies at first anterior to Meckel's cartilage, but gradually comes to assume a position lateral to it, and is continued on into the chin region. During its course it gives off a small branch, which

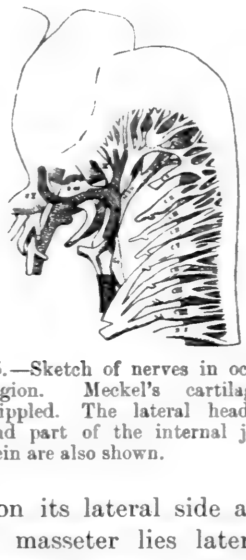

FIG. 5.—Sketch of nerves in occipital region. Meckel's cartilage is stippled. The lateral head vein and part of the internal jugular vein are also shown.

crosses Meckel's cartilage on its lateral side and ends in the mylohyoid muscle. The nerve to the masseter lies lateral to the inferior alveolar nerve and ends in the masseter muscle. The buccinator nerve lies just under cover of the epithelium at the angle of the mouth.

VI. The abducent nerve arises from an area medial and slightly caudal or posterior to the trigeminal and on the same level as the facial nerve by a bunch of small rootlets. It passes downwards and forwards towards the eye, and then curves laterally between the ophthalmic and the maxillary divisions of the trigeminal.

VII. The facial nerve comes from the ventral surface of the brain slightly medial to the acoustic nerve, and curls round its anterior border so as to lie in a groove in its lateral surface. Leaving the acoustic nerve, it develops a small geniculate ganglion and runs in a caudal direction for some distance, crossing over the long process of the incus, which at this stage lies horizontally. Soon after this it bends downwards and gives off the chorda tympani, which passes between the malleus and the long process of the incus to reach the lingual nerve. The facial nerve now gives off the nerve to the digastric and passes on to its distribution in the face.

VIII. The acoustic nerve is connected with the pontine part of the hind-brain by two roots. The more medial of the two is the mandibular root, the more lateral is the cochlear root, which, as it enters the brain, becomes associated with a group of cells which represent the dorsal and ventral cochlear nuclei. Outside the brain the two roots are in close apposition. The peripheral end of the trunk becomes associated with a group of cells which is in process of separation into the spiral ganglion and the smaller vestibular ganglion.

IX. The glossopharyngeal nerve lies in series with the vagus and accessory nerves on the lateral aspect of the hind-brain. It arises as a single thick trunk, which expands slightly to form the superior ganglion. It passes down ventral to the vagus, and, at the level of the auditory ossicles, it shows a much larger petrous ganglion, which gives off from its ventral side a small twig—the tympanic nerve of Jacobson. Below this point it curves forwards and medially to the tongue.

X. and XI. The vagus and accessory nerves arise by means of a long series of rootlets, which spring from the side of the hind-brain along a line corresponding in direction with the cervical flexure. These run together to form a single large trunk. The spinal root of the accessory can be traced down on the medial side of the cervical nerves as far as the rootlets of the third cervical ganglion. Numerous small ganglionic swellings are seen on the rootlets before they unite to form the vago-accessory trunk. At the upper part of the trunk is a collection of cells which represents the jugular ganglion, and at a lower level the fibres of the trunk become intermingled with cells of the ganglion nodosum. Some of the most caudal rootlets communicate with the first cervical ganglion, and at the point of junction a small ganglion of Froriep is seen. The vago-accessory trunk passes down ventral and lateral to the vertebral column, and opposite the second, third, and fourth cervical vertebræ is the ganglion nodosum, which has been already mentioned. This ganglion is large and spindle-shaped, and gives off from its medial aspect a short superior laryngeal nerve, which passes straight into the larynx. The vagus is continued down into the thorax dorsal to the pericardium.

XII. The hypoglossal nerve arises in a plane medial to the vagus and accessory nerves and in series with the spinal anterior nerve-roots. Its eight or nine slender roots fuse to form a flattened trunk, which comes to lie in contact with the dorsal surface of the ganglion nodosum. It then winds round the ganglion nodosum in a groove on its lateral surface. From this point it turns forwards and medially to the root of the tongue. A descending branch is given off, which accompanies the vagus nerve some distance further.

The first cervical nerve has a small ganglion, which forms communications with the roots of the vago-accessory nerve and with the second cervical nerve. The other cervical ganglia are much larger. The anterior roots are not easily seen. As the nerves emerge from the intervertebral foramina each gives off a small posterior branch. The lower cervical and upper thoracic nerves converge as they leave the spinal medulla and unite to form the brachial plexus.

The sympathetic gangliated trunk in the middle of the neck lies dorsal to the vagus. As it is followed towards the head it comes to lie medial to the vagus, and at the level of the petrous ganglion of the glossopharyngeal nerve it turns abruptly forwards with the carotid artery in the direction of the forebrain. As the trunk is traced towards the thorax it gradually diverges from the vagus, but is still dorsal to it. At the level of the seventh cervical vertebra it forms a loop and is continued into the thorax.

Streeter (5) has reconstructed the nerves in the occipital region of a 17·5-mm. embryo. In most respects the anatomy is very similar to the embryo here described. There are, however, some points of difference—thus in Streeter's specimen the glossopharyngeal nerve arises by several rootlets, and the gangliated trunk of the sympathetic fuses with the ganglion nodosum of the vagus. In this embryo the glossopharyngeal arises by a single root, and the sympathetic is separate from the vagus. The rootlets of the spinal ganglia in Streeter's embryo are much shorter than in mine.

Vascular System.—The carotid artery passes up the neck medial to the vagus, and opposite the first cervical vertebra it curves forwards in the direction of the forebrain. The stapedial artery is present and passes through the hole in the stapes. The two vertebral arteries unite in the concavity of the cervical flexure to form the basilar artery, which at this stage is a long vessel following closely the ventral surface of the pons as far as the cephalic flexure.

The blood from the frontal end of the brain is conveyed by the anterior cerebral veins into the large primitive head vein, which lies medial to the semilunar ganglion and represents the future cavernous sinus. Here it receives a small tributary from the region of the hypophysis. At the posterior edge of the semilunar ganglion it is joined by the middle cerebral vein, which drains the mid-brain and roof of the fourth ventricle. The large vessel (vena capitis lateralis) thus formed is continued posteriorly, lying immediately lateral to the facial nerve and accompanying it out of the cranium. It now lies lateral to the IX., X., XI., and XII. nerves. Opposite to the vagus it receives a large tributary (posterior cerebral vein) from the medulla oblongata, and emerges from the cranium by an opening which later becomes the jugular foramen. The vena capitis lateralis now turns sharply downwards and accompanies the vagus nerve on its lateral aspect, where it becomes the primitive jugular vein.

In the earliest stages of development the frontal part of the primitive head vein is represented by the vena capitis medialis, which lies medial to the cranial nerves. Later on loops are thrown round the nerves and the medial part disappears, transforming the vessel into the vena capitis lateralis. This series of changes has been fully worked out by Salzer (6) in guinea-pigs, and by Grosser and Brezina (7) in reptiles. Rabl (8) has pointed out that in selachians the persistence of the vena capitis medialis is the normal condition, though in *pristiurus* there are both medial and lateral vessels. The vena capitis lateralis is identical with the "Basalvene" described by His (3).

This embryo shows an intermediate stage in the development of the veins of the head. The early vena capitis medialis has been entirely replaced by the vena capitis lateralis, with the exception of that part medial to the semilunar ganglion, which persists as the cavernous sinus. Later the three cerebral veins anastomose and the vena capitis lateralis atrophies and disappears, so that all the blood leaves the cranium through the jugular foramen (Mall, 9).

The Upper Air-Passages.

The buccopharyngeal cavity (fig. 6) is widest at the angle of the mouth. From this point backwards it narrows rapidly to the level of the middle ear recess, where it again widens, and behind which it tapers away gradually into the œsophagus, the lumen of which is uniformly narrow. The cavity as a whole is curved on itself, with a ventral concavity, to the extent of about half a circle. In the roof the primitive choanæ are seen as oval openings. The primitive palate, *i.e.* that part of the roof of the mouth between the lip margin and the choanæ, presents a shallow groove, the labio-dental sulcus, which runs parallel to the lip margin. The epithelium on the floor of this groove is somewhat thickened. The palatal processes commence from the primitive palate at the anterior end of the choanæ, form the lateral boundary of the choanæ, and are continued backwards along the roof of the mouth till they reach the medial surface of the mandibular arches, which they cross and fade away on the anterior wall of the first cleft, which at this stage is becoming the lateral wall of the middle ear recess.

The middle ear recess is a wing-shaped extension from the side of the pharynx (fig. 6). Its upper wall or roof shows a convexity caused by the tip of the cochlea. There is an antero-lateral wall and a postero-lateral wall separated by a deep cleft, which corresponds with the angle between the first and second arches. The body of Meckel's cartilage bulges into the antero-lateral wall, while the handle of the malleus similarly causes a bulging on the postero-lateral wall. The most anterior or oral end of the middle ear recess is in the form of a narrow cleft, which runs from the

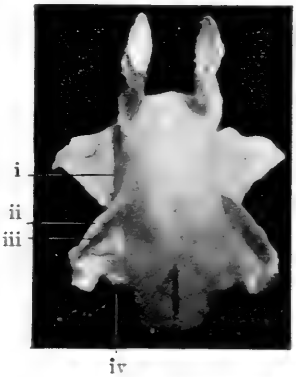

FIG. 6.—Model of the upper air-passages. Nasal cavities form top of model. At the side is a groove corresponding with palatal process. Further down middle ear recess is seen, and beyond that the cavity narrows into the œsophagus.

i, Palatal process; ii, sulcus tubo-tympanicus; iii, eminentia cochlearis; iv, second visceral pouch.

tympanum forwards and medially along the roof of the buccopharyngeal cavity. This cleft has been named by Hammar (10) and others the sulcus tubo-tympanicus. It is bounded laterally by the continuation backwards of the palatal process on the lower and posterior surface of the mandibular arch. Its medial boundary is the eminentia cochlearis.

The dorsal extension of the second pouch can be distinguished as a shallow pocket in the posterior edge of the middle ear recess, where it opens on to the pharynx (fig. 6). None of the other pouches or clefts can be distinguished in the lateral wall of the pharynx.

The parotid gland is represented by a solid bud of epithelium, growing into the cheek just behind the angle of the mouth. The submaxillary gland is also a solid bud of epithelium, growing downwards from the bottom of the alveolo-lingual sulcus. The sublingual gland has not yet appeared.

In the margin of the lower lip there is a labio-dental sulcus similar to that in the upper lip. The tongue occupies most of the floor of the mouth. Its tip reaches nearly to the lip margin, and is bound down by a short frenum. The organ is long and narrow, with a shallow median groove. It is sharply defined from the floor of the mouth by a deep alveolo-lingual sulcus. The root of the tongue can be faintly distinguished from the rest by a shallow transverse groove. There remains no indication of the relative parts played by the tuberculum impar and the lateral tongue rudiments, the anterior two-thirds of the tongue being quite uniform and smooth.

The epiglottis is a thick transverse ridge behind the root of the tongue. The upper aperture of the larynx is bounded behind and laterally by two rounded arytenoid swellings, which are in close apposition to the epiglottis and each other, so that the interval between them is a T-shaped cleft. Below this point the anterior laryngeal wall presents no special features. The laryngeal cavity consists of a transverse and a sagittal part. The transverse cleft is bounded behind by the arytenoid swelling and in front by the epiglottis, and the sagittal cleft lies between the two arytenoid eminences. A large part of the transverse cleft becomes the superior laryngeal aperture of the adult, the arytenoids later becoming separated from the epiglottis. The sagittal cleft is for the most part only a potential cavity, the two arytenoid swellings lying in close apposition, leaving only a narrow channel posteriorly. Lower down the sagittal part of the cavity opens out, the lumen being at first triangular, then oval as it passes into the trachea. There is as yet no trace of the chordal tubercle described by Frazer. The laryngeal cartilages are represented by condensations of precartilaginous tissue.

The Nose.—The nasal cavities open in front by the anterior nares and communicate with the buccal cavity by means of primitive choanæ, which are oval openings in the roof of the mouth. Their greatest diameters are in the antero-posterior direction. The anterior nares are narrow, and their lumina are almost entirely occluded by epithelial plugs, as is usual at this stage. Behind this point the cavity increases rapidly in its vertical diameter. The floor slopes down from the anterior orifice to the anterior border of the choana, and is formed entirely by primitive palate; while the roof runs first upwards and backwards, and then arches downwards to the posterior end of the choanal orifice. The lateral wall (fig. 7) is as yet fairly simple. Near its lower boundary there is a rounded swelling representing the concha inferior. This is limited below by a furrow, with which the solid naso-lacrimal duct is connected. The infundibulum ethmoidale is represented by a deep oblique cleft in the lateral wall near its roof. Immediately above and behind this the first ethmoturbinal is seen on the roof of the cavity. This illustrates a stage of the process described by Peter (11), in which the ethmoturbinals, which are originally on the medial wall, migrate across the roof on to the lateral wall. On the medial wall of the nose (fig. 8) is an antero-posterior sulcus, situated about midway between the floor and the roof. It deepens as it passes back to become a pocket, and obviously represents part of Jacobson's organ. In the region of the pocket the epithelium is thick and columnar, and nerve fibres can

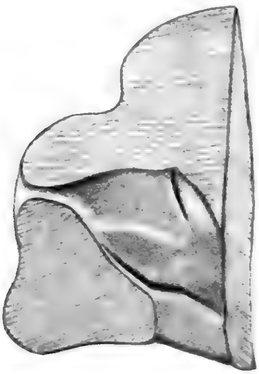

Fig. 7.—Lateral wall of the nasal cavity showing the concha inferior, the commencement of the infundibulum ethmoidale, and the first ethmoturbinal.

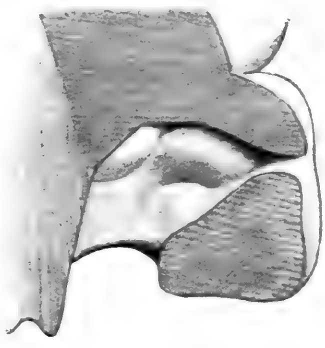

Fig. 8.—Medial wall of nose showing Jacobson's organ and one of the ethmoturbinals.

be traced from it to the olfactory part of the brain. In the upper and posterior part of the septum there is a small bulging area, probably representing the second ethmoturbinal.

The Eye.—The retina is a cup-shaped structure formed of two layers, which are as yet distinct. The outer layer already contains some pigment. The hyaloid artery is still present. The lens is a spherical mass lying in the retinal cup. It still shows a crescentic cavity in its interior.

The extrinsic muscles of the eye are just beginning to appear, and are still in a very rudimentary condition.

I have been unable to discover in this embryo any trace of a lacrimal gland, although there is a well-developed conjunctival sac both above and below. The naso-lacrimal duct is present as a solid column of cells, which arches in from the medial commissure to the inferior meatus of the nose.

The Labyrinth.—The labyrinth as a whole is situated slightly dorsal to the external acoustic meatus. Its oral or ventral extremity is formed by the cochlea, the saccus endolymphaticus is its most dorsal extremity, while the vestibule occupies an intermediate position.

The cochlea (figs. 9 and 10) is beginning to show a constriction at its junction with the vestibule, but the ductus reuniens so formed is as yet very wide. The ductus cochlearis is short and thick, and of its windings only two-thirds of a turn are completed. It lies very close to the middle ear recess and causes a bulging into its roof, as already mentioned.

The vestibule is somewhat elongated, and shows on its medial surface two rounded projections, which represent the beginning of the differentiation into saccule and utricle.

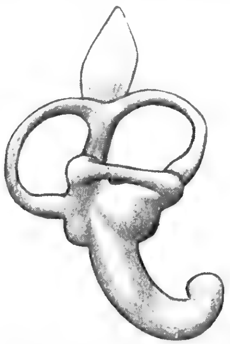

FIG. 9.—Lateral aspect of the membranous labyrinth.

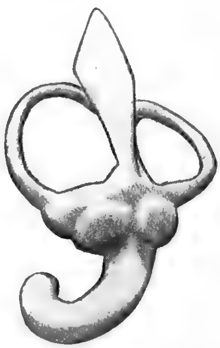

FIG. 10.—Medial aspect of the membranous labyrinth. The commencing separation into utricle and saccule is seen.

The semicircular canals or ducts are well developed and occupy the same relative positions to one another as they do in the adult. The ampullæ are already evident. The lateral or horizontal canal is considerably shorter than the superior or posterior semicircular canal.

The ductus and saccus endolymphaticus are represented by a spear-shaped diverticulum from the vestibule, medial and parallel to the crus commune.

Streeter (12) has reconstructed and described the labyrinth of a 20-mm. human embryo, which corresponds in every respect with the specimen described in this paper.

Branchial Derivatives.—The thyroid gland is a U-shaped structure. The limbs of the U are flattened at their cranial ends, but as they are followed downwards they become more rounded and meet in the middle line in front of the trachea. The upper or cranial extremities lie lateral to the lower part of the pharynx, though they have no connexion with it. The thyro-glossal duct has also completely disappeared. The thyroid is seen to be composed of loosely-connected columns of deeply-staining round cells. There is no distinct capsule. The thymus is in the form of two rounded cords, which lie close to the vagus carotid. Each cord begins about the level of the third or fourth cervical vertebra, just lateral to the thyroid gland, ventral to the carotid, and medial to the vagus. It passes down the neck, preserving these relationships, and comes gradually forwards towards the middle line, and unites with its fellow of the opposite side in front of the aortic arch. It is a mass of deeply-staining, closely-arranged cells. It has a definite capsule, and, in the greater part of its length, a narrow lumen.

The Skeleton.—The base of the skull is composed of precartilaginous tissue, with here and there chondrifying centres. The outlines are as yet somewhat indefinite.

The vertebræ are mostly cartilaginous, while the spaces between the bodies of the vertebræ are filled up by condensed tissue, not unlike cartilage in appearance. The vertebræ and intervertebral substance form a continuous column in front of the spinal medulla. The neural arches are quite open dorsally, the laminæ extending only about half way round the spinal medulla. The transverse processes are flattened and are pierced by the canal containing the vertebral artery.

The notocord runs up the centre of the vertebral column into the base of the skull. It then bends ventrally, and, emerging from the base of the skull, travels forwards between the mucous membrane of the pharynx and the base of the skull to end near the hypophysis.

In conclusion, I wish to express my thanks to Professor Robinson for placing his specimen at my disposal, and for much valuable advice.

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ANATOMICAL NOTE.

A New Roller for Making Wax Plates. By Professor Fawcett, *University of Bristol.*

This roller, of which an illustration is given, was suggested to me by the maker, Francis of Colston Street, Bristol.

After a thorough trial it seems to me to present many advantages over the various rollers in use at the present time.

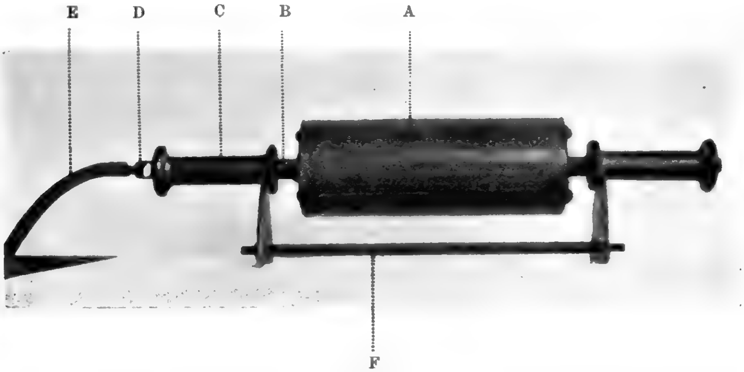

Fig. 1.

A, barrel of roller; B, axle; C, handle; D, bunsen; E, gas tube; F, stand.

As will be seen from the accompanying illustration, the barrel of the roller is of considerable diameter—some 4 inches, and it is heavy. The axle is hollow and perforated within the barrel of the roller to form the oven. Gas is led to the axle through a tube, and it passes on its way a Bunsen which is fitted to the axle. The handles are fitted to the axle. A stand is supplied on which the roller may rest. The axial position of the handles enables one to work the roller with great ease, and the gas may be turned up or down to vary the temperature. The price is 35s. for a 24-inch roller with stand.

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