V

RECONSTRUCTION OF THE HUMAN FOETAL PELVIS.

- A Study of its Development -

THESIS

for the Degree of M.D.

by

CHARLES F. PATTIE, M.B., Ch.B.

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INTRODUCTORY REMARKS.

This work:- The Reconstruction of the Early Foetal Pelvis, with a View to a Study of its Development, was undertaken at the suggestion of Professor Cunningham and Dr. Waterston and was carried out in the Laboratory of the Anatomy Department. It seemed possible that, by this means of investigation, something of interest might be added to the already known facts about this region of the embryo. That, by supplementing the work done by other methods - particularly the study of sections serially by the microscope - a fuller and more perfect knowledge might be had of this interesting region.

Special attention was to be directed to the hard parts, the general shape of the pelvis, and any peculiarities in this or in its constituent elements, seemed to be a very interesting field for research; and, I think I may say, that the results obtained have fully borne this out.

Whilst the bony (or, really, cartilagenous) pelvis was the main point of investigation, it seemed to me that to reconstruct a model, with the viscera in situ, might prove instructive; this, particularly to/

to study the topography of the viscera at this early stage with their general form and arrangement. A study of these in their natural size is of course very difficult and well nigh impossible. Very beautiful models of the tail end of the early embryo have been reconstructed by Professor Keibel of Freiburg. They do not, however, give a good impression of the topography of the viscera, as organs are only in many cases shown in section, and their limits and relations to the hard parts not made clear.

If suitable material were to be had (and I regret that it was not - indeed, there was a great scarcity for one reason and another - everybody seemed to wish his specimens for private museums), it was hoped that something might be done on the development of the urethra in the male. I particularly desired to investigate the sexual characters of the hard parts and to discover whether there were any differences between male and female at this early period. Unfortunately I have been unable to do so since all my specimens have turned out males.

However, with the measurements fully recorded (in one pelvis from a foetus eleven to twelve weeks old) of this male pelvis, some future workers may be more fortunate with his material and be able to prove that/

that there are or there are not sexual differences at this age.

Professor Arthur Thomson (Journal of Anatomy and Physiology, Vol. XXXIII, 1899) has shown that as early as four months there are distinct differences between the pelvis of the two sexes, as distinct as in the adult. His method of investigation was by means of dissection, a much more risky method (as he admits) when dealing, as he had to do, with small and delicate parts. However, the results in the various specimens were uniform and there does seem to be a difference as early, at any rate, as four months.

Reconstruction, as a method of investigation in Embryology, did not, it would seem, at first receive the attention it merited. Its value is not apparent in many cases at first sight and so the method has, until comparatively recently, been neglected; except perhaps by those under the immediate influence and direction of the originator, Professor His.

When we consider, however, it is clear that this method must be of great service in dealing with very early embryos when we wish to study the form and make measurements of these embryos or any particular organ. By magnifying the structure and modelling it in its enlarged form we can not only make more accurate observations/

observations as to the form and size of any structure at any age, but also study the development of that structure from its first appearance up to the stage when it can be studied accurately in its natural condition.

A study of serial sections of a structure has, of course, its own particular value and much may be made out by the aid of the microscope and other aids even as to the form of the structure. This indeed was what His did in his earliest reconstruction models - models which are famous. He studied a complete series of sections of an embryo so carefully that he was able to model the embryo freely in wax or clay. This, to His with his great powers of observation, must have been a very difficult task and it is not, as Professor Peter Thompson says, for the ordinary man. One may be allowed to doubt whether such models were, in their finer points, strictly accurate. For myself I have studied these serial sections pretty closely and have often been amazed at the appearance after reconstruction. Taking the cartilaginous pelvis as an example it seems to me well nigh impossible to form an accurate idea of such a structure with its many processes and fossae, or what are the correct shape and dimensions of such processes/

processes and fossae, by a mere study of sections. In any case, in such a study, the investigator alone would have the mental picture complete, which he could give to others by description; but where we can reconstruct a model we have a visual picture for all to study from.

The value of this method therefore lies mainly in this, that, where we wish to study form, at any particular stage in a developing structure, we have an accurate, enlarged, visual image of the structure so that we can handle it and measure it and note the relations of one part to another.

So much for the advantages of this method of investigation. What are its disadvantages? The most important is that it consumes much time; though after working at it for some time one gets along much more rapidly than at first. There is always, of course, much of interest in the work; but in certain parts the procedure is very tedious and a good deal of patience is required to keep steadily at the work from day to day.

The other disadvantage, or rather difficulty, is that there is a good deal of risk in certain parts of the technique. Everything must work smoothly during the/

the process until the sections are aafely mounted. For example, the tissue must be in good order for cutting so that the sections will be complete; the microtome must therefore also be cutting well; draughts have to be avoided when handling the sections for fear of mixing them; the sections must stick well to the slides; etc. But after all, these difficulties can be overcome by careful technique, so that there is nothing much to be said against the method, nothing that will weigh against the advantages, for time is required in all methods of investigation.

HISTORICAL NOTE - GENERAL.

Before reconstruction methods could be accurately employed it was first essential to get proper serial sections - sections of uniform and known thickness. Thus the first development in this direction was the invention of the microtome. Professor His in 1870 described a microtome which seems to have been the ancestor of all the modern instruments. Previous to this, serial sections had been cut with cruder apparatus; but His's microtome seems to have been the first to give satisfactory uniform sections. In 1870 His had been using his microtome for four years during which he says he cut 5000 sections.

Serial sections now being obtainable, it appeared to His that it was necessary to reproduce in a magnified condition the form of the sectioned embryo. Thus he devised and worked with his "Projective Reconstruction Method." This was as follows:- "He employed millimetre paper, each line of which was taken to represent a section. Beginning from a base line, the back in the case of a profile reconstruction, and the middle line in the case of a frontal reconstruction, he measured along the lines of his paper the distances of/

of any organ as shown in the drawings which he made of the sections enlarged, say, 100 times. When he had entirely worked through his series of sections the corresponding points on the lines were joined up, and thus was projected on paper the profile form of the object with which he was dealing magnified 100 times. After working through the sections in this most exact way he set to work to model freely the embryo in clay or wax. That is to say: he had obtained such a knowledge of the embryo from working through the serial sections that he was able to make a model of the form he conceived the embryo to be, controlling all the time the size and distances, etc., by means of callipers and references to the enlarged drawings of the sections." (Professor Peter Thompson "Lecture on the Study of Embryology" Lancet, January, 1908). This was the method employed by His in his earlier work on reconstruction and by this means were reconstructed those models of the human embryo which have become so famous.

Krieger independently thought out the same scheme for getting a visual picture of the structures he was working with - central nervous system of the crab.

Then came the method suggested by Professor Born (Morph. Jahib. II; Arch. f. Mikr. Anat. XXII. p.584), and/

and which Professor His employed in his later work on reconstruction. This method was announced briefly by Born in 1876 and described more fully by him in 1883.

In 1879, Mr. E. T. Newton, evidently quite independently of Professor Born's invention, which seems to have been unknown to him, employed thin soft pine wood plates piled one on top of the other, in order to demonstrate his lecture, on the brain of the cockroach, to the Quekett Microscopical Club.

Professor Born's method of reconstruction, or modifications of it, is the one used now-a-days and is much more accurate than the earlier methods employed by His and Krieger. The method was much as follows:- Drawings of the sections enlarged, say, 50 times, were made upon thin paper, the whole series being worked through. These drawings were then serially placed on a lithographic stone and boiling wax was poured over them. Brass rods of the required thickness, say, 1 millimetre, were placed at the sides and controlled the thickness of the wax plate. A hot roller was then passed over the surface of the wax to keep it the proper thickness. Those figures were then cut out with a sharp knife. Thus the series of sections were represented in the series of wax plates - magnified/

magnified in thickness and surface area. These plates were then piled and fixed together and so the model reconstructed.

Since Born described his method in 1883, reconstruction, as a method of investigation in Embryology, has gradually advanced in popularity. For a time most of the work was done in Germany under the influence of His, Born and others and, up to the end of last century, the advance was slow. The scope of its application has been greatly increased in recent years and much work has been done in many directions, particularly in America. There many workers, including Professors Mall, Bardeen, Lewis and Miss Sabin have added much to the study of embryology.

Recently a good deal of work has been done in this country, both in human and comparative embryology; and it would appear that still more is to be done in the future by this method of reconstruction.

T E C H N I Q U E.

This section of the paper may appear unduly redundant, but it seems to me to be necessary for a complete and full account of the whole process, will save much time, in a necessarily lenghty investigation, for any workers who may not be acquainted with this method of working. Professor Bardeen has given a fairly complete account of the method he employed (Johns Hopkins hospital Bulletin, April 1901). In spite of the assistance of that, however, a good deal of time has been spent with details in the work which would have been saved had an account, fuller in certain points, been to hand. It is hoped that this account will fill in those deficiencies.

The description will take the following order:-

(1) Photographs and drawings of the external form of the object.

(2) Preparation of the specimen,

a. Fixing and hardening.

b. Preparation for embedding in paraffin.

c. Embedding the specimen along with the guides to be used.

(3) Cutting the sections, staining and mounting them.

(4) Wax plates - their preparation.

(5)/

(5) Enlarging the sections by projection apparatus, and making drawings on paper and wax.

(6) Cutting out the figures as drawn on the wax plates.

(7) Piling the plates and fixing them together.

(8) Strengthening the model and finishing it.

1. Photographs of the embryo are taken before anything is done, so that they may be had for reference later, and the relation of the normal size noted. The length of the foetus - particularly of the trunk and head, excluding the lower limbs must be carefully measured, for this is a valuable guide to the age of the embryo - where that age is not definitely known, as is often the case. Where the external form of the embryo is to be reconstructed, enlarged drawings should be made (magnified the number of times the sections are to be magnified) so that they may be had for reference, as to the curves, etc., when the piling is in progress. Where one side of the embryo only is to be resonstructed, a profile view cut out in cardboard is of value as a base upon which to pile the sections.

2. Preparation of the Specimens to be reconstructed.

a. Fixing and hardening.

It is absolutely necessary to get the specimen into/

into a good state for cutting; for the sections must be uniform throughout and must not be torn or the shape in any way altered. It is clear that any such distortion would be greatly exaggerated after magnification, say 20 times. 4% formalin makes an excellent hardening reagent and does very well for studying the hard parts.

B. After the specimen has been sufficiently long in the hardening fluid the tissue is put through a somewhat lengthy process in preparation for embedding in paraffin. The process is preferable to the more rapid one employed often for ordinary section cutting. The process employed in these models was as follows:-

From formalin into:-

1.	Methylated spirit	24 hours
2.	Then into absolute alcohol	12 "
3.	Then absolute alcohol and chloroform (equal parts)	12 "
4.	Then pure chloroform	12 "
5.	Then pure chloroform and paraffin (melting point 52°) kept in oven	12 "
6.	Lastly Paraffin - in oven	12 "

c. Embedding the Specimen, along with the Guides.

This is done in the usual way; but special care must/

must be taken in placing the specimen according as to whether the sections are to be sagittal or transverse. This seems to me important, for, though it may seem that after reconstruction the result will be the same, it did not prove so in practice and the model is apt to be distorted accordingly where the section is not truly transverse or sagittal. The placing of the specimen too is important in relation to the guides which are to be used and according as these are placed vertically or horizontally in the mould.

GUIDES.

The question of Guides is an important one. We must have something constant upon which to work when orienting our sections. The guides have proved somewhat of a difficulty and many have been used and suggested. Nerve stained with parosmic acid is a very good guide but sections of such will not stick to the slide and so the slide must be albuminised. Minute arteries have been suggested and these would stick to the slide. In this work waxy liver, stained with carmine, was used and was found more or less satisfactory, the difficulty being that it was apt to break away in some of the sections. Often some structure or structures in the actual section are of more/

more value than any extraneous substance. In the reconstruction of some species of worms Dr. Ashworth has used the central nervous system. In the reconstruction of these pelves more attention was often paid to the internal guides than to the waxy liver guides.

Where one side of an embryo is being reconstructed, as mentioned above, we can use the profile drawing of it, magnified the proper number of times, as a base line upon which to build the plates - the plates lying perpendicular to the surface of the drawing.

The guides must be placed absolutely perpendicular to the surface of the section or else they are useless. Thus they must be placed against the sides of the mould. A very good way is that used by Professor Bradley. He uses albuminised slides and parosmic nerve. The nerve is stretched on a glass plate; the object to be sectioned is placed, with a due regard to the direction of section, as close up to this as possible and the paraffin is poured over them. The only disadvantage seems to be that the guide is on the edge of the section and may possibly move in some of the sections during manipulation. Splendid models (of e.g., early embryo of Flying phalanger) have been reconstructed by this method.

3./

3. Cutting, Staining and Mounting the Section.

In this work it is desirable to have a microtome which cuts on the flat. The Cambridge "Rocker" is therefore not so good because it cuts with a slight curve. One of the best is the Minot which cuts vertically. It was used in this work and gave very satisfactory results. The sections were fairly uniform, in 10 mikrons sections. Where 20 mikrons was used the sections were beautiful. Great care is necessary to have everything working well before the tissue is reached so that the specimen may be cut at once without interfering with the arrangements of the parts. The sections are taken off in long ribands and laid carefully on some surface so that they shall not get mixed up. When the cutting has been completed the sections are systematically mounted, commencing at the head end, in transverse sections, and at one side in sagittal sections. Care must be taken to have the proper side downwards and this is easily accomplished by having the smooth side of the section downwards in all cases, this, too, obviates the difficulty from the collection of bubbles of air when the sections are floated out. It is important to have the water, upon which the sections are floated out, at a sufficient temperature to remove all the wrinkles in the sections.

If/

If this be not attended to the sections will not superimpose properly.

The sections are floated on to ccoverglasses in the ordinary way. Coverglasses were used instead of slides as they are more convenient for handling. Coverglasses of such a size that they would hold three sections were used; so that, by taking three at a time, the whole series could be rapidly got on to the cover-slips and this part of the process accellerated. The coverslips are supported in wooden frames and dried over night in the oven at 37°. They should be put in the oven as soon as the sections are mounted else the sections are apt to move.

STAINING.

This may be done en bloc or after sectioning. The latter method was employed in two specimens and it was found that much better definition was got by this differential staining. Some workers prefer the former, however, since there is less risk of losing sections by that method. With care, however, it is not much more risky and, where every section is not reconstructed, an account can be kept of those lost and allowance made when orienting. The sections were stained in large numbers in a frame and thus much time was again saved. By/

By using these means, about 500 sections could be stained and mounted in a day.

The stain employed and found very satisfactory was Meyer's Haemalum, and, for a differential, Van Gieson's stain. The former about 10 minutes; the latter about 30 seconds.

When sections of 10 mikrons were used they stuck well to the coverglasses; but, in one case where 20 mikrons was the thickness, they did not stick well and some sections were lost; and so a valuable pelvis was spoilt for reconstruction work. It may have been due to faulty technique, but it would seem that albuminised slides are necessary for thick sections. By using thicker sections, and the same thickness of wax plate, every second section or so, instead of every fifth, would be reconstructed and perhaps even more accurate results would be got. So much for the procedure in the preparation of sections, we now come to a part of the technique which has more to do with reconstruction work.

4. Wax Plates and their Preparation.

The mixture that was used in the preparation of the wax plates was that recommended by Bardeen and consists of a mixture of beeswax and white rosin.

Beeswax 19 parts
White rosin 1 part.

This/

This mixture gives very good plates which are firm and not brittle when worked in a warm room. In the process of preparation used the powdered rosin is no use since it floats on the surface of the water and apparently oxides. This leaves black masses when the wax sets. These masses are of a gritty consistence and spoil the plates; moreover, bubbles of air collect in them and the main object is to prevent these forming under the cooling wax. The lumps of rosin, which sink and melt under the surface, were employed and are very satisfactory.

Methods of preparing Plates.

There are two recognised methods:-

1. That known as the Freiburg method which is as follows:- A magnified image of the sections is drawn serially on very thin paper. Each of these drawings is treated in the following way:- the paper is laid upon a lithographic stone; brass rods, of the thickness the plate is to be, are laid upon this; then the boiling mixture of wax and rosin is poured over it. A hot roller is then passed over the surface to render the plate level and uniform. It is then allowed to set sufficiently, when it is cut out with a sharp thin knife. Plates made in this way are now made in Germany and can be had in the market. The plates, thus made, are very good, but they are not so smooth and regular as those prepared/

prepared by the next method.

2. The method that was employed in this work was that recommended by Bardeen. It has given very excellent results. The plates are uniform throughout, except at the edges, and, if care be taken, any flaws can be avoided. Various difficulties presented themselves at the beginning, but we ultimately arrived at a fairly perfect treatment. The method is as follows:-

Shortly:- The mixture of wax and rosin is allowed to melt as the water boils and then to cool after having spread out over the surface.

More in detail:- To get a definite thickness of plate a vessel must be constructed so that a certain amount of wax mixture when melted will cover the surface of the water to the thickness desired. A fairly large vessel is best so that a good many plates may be made out of the one boiling. A vessel of zinc was constructed of such a size that 1 kilogramme of the mixture when spread over the surface would give a plate 1 millimetre thick. (Bardeen). This result was obtained by melting 1 kilogramme of the mixture in a small vessel of known area. The height to which the melted wax rose was measured. The area for that depth of wax being known, the area for a depth of 1 millimetre was easily calculated. The vessel must have vertical sides/

sides . This size is theoretically correct; but it is only by experience that the exact thickness can be obtained. The reason of this is that, when cooling, there is a good deal of contraction in the plate which therefore becomes thicker and the surface area diminished. A good deal of the surface of the water is thus left uncovered round the edges. Owing to this contraction, and the fact that the wax adheres round the edges to the vessel, the plate is apt to split, and so it is well, at the proper time, to liberate the edges by running a sharp knife round them.

The melting point of beeswax is pretty high, and rosin still higher, so that very hot water is required - indeed it must be boiling. At first the wax mixture was melted and poured on to the surface of boiling water which had been run into the large zinc pan. This was found hopeless as the mixture cooled too soon to allow of its spreading over the surface. The large vessel was then supported upon an iron frame and heat applied by means of large Bunsen burners. Much cooling takes place necessarily, from such a large surface, but with sifficient Bunsens it soon boils; water to the depth of about two inches is sufficient. The wax and rosin can be simply weighed out and added and allowed to medt as the water boils. It is kept boiling briskly until/

until all the rosin has melted and then the water is allowed to settle and cool gradually. Bubbles of air are apt to collect as the wax cools but these are readily dispelled by plying a Bunsen lightly over the surface every few minutes until the wax is becoming opaque, when the bubbles cease to form. All that is now required is to liberate the edges when it has sufficiently set. Before the water gets too cold and the wax brittle, plates of the desired size can be cut with a sharp knife.

By this method, not only are better plates obtained, but there is also a great saving of time. It must take much time to roll out a sufficient number of plates for the reconstruction of, say, a pelvis. But by this last method a few boilings yields all that is required. Moreover, during each boiling little attention is required.

5. Obtaining a Magnified Image of the Sections and recording these on paper and wax by drawing.

For this purpose a dark room is necessary. A projection apparatus or Camera Lucida may be used. A projection apparatus of a simple nature devised by Dr. Waterston was used in this work, and for the purposes required was found very satisfactory. Edinger has now a much more elaborate one, and there is a still more elaborate and costly apparatus by Leitz.

The projection apparatus employed consists of the following parts:-

1. A powerful Nernst lamp above encased in a movable metal cylinder to control the light and protect the filaments; below this a condenser; next, the stand for the slide; next the lens stand. These are all arranged upon an upright support, and all can be freely moved by sliding panels and rack and pinion arrangements. The light passes from above downwards through the various media and throws an image of the section, magnified as desired, upon the table below where it can be outlined. This arrangement is much more convenient to work with; and the drawing of the figures upon a horizontal surface much better than upon a vertical surface. A rough drawing is given of the apparatus, in profile, upon the/

the next page.

Having decided upon the magnification to be employed, it is easy to set the apparatus by means of a micrometer scale. When the lens frame is set, it must not be touched until all the drawings are finished, or else the size of the section drawings may be altered.

<u>How to arrive at the proper magnification</u> according to the thickness of the section, the thickness of the wax plates and according as we desire to orientate every section, or every second, or every fifth, etc.

If, say, the sections are 10 mikrons in thickness and we wish to magnify to 20 diameters; then, working with wax plates of 1 millimetre in thickness, the proper proportions will be maintained by reconstructing every fifth section.

Thus:- 1000 mikrons = 1 mm.

10 " = 0.01 mm.

Magnification 20 gives 0.20 mm.

by taking every section, wax plates of 0.20 mm. in thickness would be required, or for every fifth section plates of 1 mm.

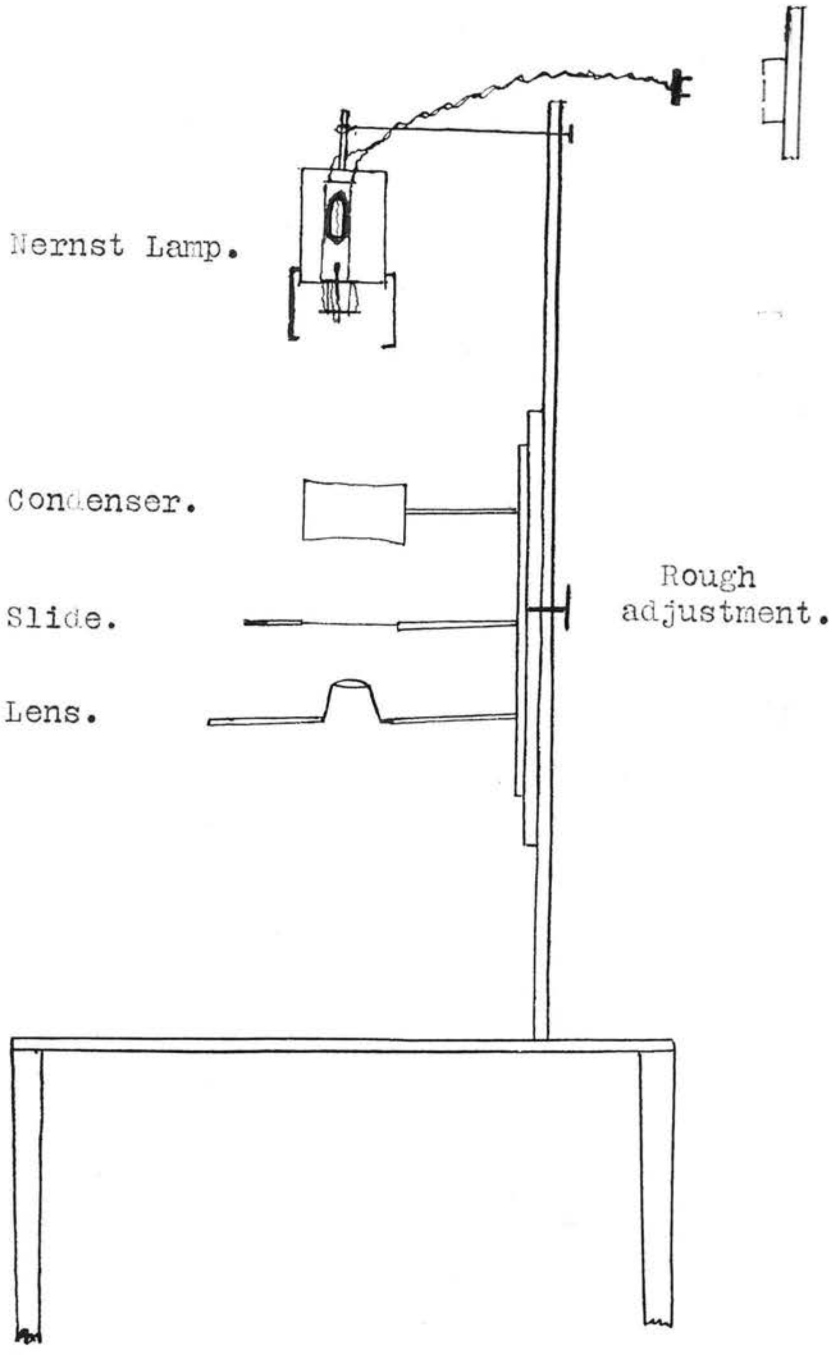
Again Sections 20 mikrons thick

Magnification 50 diameters

20 mikrons = 0.02 mm.

Magnification 50 gives 1.0 mm.

Thus/



Projection Apparatus.

Thus, using every section, 1 mm. plates would be required. For every second section plates of 2 mm., and so on. The best thickness for the wax plate is about 1 millimetre. This is the most workable thickness. Thinner plates would more readily break and perhaps would be modified by pressure. Thicker plates, on the other hand, are more difficult to cut accurately.

Making the drawings and transferring them to wax:- The structures, in the projected image of the section, which it is desired to reconstruct are carefully traced on paper with a fine pencil. Coloured pencils may be used to indicate different structures, but this is unnecessary.

These drawings are then transferred to the wax plates, along with the drawings of the guides, by means of carbon paper. To save this second drawing, and thereby much time, the projected image was drawn straight on to the wax by inserting carbon paper between the paper and the wax plate. The question was asked "What if a mistake were made in the drawing?" This does not spoil the plate, for all such mistakes are scored out on the wax, and also on the paper for reference. This however is seldom necessary. The enlarged image of the sections is thus projected straight on/

on to the wax plates.

6. Cutting out the Figures on the Wax Plates.

The sections are now serially recorded upon the wax plates with the particular guides upon which the model is to be built up. When the drawing was in progress all the sections were carefully numbered in some permanent place so that there was no fear of mixing them. The cutting out should be done in a warm room so that the edges will not break. The plate is placed upon a glass slab and a sharp, thin knife run round the lines drawn on the wax. All the parts are kept in the proper relation to one another by a sufficiently strong bar of wax which can be cut away later when natural bridges have been formed by joining up the parts in the different plates. The cutting out may be done all at once or in portions to give variety to the work, for this part of the work is trying and tedious. The figures may be roughly superimposed as the cutting out proceeds so that the work is controlled and a note can be made of any plates which do not superimpose properly - from some fault, perhaps, in the section - which can at this stage be investigated.

7. Piling the Plates and fixing them together.

The/

The figures, all numbered, are now ready to be reconstructed. The procedure adopted in this work will be described first. Assuming all the plates to be of exactly 1 millimetre in thickness they have simply to be piled and fixed together in portions. It is well however to control each portion with a millimetre scale to avoid error in thickness. Five to ten plates may be taken at a time and all the permanent structures fixed together with small pins. The particular guides used are left attached and can be cut away later. The drawings on the paper, all correctly numbered, can be studied along with each lot, thus the piling is controlled and the variations in the sections readily made out. The use of definite vertical guides is necessary in the reconstruction of curves, such, for example, as the curve of the spinal column, in transverse sections. Two or three guides are best so as to avoid any lateral movement in the construction.

As each lot of plates is fixed together with pins the sections of the model are partially smoothed off, as it is easier to do this at this stage than when the model is finished. A hot knife is run over the surface and, where there are big gaps to fill, melted wax is applied. This is often the case where the obliquity is marked. The accuracy of the model is in no way interfered/

interfered with if care be taken in this proceeding.

As each lot of plates is finished they are added to the model and fixed to this by pins and copper wire which is allowed to burn its way into the wax. This again is smoothed off in its relation to the whole model. By this means variety is given to the work and interest is added by studying the parts gradually taking shape. When it can be done without injury to the model, the intervening bars of wax are cut away. This often has to be done in each lot, or else they would be covered up later and could not be removed. So the reconstruction proceeds until all the plates have been added to the model. The guides can then be cut away and the whole model smoothed over with melted wax.

8. Strengthening the Model and finishing it.

The model is finally strengthened by binding the parts firmly together with stout copper wire. For finer structures, such as membranes, copper guaze may be used. Vessels and other small elongated structures are strengthened by a piece of wire. This is heated and allowed to burn into the structure and the track then filled up with wax.

Lastly the model is painted. This prevents the heat/

heat in summer affecting the model. Painting is also useful for mapping out the different structures by different colours.

Where it can be done casts can be made of the models for rough handling, as the models are somewhat fragile.

Another Method of Reconstruction.

After the figures are cut out, two preliminary piles may be made, one of the parts which represent the sections, and one representing the wax plates after removal of the former parts. The former gives a positive image and the latter a hollow, negative image of the original object. Here the enlarged picture taken of the object at the commencement is of value. In case of symmetrical objects a surface outline drawn on card board and cut out makes a good basis to build upon (Born). Where only one side of the embryo is to be reconstructed from transverse sections the figures can be cut down the middle line and then the plates can be piled against the profile outline of the object which is placed against a surface perpendicular to the plane of the plates.

When the plates of the positive image are correctly arranged the negative can be corrected from this by taking/

taking some of the main curves in the positive and moulding wire to them and then applying this to the negative surface. A cast can then be taken of this cavity which will give the external characters of the embryo.

Reconstruction of Embryonic Pelves.

Historical Note.

Until I had described my pelvic models and had completed my paper I was not aware that any work had been done upon the hard parts of the pelvis by reconstructive methods. Since then I have discovered that

The actual models, which are also submitted with this thesis, have been left under Professor Cunningham's charge in the Anatomy Department, Edinburgh University. It was thought advisable not to send them round since they are fragile and might readily be injured in the carriage. They may be seen at any time by applying to Mr. Henderson, Assistant Conservator, Anatomy Department.

In 1905 Professor Bardeen also made a study, by this method, of the very early cartilagenous pelvis and reconstructed a model of a male pelvis in an embryo of 33 millimetres long. This he compared with the description given by Petersen of his female pelvis, (American Journal of Anatomy, Vol. IV, 1904 - 5). These two pelves, being about the same age, could be readily compared/

compared for sex characters, but nothing very definite seems to have been made out exhibiting differences. After reading Petersen's paper I decided to rewrite mine so that any points bearing upon development and growth of the pelvis might be introduced. The general description of my models has not been altered since they are all from older embryos and must be regarded therefore as exhibiting a further stage in the development of the pelvis.

Professor Keibel of Freiburg has reconstructed a series of models particularly to show the development of the genito-urinary apparatus in the female.

The Material.

These reconstruction models have been made of the developing cartilagenous pelvis from three different embryos. These embryos were all that I could obtain at the time the work was in progress. The embryos are all older than those of Bardeen and Petersen and a description of them will furnish another step in the development of the hard parts. They pass from one of fully 8 weeks to the largest of about 11 - 12 weeks, and exhibit some important points in development and growth of the hard parts. In the middle one of the series the viscera have been reconstructed in situ, and a reconstruction model has been made of the genito-urinary apparatus (exclusive of the kidney) from the same specimen, which is a male of about 9-10 weeks old.

No. I Model.

This is a reconstruction of something more than half the pelvis (right half) from an embryo of fully 8 weeks old, magnified 20 diameters. This specimen belonged to Dr. Waterston. He kindly lent me the sections to commence the work with. I do not know the length of the embryo but, from the appearance of the ossific/

ossific centre in the ilium already, I conclude the age to be fully 8 weeks. The embryo was sectioned elsewhere and unfortunately the coccygeal part was not represented in the sections and consequently has not been reconstructed. For a study of the next stage in the development of the os innominatum and part of the sacrum it has been useful. Only one side was reconstructed because it appeared that the left side had been modified in shape previous to section.

No. 2 Model.

This is a reconstruction of the pelvis from an embryo of about 9-10 weeks old. It measured, exclusive of the lower limbs, 37 millimetres. Magnification, 20 diameters. This is the next stage in the development and exhibits some marked changes in the ilia from No. 1 model. In this model the viscera have been reconstructed in situ so that for the most part the external form of the cartilage alone can be studied for comparison. In addition to the viscera, the musculature of the floor of the pelvis has been reconstructed.

No. 3 Model.

This is a model of the hard parts complete of the pelvis of an embryo 11-12 weeks old. It was 60 mm. long, exclusive of the hind limbs. The head and neck measured/

measured 26 mm. and the trunk 34 mm. Magnification, 20 diameters.

In Nos. 1 and 2 the sections were transverse; and, in No. 3, sagittal. In all, sections of 10 mikrons were employed.

Between Model No. 1 and model No. 3, magnified the same number of times, there will be seen to be marked differences; so that a study of the series should prove of value.

A complete study could be carried out in No. 3 model alone, for No. 1 is incomplete and in No. 2 the presence of the viscera prevents the study of the cavity of the pelvis.

The order that has been followed in this paper has been, first, to describe the earliest model (No.1), particularly the innominate bone and its relations to the sacrum; and comparing this with Bardeen's and Petersen's accounts of their early pelves.

Then a description of the hard parts of model No. 2 and comparing this with No. 1.

Lastly, in the hard parts, a full description of model No. 3, followed by measurements of the pelvis for comparison with a female pelvis when it shall be reconstructed.

After the hard parts have been considered a note/

note has been made upon the reconstruction of the viscera in No. 2 model and in the model of the genito urinary system.

A Short Description of Model No. 1.

Petersen studied the development of the innominate bones (or cartilages) from their earliest appearance at the proximal extremity of the femur. Three pieces of cartilage developed in the condensedcellular tissue surrounding what was to become the pelvic cavity where the viscera, blood vessels and nerves were developing. These cartilages formed a triradiate arrangement and the direction of their growth, he held, was controlled by the three nerves - sciatic, obturator and crural. The cartilages grew towards the acetabulum and all took part in its formation. While this was going on the distal ends were growing away from each other. The iliac bar passed backwards and became attached to the lateral mass of the sacrum, first by its anterior or costal parts. The connection between the transverse process and the ilium was brought about by the development of a longitudinal bar of cartilage posterior to the costal connection with the ilium. The ischial ramus grew round the obturator nerve/

nerve and gradually completed the obturator foramen by uniting with the pubis internally. Lastly the pubes came together in the middle line anteriorly. He traced the changes which occurred up to the condition found in the embryo L0 - 29 mm. long.

Bardeen also traced the development up to that found in an embryo 33 mm. long. Their results were much the same.

Model No. 1 may be taken as the next step in the development, and a short account will be given here of it. When describing the large model (No. 3) the changes that have occurred will be noted and the pelves compared in so far as they can be.

Innominate cartilage. (see fig. 1)

Ilium.

The most striking thing about the ilium is that the expanded part is very short perpendicularly. There is a great advance in vertical growth between this and the next stage. The expansion is however comparatively broad antero-posteriorly, and the antero-superior and postero-superior spines are sharp and prominent. The postero-superior spine is directed backwards and forms the most posterior part of the ilium, differing therefore apparently from the other models and the adult bone. This spine is not so massive/

massive as it is later on. Accordingly also the postero-inferior spine appears much further down upon the lateral mass of the sacrum than in the other models. This is more apparent than real because the tip of the spine reaches down to the level of the middle of the anterior sacral foramen and not to the upper limit of the third as is the case in the adult. Between this stage and that in model No. 3 there is evidently an increase in bulk of the posterior ends of the ilia with a displacement downwards of the postero-superior spines. In models No. 2 and 3, the summit of the great socio-sciatic notch, and the postero-superior spine are nearly in the same horizontal plane; but in this model the postero-superior spine is placed much higher. The general shape of the iliac expansion, from without, is more or less oval, with the long axis directed antero-posteriorly. It has not yet assumed the quadrilateral shape seen later on.

The notch below the antero-superior spine is deep and narrow. The antero-inferior spine is small and overshadowed by the superior spine. It is placed well to the inner side of the superior spine. There must therefore be a great growth in this anterior part of the ilium to arrive at what is found in model No.3.

The antero-superior spine is remarkably near the acetabulum/

acetabulum. It lies above the acetabular rim 2 cm., i.e., in the embryo, 1 mm. In model No. 2, the distance is 4 cm., i.e., in the embryo, 2 mm.

The anterior end of the iliac expansion is slightly inturned whilst the posterior end is turned outwards slightly, so that a slight S shape is already present. The iliac expansions are fairly uniform in thickness throughout and show no fossa formation. The outer surface is slightly concave.

The inner aspect of the iliac expansion is interesting. The upper part is fairly vertical but there is a portion which extends from the pelvic brim to this vertical portion which is more nearly horizontal (Fig 2). The result is that an angle is formed between them which is widely open - obtuse - inwards. It is not seen upon the outer aspect because it cuts into the thick cartilage at the base of the iliac expansion. Above this angle there is a slight concavity anteriorly and a slight convexity posteriorly. The posterior part has not yet become markedly convex on its inner aspect, and is placed well away from the neural arches - this being very different from what we find later.

Petersen described great "flaring" of the ilia in L.O. and, comparing this with the adult, he found that/

that the antero-superior spines were relatively wider apart than in the adult. He represented the conditions graphically, and, making the ilio-pectineal eminences in embryo and adult coincide, he showed that the antero-superior spines lay farther to the outer side of these eminences and also lay at a much lower level than the antero-superior spines of the adult.

The very low ilium is brought out well by taking the index of the width of the ilium with the total pelvic height

Breadth of ilium = 98 mm.

Total height of pelvis = 108 mm.

index $\frac{98 \times 100}{108} = 97$

This is a remarkably high index. In adult males Verneau gives 74.5. Between this and the stage exhibited in model No. 2 there is a very rapid growth in height of the false pelvis and the high index is due to the low false pelvis. The true pelvis in this model is relatively deep. Depth of true pelvis 56.5 mm.

Ischium.

The body of this element is well formed. The postero-external surface is markedly convex. There is no concavity at the base of the spine because that spine looks/

looks inwards towards the bodies of the sacrum. It can hardly be called a spine and is rather a roundish elevation. It is not nearly so large and prominent as it is later, because of the absence of the marked inturning of the ischial spine, and also because the ilio-pectineal eminence is not so marked, the concavity of the inner surface of the ischium is much less deep than in No. 3.

The ischial tuberosity (fig. 1) is very small and undeveloped. It forms merely a more thickened part of the ramus - a part which is directed downwards. The outer surface is convex, and so it has the appearance of being inverted (fig. 3). The groove between the tuberosity and the acetabulum is hardly to be made out accordingly.

The acetabulum (fig. 3) is a prominent feature. On front view it is seen to project well outwards particularly in its posterior part; so that this part forms the summit of a curve passing from the antero-superior spine to the outer aspect of the ischial tuberosity. The margin is sharp and well defined, since the cotyloid ligament (condensed tissue representing it) was reconstructed as attached to the cartilage. The shape of this ligament was, in the sections/

sections triangular, as seen in the adult. The addition of the cotyloid ligament exaggerates the depression above and posterior to the acetabular margin. The shape of the acetabulum is oval, with its long axis directed transversely.

vertical diameter = 28 mm.

transverse " = 33 mm.

Between this and the next model the vertical diameter has increased more than the transverse. The cavity is deep, exaggerated by the cotyloid ligament. The cotyloid notch is narrow and deep. No rough area at the bottom of the acetabulum was made out in this specimen. The head of the femur filled the acetabulum and was quite separated from it. The joint is therefore already fully formed.

The thyroid foramen is comparatively wide and oval in shape. Its long axis is directed obliquely, the upper end lying nearer the middle line, (fig. 3). Its shape etc. will be discussed more fully when considering the foramina in the three models later.

The ischial ramus projects at first forwards and then upwards and inwards and meets the pubic ramus at a point which projects well forwards. This point has been remarked by Petersen in L.O. On transverse section of these rami they are nearly circular in outline.

Pubis/

Pubis.

The surfaces of the pubis look anteriorly and posteriorly. The posterior is convex and the anterior practically flat. Below, it passes into the descending ramus and this is concave anteriorly, passing forwards to meet the ischial ramus at the tubercle referred to above. The pubic spine is more a fulness than a definite spine and from it a ridge passes downwards and outwards towards the acetabulum, above the thyroid foramen. The pubic bodies meet in the middle line, the cartilage being separated by a fairly thick dense tissue, more marked anteriorly and above. This has been represented in this model as cartilage, and so the cartilage of the one appears to pass on to the cartilage of the other. In reality the anterior edges of the bodies should be separated by a groove such as is seen in model No. 3.

The ascending ramus of the pubis is directed mostly inwards and slightly forwards - differing therefore greatly from the adult condition. It meets the body of the pubis forming an angle widely open posteriorly, because the anterior surface of the body looks forwards and not forwards and outwards as in the adult. Thus the anterior aspect of the pelvis has

has a remarkably flat appearance. This will be considered when considering the growth of the true pelvis later.

Sacrum.

In this model the sacrum is very straight, and I am inclined to think that it is somewhat too much so. The coccyx, as mentioned, could not be represented, but in the very last section of the series a piece of cartilage appeared isolated well forwards. This was evidently the upturned end of the tip of the coccyx. The connecting cartilage had not been sectioned and so this piece was not represented for it would have been difficult to keep it in place. From the appearance however of this piece of cartilage it showed that there is a very marked curve on the coccyx - much more than in models 2 and 3.

There is no suggestion of a promontory in this model and the brim of the pelvis seems to end at the side of the body of the first sacral vertebra. There is no connection across the vertebrae, between the posterior ends.

The lateral mass appears more isolated in this model than in the others. The costal elements are thin when compared with model No. 3. So also are the transverse processes. Of course these are fixed together/

together at this stage. The anterior sacral foramina are comparatively large when compared with the thin lateral processes of the vertebrae. This is only what we would expect since the nerves are very large structures at this stage, and, as has been stated, some of them play an important part in the growth of the early innominate cartilage, (Petersen). The slender costal element of the first sacral vertebra where it forms the ala, instead of being a stout bar as in model 3, forms a thin edge to the brim at this part; thus bridging over the large anterior sacral foramen. In this model the upper surface of the ala seems to pass insensibly on to the inner aspect of the ilium - very different from that seen in No. 3, and even in No. 2, though in the latter this is not so marked.

In this specimen, I believe, some dissection was done to expose the cord before section, so that the condition of the neural arches cannot be recorded. The spinal canal is however very large and capacious. The posterior sacral foramina look well outwards and not much backwards. The upper ones are not covered over by the posterior ends of the ilium. The lateral mass, broad above, tapers away to a point opposite the last sacral vertebra.

Cavity/

Cavity of the Pelvis.

Unfortunately only one side can be considered. The brim is well formed. But it must be made clear that here again the outline of the condensed tissue was taken. This was not the case in model No. 3 where the definite outline of the cartilage was rigidly adhered to. This condensed tissue took on a different and a deeper stain and on microscopical examination was found to contain cartilage cells in the transition stage, more like connective tissue cells the farther from the cartilage. It is indeed a thick perichondrium - denser in some parts - which is completing the form of the cartilage upon this aspect. The brim is fairly sharp therefore amd this is exaggerated by the "flaring" of the lower part of the false pelvis which is very marked. The ilio-pectineal eminence does not encroach upon the pelvic brim as it does in model No. 3.

The ischial spine projects well into the cavity of the true pelvis as a rounded eminence and the ischial tuberosity has a marked inward inclination, and would thus greatly narrow the outlet. Unfortunately, measurements cannot be made of the pelvic cavity in this case, except the conjugate, and the depth which has been given before in comparing the height of the true pelvis with the total pelvic height.

A Short Description of Model No. 2 - the Hard Parts.

This pelvis has been reconstructed in two parts, an upper and a lower section. This was done so that the viscera may be traced more easily and also that the contents of the true pelvis and the pelvic floor may be seen and not obscured by the expanded peritoneal cavity above.

The outward form can, in most cases, alone be described in this model since the viscera occupy the cavity. The pubic arch, too, is filled up by the soft parts and thus cannot be considered.

Innominate Cartilages.

Ilium. (figs. 4-16)

The iliac expansion has grown considerably in this model but it is still small when compared with the rest of the innominate. That is, the true pelvis is still relatively deep. The sacral portion of the ilium is large and has become more massive than in Model No. 1. A line drawn from the antero-superior of the postero-superior spine is about bisected by a line continued upwards from the anterior margin of the great sacro-sciatic notch and parallel with it. This line meets the iliac crest at about its middle point. The expansions have/

have become more quadrilateral in shape but have not yet assumed the shape of the adult. They are not in this respect so far advanced as model No. 3.

The most posterior part of the ilium is not now apparently the postero-superior spine but a point in the crest a little above this. The spine appears to me to project now downwards and lies about 15 millimetres in front of the most posterior part of the crest. The point, which seems to me to be the spine, is situated therefore upon the inferior border of the iliac expansion. It has assumed therefore the position of the adult where the spine is directed downwards. The postero-superior spine is here and in No. 3 model practically on the same horizontal plane as the postero-inferior spine. This is markedly different from the adult where the inferior spine is much lower. Part of this elongation in the adult of the postero-inferior spine is no doubt due to the traction of powerful ligaments, but it would not account for such a marked difference and there must therefore be a growth downwards of this spine later. Everything indeed seems to point to this. The ilia have a slight inclination outwards in their expansions, much as in the upper part of the expansions of model No. 1.

The external surface presents a slight concavity below/

below. It becomes convex as we pass towards the crest, and at the crest there is a slight incurving of the summits.

The notch below the antero-superior spine is still deep and narrow, exaggerating the prominence of the superior spine. The antero-superior and inferior spines are still close together but the superior spine has been raised twice the distance (viz., 4 cm.) above the acetabulum of that found in Model No. 1. The inferior spine has at the same time been raised almost equally so that the growth between these ages has taken place more in the lower part of the anterior border than in the upper part.

The inner surface of the iliac expansions is concave and this is exaggerated by the incurved upper limit of the iliac crest.

The great sacro-sciatic notch has its summit completed by the innominate cartilage, but its posterior border is almost entirely formed by the lateral mass of the sacrum, there being very little development of the postero-inferior spine of the ilium. The summit of the arch is on a level with the postero-superior spine.

A few measurements that can be made will be given/

be given here:-

Breadth of Ilium (from Antero-superior to postero-superior spine)	=	95 mm.
Height (total) of pelvis	=	148 mm.
Index, taking total pelvic height at 100 = $\frac{95x100}{148 \text{ mm.}}$	=	Index. 64.1
Thomson gives for male foetus = $\frac{29.3x100}{42 \text{ mm.}}$	=	69.7
Verneau for adult males = $\frac{164x100}{220 \text{ mm.}}$	=	74.5

There is a gradual increase therefore, and this is due to the greater breadth of the ilium in proportion to total pelvic height in the adult than in the foetus. There is a very great difference between the index of this model and that of model No. 1. In this it is 64.1 in model No. 1 it is 97. Sȯme allowance must be made for errors in technique, and the wax plates in model No. 2 may have been slightly thicker than in Model 1; but this will not account for anything like the difference. The explanation is that there has been a very rapid growth in height of the pelvis, mostly in the false pelvis but also in the true. This is evidenced by the fact that the acetabulum has now become longer in its vertical diameter than the transverse, and, in the false pelvis, the great increase in the distance between the acetabulum and the antero-superior spine/

spine while the notch below that spine has remained much as in model No. 1.

After this stage has been reached the breadth of the ilium increases more rapidly than the total height.

Professor Thomson selects this index (breadth of ilium to pelvic height) to demonstrate the fact that there is a greater increase proportionately in breadth of the ilium to total pelvic height as age advances, and that this is due to rapid growth in that portion of the innominate bone which forms the summit of the great sacro-sciatic notch. This may be the case, but it seems to me that the posterior part of the ilium is as well developed in this part, at any rate in the embryo, as in the adult. The increase in breadth of the ilium is rather due to a greater growth in the anterior part (abdominal part) of the false pelvis and this is demonstrated by the following measurements in the model and adult. Taking the junction of the anterior and upper borders of the great sacro-sciatic notch and measuring to the postero-superior spine on the one hand, and the postero-superior spine on the other, we get striking results.

	Notch to antero-superior spine.	Notch to postero-superior spine.
Model No. 2	= 57 mm.	46 mm.
Adult	= 102 mm.	66 mm.

There/

There is therefore a very marked increase in the measurement from the notch to the antero-superior spine, much more so than in that from the notch to the postero-superior spine. Therefore the increase in the breadth of the ilium in relation to the total pelvic height in the adult is due largely to this great growth in the abdominal part of the false pelvis. This goes along with the widening of the notch below the anterior spine.

Ischium.

The postero-external surface is markedly convex and passes up to the brim of the acetabulum, which does not present a depression upon its upper and posterior aspect.

The ischial spines are obscured by the soft parts; but in the sections their prominence was well seen, projecting into the cavity of the pelvis.

The tuberosities are still small and rounded and project well forwards. The groove between this and the acetabulum is greater than in model No. 1 but much less than in No. 3. The tuberosities are not so much inturned as in No. 1 though they still are not everted.

The same flat appearance of the anterior aspect of the pelvis, described in model No. 1, is again well seen here.

Pubis/

Pubis.

This cannot be described, for the soft parts obscure it. The ascending ramus has much the appearance seen in model 1 and is directed well inwards and slightly forwards.

The Thyroid Foramen. (Fig. 16)

Is longer than in model 1, and slightly broader. It has assumed a different appearance, for now the long axis is placed vertically. The foramen looks almost directly forwards, mostly above, because of the flatness of the pelvis in front. The foramen is covered over posteriorly by the obturator internus muscle.

The Acetabulum.

This is a prominent feature and is well developed. It looks well forwards. The notch (cotyloid) is much wider than in No. 1, and the rough area at the bottom of the cavity is represented in a triangular shape with the base towards the cotyloid notch. The vertical diameter has now become slightly the greater or equal with the transverse.

Vertical diameter	=	36	mm.
transverse "	=	35	mm.

A few outside measurements are here given:-

Distance between antero-superior spines	=	147 mm.
Distance between antero-inferior spines	=	131 mm.

Distance/

Distance between outer limits of cotyloid cavities = 134 mm.

These figures demonstrate well the absence of "splay" of the iliac expansions and, when taken with the next measurement:-

Distance between the outer aspects of the ischial tuberosities at their lowest points, = 80 mm.

the convex appearance of a line joining the antero-superior spine and the outer aspect of the tuberosity, passing through the posterior limit of the margin of the acetabulum, can be understood.

Distance between the bottom of the acetabular cavities, measuring from the upper angle of the rough area = 78 mm.

Distance between the postero-superior iliac spines = 74 mm.

Sacrum and Coccyx. (Fig. 13)

The curve of the sacrum is somewhat greater than in the next model (3), and this is what we would expect. The most of the curve is however in the coccyx which turns well forwards under the arch of the pubis. There is a suspicion of a promontory here, i.e., the first sacral is somewhat more prominent than the last lumbar or second sacral. The absence of a definite/

definite promontory gives the appearance of a more general sweep from the lumbar on to this region of the column.

The lateral masses are well developed and present a general convex outer surface. They slope gradually to end at the last sacral vertebra. A large part of the lateral mass is exposed externally because the postero-inferior spine is still short. The bars of cartilage connecting the lateral masses with the bodies of the vertebrae are thicker and better developed than in model No. 1. The intervertebral and anterior sacral foramina are still relatively large.

The spinal canal is very large and tapers gradually from above downwards. It is open posteriorly all the way. The arches consist of the pedicles, the distal ends of which are formed by a bar of cartilage representing the articular processes. In transverse sections one could not make out any indication of joints between these articular processes. Beyond this bar of cartilage the arches project backwards and inwards as straight bars of cartilage separated from each other above and below, by a wide space. There is no indication of fusion of the laminae with each other as yet. These arches end in sharp points and leave the canal open behind in its full extent.

The/

The processes of the third sacral arch have most nearly approached completion posteriorly. Above and below this they are more widely separated. The posterior sacral foramiva look more outwards than backwards, as in Model 1.

The base of the sacrum approaches more unto the appearance seen in the next model and which will be fully described there. The superior articular processes of the first sacral look outwards and backwards and not inwards and backwards as is the case in the adult. These processes are wider apart relatively to the width of the sacrum and are placed external to the body of the vertebra, (see later).

The coccyx consists of four pieces definitely marked off from one another. The terminal piece has a bifid appearance on its under aspect. Two little tubercles, one on either side, are placed upon the inferior aspect distally. I could find no indication of a fifth piece. Petersen figures a fifth vertebra in L.O. Steinbach holds that a fifth piece is present even in the adult. (Die Zahl der Candalwirbel beim Menschen. Dissertation, Berlin, 1894).

The coccyx is attached to the sacrum at this stage by the bodies alone. There is no connection between the arches. The cornua are small and undeveloped.

The/

The sacral cornua project downwards as small stumps. The transverse processes of the first coccygeal are likewise small and rudimentary.

Viewing the pelvis from behind, the large part that the sacrum takes at this stage in the formation of the pelvis becomes apparent.

General Description of Model No. 3 from an Embryo 11 - 12 weeks old, with Remarks upon the Development of Certain Parts when compared with the Earlier Models.

This model was reconstructed from sagittal sections and was found, when completed, to be slightly higher and also slightly farther back on the left side than on the right. This has given the appearance of a slight distortion. Whether this was due to some alteration in shape owing to pressure before section, (for the specimen had been kept for some months) or to some fault in the technique, I cannot say. Probably, however, the latter was the cause. This does not greatly alter the anatomy and arrangement of parts. The model may therefore be taken as fairly accurate. As the two sides are, in the main, symmetrical we may leave the distortion out of account in the consideration of the anatomy. Hereafter certain measurements will be given with their relations to younger and older foetal pelves (Petersen, Bardeen and Thomson) and to adult pelves (Verneau and Sir William Turner).

Many striking differences from the adult pelvis are brought out in this model which could not be investigated in the natural condition, since the parts are so small. These peculiarities are of course exaggerated/

Taking first the innominate bones and their constituent elements:-

Innominate Cartilages. (Fig. 21-27)

Ilium.

Viewed from without, the general shape of the ilium resembles the ilium of the adult. (see fig. 21). The posterior portion (sacral element) of the iliac expansion is very large and massive. A line drawn upwards from the great sacro-sciatic notch, and continuous with the anterior margin of that notch, meets the crest of the ilium at about the junction of the middle and anterior fourths in the adult. In the model it is much the same but somewhat posterior to this point. This varies a good deal in the adult so that it should not be emphasised too much. It shows, however, that the posterior part of the ilium is as large as in the adult. The part of the expansion posterior to the auricular surface is particularly massive and very thick, having a marked convexity on the inner aspect, towards the neural arches. The sharpest point, which may be taken as the posterior-superior spine, is not the most posterior part of the ilium, but is directed downwards from the inferior aspect of the massive hinder part. (see fig. 21). Both Bardeen and Petersen have remarked the large postero-superior spine in their/

their early models. In my earliest, (older than theirs) this spine is directed backwards, and is sharp and well developed, but nor particularly massive. When considering this region in the three models, it is seen to become gradually more massive and approaches more to the type of the adult. There is a gradual advance then, in this region. Moreover, as exhibited by these models the postero-superior spine gradually comes to occupy a lower place and points more downwards than backwards. This is the case in the adult pelvis.

The antero superior spine is very remarkable in this model. It is large and prominent and curves slightly inwards. This prominence is exaggerated by the presence, particularly well marked in this specimen, of a very deep notch below the spine on the anterior border of the ilium. This is such a striking feature that one would like to see another pelvis reconstructed of the same age for comparison. This deep notch is present in all the models, though more marked in this one. Petersen, in his description, also mentions the fact as occurring in his models. Below this large notch, and well to the inner side of the antero-superior spine, the antero-inferior spine is well developed. This spine is placed at the end of a ridge which runs vertically upwards from the brim of the acetabulum. From/

From the outer side of this spine, at its upper end, the anterior border of the ilium is continued upwards. When this region is studied in the three models we get a good impression of the development and growth of this portion of the pelvis. In model No. 1 the notch is deep but very narrow and the distance between the inferior and superior spines is small. In No. 2 the notch is deep but somewhat wider. In No. 3 the notch is very much wider. In No. 1 the antero-superior spine is not far from the acetabular brim. (20 mm.) But in No. 3 it is raised much farther away (40 mm). So that between these ages there is a marked vertical growth in the anterior or abdominal part of the false pelvis. In the adult the antero-superior spine is still higher, relatively, and farther back. At the same time the notch referred to is much shallower, but also much wider vertically. From this age to the adult state, then, there must be a widening of the notch which results in a raising of the antero-superior spine and a placing of it more posteriorly. This growth in the anterior part of the false pelvis has been referred to in connection with increase in breadth of the ilium as compared with total height of the pelvis in the adult.

The crest of the ilium ascends fairly steeply from the/

the antero-superior spine and then curves gradually backwards to the posterior spine. Viewed from above the crest is S shaped, the posterior end is curved slightly outwards and the anterior slightly inwards. The curve is noticeable even in the earliest model, (No. 1).

The postero-inferior spine is short and rounded and is indeed not well marked. It is much shorter than in the adult. It appears to grow downwards upon the lateral mass of the sacrum. Below the spine there is a flat shelf on the lateral mass which extends down to the third anterior sacral foramina. The postero-inferior spine in the model extends down to a point opposite the lower margin of the second anterior sacral foramen, but in the adult down to a point opposite the upper margin of the third sacral foramen, (i.e., down to the lower margin of the ledge on the lateral mass). In the adult the sacro-iliac cavity extends down to this point (third sacral foramen) but in the model only down to the lower margin of the second foramen. Therefore as age advances the sacro-iliac joint is increased in depth by being continued downwards upon the ledge of the lateral mass.

The deepening of the great sacro-sciatic notch is/

is apparently influenced by this downward growth of the postero-inferior spine. In the model the ilium forms the summit of the arch of the notch and very little of its posterior border - the main part being formed by the lateral masses of the sacrum. In the adult the notch is much deeper in the ilium, i.e., its spine is longer, and a fair amount of the posterior border is formed by the ilium. In the adult the arch rises 10 - 20 millimetres above the apex of the spine; but in the model only 2 - 3 mm. i.e., about .1 to .15 mm. in the natural state.

Professor Thomson has emphasised the point that the posterior part of the ilium is greater in the female than in the male in foetuses from four months onwards at any rate. This is the same as in the adult (Testut.). This is exhibited by a wider sacro-sciatic notch. Thomson therefore holds that in this regard, as well as in many others, the distinctions between male and female is apparent in the foetus. He refrains from measurements of the notch as there are obvious objections to this in so small a pelvis. From his photographs and drawings, however, the notches appear distinctly wider in the female, though some of this appears to be due to the greater backward curvature of the sacrum or perhaps from a different set of the sacrum in relation to the innominate bones.

The/

The measurement he suggested and employed in the adult was from the postero-inferior iliac spine to the junction of the anterior and upper borders of the great sacro-sciatic notch. The ill defined shape of the spine in this model makes it difficult to measure. I have taken, however, that point of the spine which meets the anterior and outer limit of the lateral mass. By this measurement I got 28 mm. (magnified 20 times); therefore the natural distance is 1.4 mm.

None of the characteristic rough areas and spines of a bony pelvis are, of course, yet developed; pressure and tension, in part, at any rate, determining this later. The surfaces are smooth and the edges rounded. Therefore, the area for the origin of the gluteus maximus is smooth and not so prominent as in the bone. The ridge of bone, stretching upwards from the acetabulum to the crest, is not present in this model on the external surface to any extent. From the absence of these two thickenings the external surface of the iliac expansions is straighter than in the adult, there is a slight concavity, however, anterior to the gluteus maximus origin.

On the inner surface of the ilium there is a marked convexity just anterior to the sacro-iliac articulation/

articulation. It commences at the pelvic inlet and for a short distance upwards it is markedly convex. It then runs up towards the crest as a narrower ridge, ending halfway between the pelvic brim and the crest. It has the appearance of a sort of buttress with a broad base at the inlet and tapering off above. Between the convexity and the anterior border of the ilium the surface is concave. This is partly owing to the inturning of the antero-superior spine. Just above the antero-inferior spine there is a short horizontal depression of about half an inch in length. The surface just posterior to the antero-superior spine is convex in the adult, due to the "flaring" of the antero-superior spine more than the rest of the false pelvis. The region corresponding to the iliac fossa, posterior to the ridge running up from the inlet, is concave but not nearly so marked as in the adult bone. The concavity, posterior to the ridge mentioned, connects with the anterior above the ridge. The cartilage here is very thick and shows no thinning as in the adult bone. In the bony pelvis this portion is very thin and often translucent in the adult. In the newly born it is comparatively thick; so that the counter action of the powerful muscles taking origin on each surface no doubt produces the thinning. Along with/

with this thinning, a condensation of the bone in this part takes place so that the bone becomes lighter and at the same time remains strong. Posterior to the iliac fossa the bone again becomes convex and this convexity is very marked posterior to the articular surface.

Ischium.

The outer aspect of the ischial body has assumed very much the shape and appearance of the condition in the adult bone. The surface posterior to the acetabulum is markedly convex. The concavity seen in the adult on the outer aspect of the base of the ischial spine, and continued into the groove between the tuberosity and the acetabulum, is suggested in the oldest model; but in the youngest the surface is full and rounded. The explanation of this is that the ischial spine is directed more inwards than in the adult. In the model No. 1 the spine is directed towards the bodies of the vertebrae and not towards the edge of the sacrum. In the adult the spine is directed towards the edge of the sacrum and points to about the junction of the last sacral with the first coccygeal. In the large model (No. 3) the sharpest point of the spine is directed inwards and towards the one on the other side. This seems to be the apex of the spine and will, when depressed/

depressed and directed backwards, point to about the junction of the sacrum and coccyx. In this model there is a sharpish point directed backwards and downwards towards the second piece of the coccyx. This has the effect of deepening the notch between the spine and the tuberosity. The anterior margin of the great sacro-sciatic notch is full and rounded and, tracing it downwards, it passes more over the base of the ischial spine than over its apex. Whilst the body of the ischium is well developed and much like the adult, the ischial tuberosities are small and undeveloped. They are smooth and rounded and, of course, do not exhibit that rough and irregular appearance of the adult bone. They appear as if placed upon the inferior aspect of the body of the ischium and being at first somewhat stout and gradually tapering off into the ramus. This is particularly the case in model No. 1. In the earliest model the tuberosity is somewhat inverted and so helps in the obliquity of the lateral wall of the pelvic cavity. The same is true in the oldest model, but this is not so marked. There seems then, as if the tuberosities had already commenced to widen. In an eight and a half months female foetus the widening is already well marked although the inner and lower margins of the tuberosities are inturned; but this last holds in the adult also. The sides of the true pelvic/

pelvic cavity in this foetus (8½ months) are apparently as vertical already as they are in the adult. A line drawn from the antero-superior spine, touching the posterior margin of the acetabulum, to the outer margin of the ischial tuberosity, has the appearance of being concave outwards in the adult. In the newly born it is practically straight, and in model No. 3 it has become convex. The convexity is most marked in model No. 1. This is mostly due to the small tuberosities and absence of eversion in the embryo. It is partly, of course, due to the fact that the antero-superior spines have become more everted, in the adult.

The groove so well marked in the adult bone between the ischial tuberosity and the acetabulum is much more shallow in this model, and still more so in the early models. The notch between the ischial spine and the ischial tuberosity is present, and fairly well marked in this model (3); much shallower in model 1.

The inner aspect of the body of the ischium presents in this model a marked concavity. This is brought about by the large ischial spines. These have broad bases and are blunt and rounded. They project well into the pelvic cavity, thus greatly encroaching upon it and diminishing its transverse diameter. They have/

have not the direction observed in the adult, i.e., backwards and inwards; so that their apices do not point towards the edge of the sacrum and coccyx. The concave inner surface of the body is most marked in the oldest model where the spines are particularly large and prominent. The concavity is elongated and runs from about the middle of the posterior border of the thyroid foramen upwards and backwards to near the upper end of the anterior border of the great sacro-sciatic notch. The concavity opens out, and is not so deep in the adult bone, due apparently to the depression of the ischial spine along with the eversion of the lower end of the ischium. The ischial tuberosity is directed, in its long axis, mostly forwards, but also inwards. The ramus of the ischium continues in the same direction for a short distance and is very prominent. Then curving upwards and inwards it meets the pubic ramus. This junction is indicated by a prominence on the anterior aspect of the rami. This is well seen also in model No. 1. Petersen states that it occurred in his model (L O.) . This prominence of the lower part of the ischial ramus and tuberosity is an interesting feature as it is not seen in the adult bone. This seems partly due to a bending backwards of the ischial tuberosities as well as an eversion. But the absence in the adult is/

is also largely due to the relatively great growth in the pubic bone, especially an increase in length of the superior ramus of that bone. This will be referred to again in studying the growth of the true pelvis. Transverse section of the ischial ramus shows that the cartilage is nearly circular in outline. This is also true for the descending remus of the pubis. Petersen states that in L O. the greatest diameter in the ischial rami lay somewhere between the sagittal and coronal planes; for the pubic ramus, in the sagittal plane. Owing to the approximation of the ischial tuberosities towards the middle line in the early models the ischial ramus ascends more vertically than i in the adult.

Pubis.

The descending pubic ramus meets the ischial ramus, as stated, at the most prominent point. Some remains of this prominence are seen in the adult bone. Above this point the pubic ramus curves backwards, inwards and upwards, being still more vertical than the ischial ramus. The anterior aspect is therefore concave, producing a convexity on its inner surface. The pubic ramus is shorter than the ischial.

The pubic body is convex on its posterior surface and/

and mostly from above downwards. The anterior surface is concave slightly from above downwards and convex from side to side. Behind, the bodies come together in the middle line without any depression. On the anterior aspect however there, is in model No. 3, a furrow in the position of the symphysis. At the upper end of the symphysis there is a peculiar depression. This seems difficult to account for, but it is probably due to the fact that, separating the upper ends of the pubic bodies, there is a condensed tissue which, at this stage, has not yet become cartilage. In this model, when drawing the sections, the definite outline of the cartilage was in all cases selected. Thus the condensed tissue in this position has not been represented. In the eight and a half months foetus the tissue separating the pubic bodies at the symphysis is much wider above, and tapers off about the middle to a thin line. The furrow anteriorly can also be explained upon these grounds and is indeed due to the fact that this space is filled up with a strong condensed tissue which will ultimately become the strong anterior ligament. This furrow is present in the articulated adult pelvis; The edges of the furrow being rough and pitted for ligamentous attachment. This gives an irregular outline to this part of the pelvic brim, but it/

it may be taken as the shape of the cartilaginous pelvis at this age. The pubic spines are particularly prominent and project well forwards in this model. In model No. 1 the spines are hardly visible and do not stand out from the rest of the cartilage. The ascending pubic ramus meets the body of the pubis at the pubic spine. The direction of the ramus is forwards and inwards, whilst the crest of the pubis runs straight inwards. Consequently there is an apex at the spine and this helps to exaggerate it. The surfaces of the body of the pubis look forwards and backwards in all these models, whereas in the adult bone the anterior surface looks also outwards. Hence the front of the pelvis has a flat appearance when compared with the adult. This flatness is most marked in model No. 1, and the flatness in model No. 3 is due to the fact that the bodies of the pubes have not yet advances far forwards although the ascending pubic ramus is directed more forwards than in model No. 1. If a vertical plane be taken, passing through the apices of the antero-inferior spines of the ilia, the difference in length of a line perpendicular from this plane to the pubic symphysis demonstrates this flatness of the anterior aspect of the pelvis. This is an important point in the growth of the true pelvis and will be referred/

referred to again when considering the pelvic brim.

The ilio-pectineal eminences are particularly well marked in model No. 3. They give a very large base to the ascending ramus which abuts against the acetabulum. The eminence has an influence upon the brim causing a slight projection upon it. Anteriorly it passes into a large projection which overhangs the thyroid foramen upon its outer side. It also forms an overhanging roof for the cotyloid notch. This large ilio-pectineal eminence helps to exaggerate the concavity on the inner surface of the ischium already referred to.

The Obturator Foramen.

Petersen describes this in L O. as being a relatively small roundish triangle with a lateral hypotheneuse, an upper and inner short side and a lower greater. In model No. 1 the shape conforms pretty much to this description, but there are really no definite angles in it. It is not so angular as the adult foramen. The shape, and the direction of the long axis, alters between model No. 1 and No. 3. In No. 1 the long axis lies between the vertical and the horizontal - slightly more towards the vertical. In No. 2 it has become vertical, and so in No. 3. This is evidently brought about by an increased growth in height of the true pelvis and corresponds with the changes/

changes which occur in the diameter of the acetabulum. The shape of the foramen in model No. 3 is somewhat egg shaped, with the narrow end directed upwards. The outer edge is slightly more concave, as in model No. 1, particularly opposite the cotyloid notch. The foramina look outwards and forwards, more forwards than outwards. The lower end is however modified by the prominence of the ischial ramus so that the direction here is more outwards and, at the same time, upwards. This is particularly the case in model No. 3. In the adult the lower part of the foramen looks more outwards than the upper part. This adult state has been assumed in the eight and a half months foetus. By a depression of the ischial rami, and a spreading outwards of the ischial tuberosities, the adult state would be arrived at. This occurs before birth sometime and probably is associated with the straightening of the coccyx.

Measurements of the Thyroid Foramen.

	Greatest length.	Greatest breadth.
Model No. 1. =	25.5 mm.	18 mm.
(embryo weeks =	1.275 mm.	0.9 mm.)
Model No. 2 =	29 mm.	19 mm.
(embryo weeks =	1.45 mm.	0.95 mm.)
Model No. 3 =	33 mm.	24 mm.
(embryo 11-12 weeks =	1.65 mm.	1.2 mm.)
Foetus (8½ months) =	13 mm.	8 mm.
Adult =	60 mm.	40 mm.

Acetabulum.

The acetabulum faces somewhat more laterally than in the adult. This is most marked in this model (No. 3). The large ilio-pectineal eminences in this model exaggerate this, and thus, viewing the model from the front, not so much of the acetabulum is seen as in the adult. It is, in all three, well developed. In No. 1 and 2 the rim is sharp and well defined; this is due to the fact that the cotyloid ligament (or the dense tissue surrounding the cavity which will form that ligament) has been represented in the model. In model No. 3 the edge of the acetabulum is rounded, since only the cartilage was reconstructed. The cavity in this model, for the same reason, does not appear so deep as in 1 and 2. There was no indication in these specimens of the formation of the cavity from three separate pieces of cartilage, the embryo being much older than that stage. The cotyloid notch is deep and well defined. In models 2 and 3 it is also wide. In model 1, however, it is deep and narrow and must widen out as growth goes on and the acetabulum increases its vertical diameter. The shape of the acetabulum is somewhat different in the models. In No. 1 it is slightly oval, with the greatest diameter lying horizontally. Between this stage and the next/

next (model No. 2), the vertical diameter has increased so that it now equals or exceeds the transverse. This is maintained in the other model and also in the eight and a half months foetus. In the adult the vertical diameter exceeds slightly the transverse.

Measurements of the acetabula.

	Vertical diameter.	Transverse diameter.
Model No. 1 =	28 mm.	33 mm.
(embryo weeks =	1.4 mm.	1.65 mm.)
Model No. 2 =	36 mm.	35 mm.
(embryo weeks =	1.8 mm.	1.75 mm.)
Model No. 3 =	46 mm.	42 mm.
(embryo 11-12 weeks =	2.3 mm.	2.1 mm.)
Foetus (female 8½ months) =	13.5 mm.	12 mm.
Adult =	58 mm.	56 mm.

The rough horse- shoe shaped area seen at the bottom of the acetabulum is represented in the models 2 and 3. In No. 1 it was not made out. In 2 and 3 the area is not horse-shoe shaped, but triangular, with the base directed downwards towards the cotyloid notch and the apex upwards and backwards. The acetabular brim is C shaped, the upper thickened portion of the C corresponding to the prominence running downwards from the ilio-pectineal eminence. Between the lower upturned end of the C and the posterior border of the thyroid/

thyroid foramen is a ledge of cartilage which does not yet present a grooved surface. In the adult bone this groove runs from the outer aspect of the tuber ischii into the rough area in the acetabulum. The rough area appears shut off from the obturator foramen by a ridge of bone running down from the ilio pectineal eminence along the posterior border of the foramen. In the models however this ridge is not developed and the triangular area at the bottom of the acetabulum opens over a rounded surface into the thyroid foramen. There is no undermining of the lower lip of the acetabular brim at the notch, and the surface in front of this slopes gradually towards the thyroid foramen. The sharpening of this lip and the grooving of the surface occurs before birth as is shown in the eight and a half months foetus.

Remarks upon the growth of the innominate bones as exhibited in these models will be given later. I shall now go on to a description of the sacrum and coccyx and their relation to the rest of the pelvis.

Sacrum and Coccyx.

This portion of the pelvis presents many interesting features. The two elements of this part of the spinal column may be taken together, as the description of the coccyx will, in the main, be in relation to the sacrum.

The/

The antero-posterior curve of the column in this region is interesting. Although this curvature affects the whole of the sacrum and coccyx, yet the curve in relation to the bodies of the vertebrae is different in some respects from the curve of the neural arches, and so they must be considered separately. The difference is due to the variation in the size of the spinal canal. The arches will be described later. The sacrum is remarkably straight, there being a very slight antero-posterior curvature so that it is slightly concave anteriorly. If the coccyx were removed, the curve of the sacrum would be seen to be mainly upon the last two sacral vertebrae. The posterior aspect of the bodies of the sacral vertebrae present in continuity a very slight concavity backwards in the upper part - it is almost straight. Below, it is slightly convex backwards, and this passes on to the more marked convexity of the coccyx. The greatest convexity is at the body of the third sacral vertebra. The concavity above posteriorly is exaggerated by the last lumbar vertebra which is in position. It is inclined somewhat backwards. The sacrum, then, in its curvature forms the segment of a very large circle; whilst the coccyx forms the segment of a much smaller circle (see fig. 28). In model 2 the curve on the sacrum/

sacrum is more general and passes on to the coccyx more insensibly than in model 3. Here again, however, the curve is mostly on the last sacral vertebra and the coccyx. The first sacral vertebra is distinctly more prominent anteriorly than the last lumbar or the second sacral. There is thus at this stage (model 3) a promontory; but it is not well defined and takes the form of a fulness across the first sacral. The upper border of the first sacral is rounded like the rest and in no way sharp as in the adult. Perhaps "promontory" is not a good term to use for this fulness of the first sacral; for, if by that term be meant the sharp upper margin of the first sacral, then there is no promontory at this age, for the most prominent part of the vertebra is about the middle of it or slightly above this. The "promontory" aids in the anterior concavity of the sacrum. The last segment of the column (coccyx) is turned sharply forwards especially in its last two pieces. This feature of the sacrum - its straightness - as distinct from the coccyx, is perhaps not what one would expect, since, I think, the general impression is that at this early age there is a marked concavity forwards of the sacrum and that it is not until later that the sacrum straightens out. The sections in this model were sagittal/

sagittal, so there can be no doubt about the accuracy of the curve. Indeed, it was for this reason - to determine the curvature of this portion of the column - that this pelvis was sagittally sectioned.

Of course the curvature of the sacrum in the adult varies a good deal, often being more marked in the female, particularly in the lower part. Certainly in some sacra there is a marked curvature, much more than in the model.

Sir William Turner has remarked that he has found very little curvature in the majority of the sacra that he has examined; and it is only in that form of sacrum known as "Rider's sacrum" that the curve is very marked. Therefore the sacrum of the embryo at this age has assumed the curvature seen in the typical adult bone. The sacrum in an eight and a half months female foetus is, as regards curvature, almost identical with that in model No. 3.

The curvature just described has applied to that of the bodies only. It is different in the case of the arches. When the summits of the neural arches are joined the line is almost straight in the sacral part. It is only the coccygeal that curves forwards. This is of course due to the wider canal above. Thus this line/

line would meet another, drawn along the posterior aspect of the sacral bodies, at a point below.

The bodies of the vertebrae are, in relation to the other parts, much as in the adult. But the sacral canal is quite different and exhibits some very interesting points. It is very large - a good deal larger than the bodies - and is thus very different from the adult. This is of course to accomodate the cord which extends well down into the sacral canal. The canal is elliptical in shape, almost kidney shaped, with the concavity against the bodies of the vertebrae. In the adult, as is well known, this portion of the spinal canal is very small and triangular in shape. The canal is, in the embryo, larger than the bodies above, but below it becomes more circular and somewhat narrower than the bodies of the vertebrae. The canal narrows gradually from above downwards. The cord, in this embryo, extended down to between the fourth and fifth sacral vertebrae in the middle line, and below that the membranes were seen to be attached to the last coccygeal vertebra.

The sacral canal is still open posteriorly in its whole length. The arches consist of the pedicles, the distal ends of which are joined by a longitudinal bar/

bar of cartilage. This represents the articular processes. In sagittal sections of this cartilage the positions of the joints between the articular surfaces was marked by a transverse band of more deeply staining tissue. There was no actual joint cavity but the articular processes were separated by this band of condensed tissue, so that the joint took more the form of an amphiarthrosis. There being no cavity, the continuity is represented in the model as a solid bar of cartilage. The position of the joints is well indicated on this bar by small tubercles situated upon the outer side of the posterior sacral foramina and opposite their centre. Behind this the arches are represented by curved bars which end separately before the middle line is reached. The third sacral arch is most nearly complete posteriorly, and it is also the deepest so that already there is an indication of the formation of definite laminae on this arch particularly.

The arches project backwards behind a line joining the most posterior parts of the iliac bones. This is very different from the adult where the first sacral arch - spine - lies about an inch in front of this line. It must be remembered, when considering this point, that there are as yet no spines upon the arches in the embryo and hence the condition is the more remarkable. Several/

Several processes would appear to effect this change from the condition in the embryo to that in the adult. First of all there is a great diminution in the size of the sacral canal so that there is, so to speak, a flattening and falling in of the arches. The continued growth of the posterior extremities of the ilia until adult life, as Petersen holds, has its effect. Litzmann held, but Petersen does not agree with him, that pressure of the posterior ends of the ilia upon the sacrum drove it forwards, and lastly the change of axis of the sacrum whereby the upper end is driven forwards and the lower end correspondingly backwards when the weight of the head and trunk is put upon the sacrum. Whichever of the processes, and probably all play some part, is the most important in bringing about this change, it is certain that the sacrum is more centrally placed in the pelvis in the adult than in the embryo.

The changes that occur in the sacral canal are of very great interest. With the retraction of the spinal cord from the sacral canal, or rather, with the growth of the canal away from the cord, a change occurs in the sacral canal. It changes from its elliptical to a triangular shape. There is thus an apparent falling in of the sacral arches behind the retreating cord. This may bring the sides of the arches together and so help in completing the arches and forming the spines. It is not a mere falling in of the arches, however,/

however, for there is a movement of the bases of the arches inwards carrying along with them the articular processes (see later). In the model the posterior ends of the ilia appear to clasp the sacral canal, whereas, in the adult, there is very often a wide space between the arches and the posterior, inner aspects of the ilia. With this movement of the sacral arches the posterior sacral foramina are directed backwards, whereas in the embryo they are directed largely outwards above, and the first foramen looks outwards against the ilium.

Not only are the arches flatter in the adult, but also the bodies and lateral masses. The difference is well seen when the two sacra are viewed in profile. This flattening is brought about no doubt largely by the influence of the powerful muscles attached, in addition to the causes given above for the flattening of the arches.

The lateral masses are well developed in this model and the connecting bars of cartilage (i.e., the costal and transverse processes) have much increased in thickness so that now the bar between the first and second anterior sacral foramina exceeds the depth of the foramen. The costal element of the base, forming/

forming the anterior aspect of the ala, has markedly increased in depth and now appears much as in the adult in this respect. The masses are very thick antero-posteriorly. They are wide above where the ilium is attached. This wide part continues below the postero-inferior spine of the ilium as a flat shelf, already referred to. Below this the mass narrows and ends abruptly at the transverse process of the last sacral vertebra. This termination is more abrupt than in model No. 2 where the transverse process of the last sacral is not so long as in this model. Viewed in profile the lateral mass is placed opposite the central part of the antero-posterior depth of the sacrum, so that the sacral arches project behind and the rounded bodies in front. In the adult the posterior aspects of the lateral masses are placed opposite the posterior aspects of the bodies of the vertebrae. But in the model (embryo) the masses are placed farther back, especially below, so that the intervertebral foramina look straight out against the inner surface of the masses. The fact that the lateral masses are placed farther back below than above reacts upon the direction of the posterior sacral foramina which, above, look almost directly outwards, but below, backwards and outwards. The intervertebral foramina are/

are still larger, to accomodate the large nerves. They are relatively much larger than the adult foramina, so that they do not grow so rapidly as the surrounding parts.

It is interesting to note that the posterior aspects of the bodies of the sacral vertebrae are hollowed out as in the adult bones, i.e., under the posterior common ligament.

In studying these pelves one is impressed with the enormous size of the sacrum, in relation to the rest of the pelvis, in the embryo. This is well seen in fig. 24, when compared with fig.25, from an adult pelvis.

Base of the Sacrum.

This is large in proportion to the surrounding parts. The promontory, as stated, is not well developed. This is not to be expected however since we are dealing with the cartilaginous pelvis where the borders are all rounded - and this is no exception. The first sacral is, however, distinctly more prominent and forms a connection between the posterior ends of the pelvic brim. This prominence is carried on each side into the brim in a general sweep, there being no dip from the promontory on to the lateral masses anteriorly as is seen in the adult bone.

The/

The alae are interesting. They are well developed and, as mentioned before, the costal elements are thick. The ala sweeps outwards from the body of the first sacral and terminates abruptly in an elevation. From this elevation there is a drop on to the inner aspect of the ilium. This is not seen in the adult, where the sacrum passes insensibly on to the ilium. This elevation and drop is present in model No. 2, though not so marked as in this one. The outer limit of the ala is beyond the widest part of the brim. This elevation is highest at the posterior and outer limit of the ala and fades away anteriorly so that it makes no impression upon the brim of the pelvis. The elevation ends in a tubercle posteriorly. Posterior and internal to this is a depression which separates the tubercle from the superior articular process of the first sacral. The articular process is so placed that the intervertebral foramen looks outwards and forwards. In the adult the superior articular processes are the highest points of the sacrum, but in this model they appear on the same level with the elevations mentioned on the lateral masses.

An interesting point is that the superior articular processes are much wider than in the adult, both absolutely/

absolutely, and relatively to the rest of the base. In the adult they are placed behind the body of the bone, whereas in the embryo they are placed beyond - more external to - the body. This is what would be expected from the very large sacral canal. There is a movement inwards, then, of these processes, along with the bases of the arch, as is well shown by measurements:

	Breadth of sacrum at the base.	Width between the articular processes.
adult =	118 mm.	50 mm.
Model =	114 mm.	80 mm.

From these figures it will be seen that the distance between the articular processes in the adult is relatively much less than in the embryo. This change in relationship of the articular processes is not merely a passive one due to more rapid growth of the surrounding parts, but there seems to be an active movement in the articular processes - a movement inwards and, at the same time, a rotatory movement - whereby the articular surfaces of the superior processes will come to look inwards and backwards. The superior articular processes of the first sacral look, not inwards, but outwards and backwards, so that a rotation must occur. As a result, the inferior articular processes of the fifth lumbar vertebra look inwards and forwards/

forwards as in the adult. Hence this rotatory movement must affect the lumbar vertebrae - the lower one at any rate - as well.

The displacement and rotation of the articular processes inwards will have the effect of giving the sacrum more the characters of the adult bone. The processes would be brought behind the bodies of the vertebrae and nearer to them, as in the adult. The side of the sacral arches would be straightened and flattened so that the canal would be triangular in shape, and the relative breadth of the articular processes to that of the base of the sacrum would approach more to that found in the adult. The articular processes are placed farther back, as would be expected, in the embryo.

The relation of the upper surface of the ala to the ilium has been noted. There is a curious drop between the sacrum posteriorly and the ilium. The ilium has the appearance of sweeping under the posterior end of the elevation.

Articulation of the Sacrum with the Ilium.

Here is a convenient place to consider this question. Not having reconstructed the complete embryo, or having made sections of it, I am not able to say to which number in the series of vertebrae the upper/

upper end of the ilium is attached. E. Rosenberg (Ueber die Entwickelung der Wirbelsäule u. s. w. Morphologische Jahrbücher, Bd. I, 1876) held that the ilium was at first placed opposite the 26th, 27th and 28th vertebrae, and that it moved up one later and became now attached to 25th, 26th and 27th. Petersen was inclined to agree with him for, in L O., he found the ilium attached opposite the 26th and part of the 27th and 25th.

In model No. 1 the ilium is placed much as in model No. 3. It has therefore assumed the adult position in its upper limit. It is placed opposite two vertebrae and part of a third, below. In model No. 3, counting from the tail end, the upper limit is opposite the upper end of the 10th vertebra. The lower end opposite the upper margin of the transverse process of the 8th vertebra, i.e. the third sacral. The sacrum has five pieces and the coccyx five and they are quite distinct from one another. The articular surface is broad above and narrows below. It has not however the sharp lower end seen in the adult, which lower end is, I believe, added with the down growth of the postero-inferior spine. The articular surface reaches down to the level of the middle of the second anterior sacral foramen in model 2. In model 3, down to the level of the lower margin of that sacral foramen. In the/

the adult, down to the upper margin of the third sacral foramen. The articulation has not been represented in the models, but the lateral masses are represented as fused to the ilia. This was done for strength. The outward aspect of the articulation can be studied in the models and, when taken with the sections through this part, a correct impression can be formed of its extent.

The articulation of the sacrum with the ilium is, at the brim, well forwards. This appearance is exaggerated by the absence of a definite sharp promontory, and by the set of the sacrum. If a line be drawn joining the articulations at the brim, the promontory very nearly touches it; but in the embryo the first sacral lies well behind this line. If another line join the most prominent points of the ilio-pectineal eminences we then get the plane of the brim divided into three compartments, an anterior, middle and posterior. It is interesting to compare these in the model (3) and adult in their relative depths in the conjugata vera:

		Adult.	Model.
Posterior segment	=	3 mm.	15 mm.
Middle "	=	60 mm.	47 mm.
Anterior "	=	37 mm.	22 mm.
Conjugate, in pelvis measured, was	=	100 mm.	84 mm.

These/

These figures show that the sacro-iliac joints are, at the brim, well forwards. They also demonstrate the fact that the symphysis is relatively farther forwards in the adult than in the embryo. This is a rough indication of the greater growth of the pubic elements in the brim.

The foetal sacrum is larger in proportion to its surroundings than in the adult. The sacrum is not narrow and is indeed broader in its widest part than it is long. Obstetricians have held that it is only after birth (Burns, Principles of Midwifery, said, only at the 10th year) that the transverse diameter of the brim comes to exceed that of the conjugate. Fehling (Die Form des Beckens beim Foetus und Neugeborenen. Archive für Gynaekologie, Bd. X) had already pointed out that the transverse exceeds the conjugate in the newly born. Thomson (Journal of Anatomy and Physiology, 1899) found that in his foetuses the transverse exceeded the conjugate diameter. In model No. 3 the transverse is found to exceed the conjugate considerably. The promontory has been taken in the middle line on the first sacral, above its centre. We get:

Greatest transverse diameter	=	102 mm.
Conjugata vera	=	84 mm.

This/

This is much as in adults where the average male measurements are, according to Verneau,

transverse diameter		=	130 mm.
Conjugate	"	=	104 mm.

Zaaijer's formula (Sir William Turner) for pelvic index is $\frac{\text{Conjugate diam.} \times 100}{\text{Transverse diam.}}$

This gives an index in the model — index

$$\frac{84 \times 100}{102 \text{ mm.}} = 82.3$$

This is much the index of the adult.

Sir William Turner in his challenge Report quotes figures from several authors; and, for males, the index varies between

(J.J. Watt)	87.9
and (Sir Wm. Turner)	77

There can therefore be no doubt about the fact that the transverse diameter is greater than the conjugate even in the early embryo (11-12 weeks). This is due to the relatively wide sacrum in the embryo, the greatest width being 114 mm., whereas the transverse at the brim is only 102 mm. The greatest breadth of the sacrum in the embryo is not at the brim, as in the adult, (Verneau) but farther back. In spite of this, however, the sacrum occupies a large part of the brim.

It/

It takes a relatively greater share in the formation of the brim than in the adult. Measured by calipers, which is merely a rough method, the sacrum occupies about $^1/3$ of the brim, and the innominates $^2/3$ in the adult. That is, by joining the symphysis pubis with each sacro-iliac joint at the brim, and these with one another, we get practically an equilateral triangle. In the embryo the sacrum occupies much more than $^1/3$. Consequently we get in this case an isosceles triangle with a wide base which is placed opposite the sacral element. These facts are borne out by the following figures representing the precentage for the various elements at the various ages:

	Sacrum %.	Ilia %.	Pubes %.
(Engel) Adult	26.2		
(Fehling) Newborn female	28.9	29.2	42.8
(Fehling) Newborn male	30.4	26.9	42.2
(Petersen 29 mm. embryo	37	31.7	31.3
(Bardeen) 33 mm. embryo	34	33	33
My model yielded	37.38	29.90	32.71

From these figures we see that the sacrum gradually takes less and less part in the formation of the brim as we trace from the early embryo up to the adult state. We learn also from this table that the pelvis occupies in the adult and newly born a much greater share/

share of the brim than in the embryo, and hence the growth is greatest in this part of the brim. This has the effect of pushing the bodies of the pubes forwards and causing the anterior surfaces to look also outwards. This has a marked influence upon the anterior aspect of the pelvis. The flatness is removed, the rami are straightened and the thyroid foramina assume a different shape.

To return to the sacrum. Many authors (Wood, Article on the Pelvis in Todd's cyclopoedia; Playfair, Science and Practice of Midwifery; and others) have said that the narrow transverse diameter in the foetus and newly born was due to the relatively narrow sacrum. It has been shown that there is no narrow transverse and so no cause need be sought for something which does not exist. Almost the reverse would seem to be true: that the transverse diameter is greater because of the relatively wide sacrum.

To show the relation of the sacral width to the complete pelvic breadth in the embryo, when compared with the adult, we can take figures given by Verneau for the adult.

Breadth of pelvis taken at 100

Greatest/

	Greatest breadth be-tween iliac crests.		Greatest breadth of sacrum at inlet.				Index.
Adult male	255	:	108	::	100	:	42.5
" female	245	:	109	::	100	:	44.4
Foetus male) (Thomson							44.5
" female)							47
Model No. 3	212	:	110	::	100	:	51.8

So that the sacrum is wider, even at the brim, relatively to the pelvic breadth, in the embryo than in the adult; there being a gradation from embryo (early) up through later foetuses to the adult, where the index is lowest.

When we compare the sacral breadth with the transverse diameter of the brim we get a striking difference in the index in the embryo and adult.

Verneau gives in adults:-

	Maximum transverse diameter at inlet.		Breadth of sacrum at inlet.				Index.
Adult male	130	:	108	::	100	:	83
female	135	:	109	::	100	:	80.7
			Maximum breadth of sacrum.				
Model No. 3	102	:	114	::	100	:	111.7

The transverse diameter is taken as 100.

This great difference is due to the relatively narrow transverse diameter - narrower than the base of the/

the sacrum - in the embryo. Thomson found this the case also in his older foetuses. On the other hand the transverse in the adult is much wider than the sacrum. The widest part of the sacrum in the adult is, according to Verneau, at the brim; but in the embryo the widest part is altogether above and behind the brim. There is therefore a great growth in breadth of the pelvic brim anterior to the sacro-iliac joints. This growth in breadth is evidently, from these measurements, not due to an increase in the breadth of the sacrum; but it is due to a growth in the innominate bones anterior to the sacrum - namely, the ilia. (see table, of percentages for the brim, above).

In the embryo, we have a very wide sacral base, much wider than the transverse diameter of the brim. The transverse is however greater than the conjugate in spite of the fact that the promontory is placed relatively far back. This last fact is however counteracted by the flatness of the anterior portion, and consequent diminution in conjugate diameter. To arrive at the condition found in the adult the changes in the brim are:- a great elongation of the pubes so that at birth (see table) the percentage of pubic brim has greatly increased. This increase in the pubic element/

element seems to be at the expense of sacral element and the iliac element remaining constant. The growth in breadth is no doubt due largely to the iliac portions which become more curved just anterior to the sacro-iliac joints, but I believe that the great growth in the pubes increases not only the antero-posterior diameter but also helps largely in increasing the transverse diameter.

The brim in model 3 presents a somewhat irregular, ill-defined appearance. Much of this is due to the fact that the definite outline of the cartilage has been adhered to in this model. The irregularity at the symphysis has been already referred to; also the large ilio-pectineal eminences which have their effect upon the brim. Posterior to the eminences there is a marked depression on each side which separates the eminence on each side from the ridge or convexity which passes up towards the iliac crest from the brim. The depression is brought out in the model because the place seemed to be occupied by a condensed tissue staining deeply and not yet forming cartilage. The brim is more or less rounded and has not the sharp margin seen in model No. 1. In model 1 the condensed tissue which lies along this edge has been included. It is not, however, yet cartilage; but perichondrium, thicker in/

in some places than others.

The plane of the brim is markedly oblique in this model when it is placed in the position in which the antero-superior spines are on the same plane with the pubic spines. Of course this position is not natural to the embryo, but to the adult; and is put in this position merely to compare with the adult. The obliquity is most marked in the sacral element of the brim.

Petersen gives the following table from Litzmann showing the relative angles, in adult and newly born, between the last lumbar and first sacral; between the conjugata vera and last lumbar; and between the conjugata vera and the upper sacral. He adds his findings in L O.

	Angle of last lumbar with upper half of sacrum.	Angle of conjugata vera with last lumbar.	Angle of Conjugata vera with upper sacral.
Adult male	131°	126.50°	104.2°
" female	143.6	115.4	99.2
Newly born male	151.25	143.5	65.75
female	150.25	142.5	67.2
L O. female	176.4	121.4	62.4
Model 3. male	164	125	65.

From/

From these figures we see that the sacro-vertebral angle has become more acute in model 3 than in L c (a younger embryo); that the angle between the conjugata vera and the last lumbar has become greater - which continues until birth and then diminishes, because of the development of the lumbar curve with the erect attitude; and that the angle between the conjugata vera and the upper sacral has become much as in the newly born.

Length of Sacrum compared with Breadth, in Model 3.

Professor Thomson made measurements of the sacrum of his foetuses after dissection. He admits however that the length measurement was open to error since the parts are very small and readily amenable to changes in shape and position from manipulation. He however made out that both the male and female sacra (particularly the male) belonged to the platyhieric group of Turner (i.e., where the breadth equals, or exceeds, the length). This model definitely belongs to this group and the index was found to be:-

	Length of Sacrum.		Greatest Breadth.	Index.
Model 3.	100	:	114	:: 100 : 114

Thomson found that the length equalled the breadth in females and nearly so in males, so that the female just/

just came into the platyhieric group. The real measurements of the embryo are:-
Length of sacrum = 5. and breadth = 5.7.

In a very small pelvis, where a millimetre makes a tremendous difference, this fraction .7 of a millimetre, is a comparatively great difference.

Comparing the measurements of the natural size and that of the model, magnified 20 times, we can see the value of reconstruction for the purpose of making measurements more accurately.

Comparison of the Length of the Sacrum to Total Pelvic Height.

Pelvic height is taken at 100.

	Height of Pelvis.	Length of Sacrum.		Index.
adult male (Verneau)	220 mm.	: 105 mm.	:: 100	: 47.7
" female	197	: 101	:: 100	: 51.2
foetus male (Thomson)	42	: 21.6	:: 100	: 51.4
" female	41	: 22.7	:: 100	: 55.3
Model 3. male	182	: 100	: 100	: 54.2

So that the total pelvic height is relatively greater in the adult, and this is just what we would expect. The innominate bones grow more rapidly in length than the sacrum.

Cavity of the True Pelvis.

The ischial spines project markedly into the cavity/

cavity in model No. 3; not so much in model No. 1.

Comparing the distance between the ischial spines with the transverse diameter at the brim.

Transverse diameter at brim taken as 100

		Transverse at brim.		Distance between ischial spines.		Index.
(Verneau)	adult male	130 mm.	:	90 mm.	::	100 : 69.2
	" female	135	:	108	::	100 : 80
(Thomson)	foetus male	21.2	:	12	::	100 : 56.6
	" female	20.8	:	14	::	100 : 67.3
	Model No.3, male	102	:	56	::	100 : 54.9

From these figures we see that there is a gradual rise in the index from the early embryo up to the adult state and this is due to the relatively greater breadth between the ischial spines in the adult. The marked concavity of the inner surface of the ischium in model No. 3 has been mentioned before. It is more marked than in the adult, due to the projections of the ischial spines. In a foetus of eighty and a half months it is still fairly well marked but less than in model 3.

The outlet of the pelvis is greatly narrowed by the approximation of the ischial tuberosities and the marked curve forwards of the tip of the coccyx. The antero-posterior diameter of the outlet is greater than the transverse in spite of the tip of the coccyx being well/

well forwards.

The antero-posterior, measured from the tip of the coccyx to the lower end of the symphysis pubis = 60 mm.
Transverse diameter = 55 mm.

This was the case in L O. measured from the tip of the sacrum and also from the coccyx.

In the newly born the transverse is still less than the antero-posterior diameter, more so in the male.

In the adult, however, different figures are given by different observers. It is generally regarded I think as a fact that the transverse at the outlet is less than the antero-posterior diameter.

Thomson (Osteology, Cunningham's Text Book of Anatomy) gives the transverse at the outlet as less than the antero-posterior, in both sexes.

Litzmann gives the opposite in both sexes. The following table is instructive and shows results obtained by Litzmann in adults and newly born. Petersen's figures for L O. are added, and those in model 3. The table is taken from Petersen's paper.

	Female		Male.		Female	Male
	new born	adult	new born	adult	L O.	Mod.3
Inlet.						
Conjug.vera	1	1	1	1	1	1
Diam. trans.	1.07	1.292	1.11	1.294	1.16	1.214
Diam.oblique	1.05	1.20	1.11	1.294	1.1146	1.14
Cavity						
Diam.recta	0.901	1.19	0.93	1.18	0.79	0.869
Diam.trans.	0.908	1.151	0.89	1.14	0.866	0.916
Dist/						

Table contd.

	Female		Male		Female	Male.
	new born	adult	new born	adult	L O.	Mod.3
Cavity Dist.spina Ischii	0.749	0.96	0.748	0.91	0.662	0.6
Outlet Diam recta	0.97	1.05	0.99	1.07	From Coccyx 0.895	0.714
Diam. trans.	0.741	1.154	0.70	1.153	0.533	0.654

An interesting index is that obtained by comparing the transverse at the brim and that at the outlet; taking transverse at the brim as 100:

	Transverse at brim.		Transverse at outlet.				Index.
Model 3, male	102	:	55	::	100	:	53.9
Adult female	122	:	86	::	100	:	70.49

Comparing these results we see how ischial tuberosities have widely separated, thus increasing the index. They illustrate well the slope on the lateral pelvic wall in the embryo.

This slope is brought out in the following table where Fehling gives measurements for adult, newly borns, and younger foetuses. L O. is added by Petersen. Bardeen gives male measurements in embryo 33 mm. long. Model 3 measurements complete the table.

		Inlet.	Cavity.	Outlet.
Adult		100	92	81
Newly born	female	100	84	76
	male	100	82	65
Foetus 30-34 cm.	female	100	88	.70
	male	100	87	60
L O.	female	100	74.7	46.1
33 mm.	male	100	75	54
Model 3.	male	100	75.4	53.8

In this table the transverse at the outlet in the adult is greater than in the male. In the models of Petersen and Bardeen this is reversed so that this important point in determining sex characters does apparently not hold in the embryo. Bardeen suggests that it is difficult to emphasise the very slight differences by means of a wax model; because a certain amount must be allowed for errors in technique. I believe that if the model be made large enough these characters will be brought out sufficiently, if they be present at all. In models of Bardeen and Petersen sex characters were not well made out, but in such a model as No. 3 of an older embryo there may be differences to be made out.

Depth of the true pelvis in relation to the total pelvic height.

Pelvic/

Pelvic height taken as 100.

	Total Pelvic height.	Depth of true pelvis.		Index.
(Verneay) adult male	220 mm.	: 105	:: 100	: 49.6
female	197	: 101	:: 100	: 47.2
(Thomson) Foetus male	42	: 21.6	:: 100	: 47.1
female	41	: 22.7	:: 100	: 45.8
Model 3. Male	182	: 72	:: 100	: 39.5

The small index in Model 3 is due to the relatively great pelvic height; and from this we see that the false pelvis has greatly increased in height, since the stage of model No. 1, where the total pelvic height is just about twice the height of the true pelvis. Between the ages of Model No. 1 (beginning of 9th week) and the older foetuses examined by Thomson there is, then, first a growth in height of the false pelvis and then later a growth in depth of the true pelvis. The depth of the true pelvis was measured from the inner point of the ilio-pectineal eminence to the lower, inner limit of the ischial tuberosity.

The coccyx consists of five pieces, four of which are well defined. There is only an indication of a fifth piece. The cornua of the first vertebra are well developed and now are attached to the sacral cornua - an advance upon Model 2. They thus complete the fifth sacral inter-vertebral/

vertebral foramina. The transverse processes of the first vertebra are much larger than in model 2. The remaining vertebrae are comparatively large and do not taper away greatly, so that the coccyx ends somewhat abruptly in a fairly blunt end.

Measurements of Model No. 3 - being the Cartilaginous Pelvis of a Male Embryo 11-12 weeks old and 60 mm. long, exclusive of legs; magnified 20 diameters.

Professor Thomson has laid emphasis upon the necessity of working with wet preparations when making measurements of foetal pelves, because in dry specimens there is distortion as a result of shrinkage. This is necessarily conformed with here.

Although Bardeen found very little difference between his male pelvis and Petersen's female pelvis of about the same age, yet it is hoped that, with the measurements of model 3 given in full, it may be useful for a comparison with a female model when such shall be reconstructed. Bardeen compared his model with the description given by Petersen of L C. He had not actually compared the two models and he suggested that some differences might be discovered by so doing.

The measurements employed are those adopted by Sir William Turner in his "Challenger" reports ("Report on the Human Crania and other Bones of the Skeleton" Challenger Reports - Zoology, Vol. XVI.) and also employed by Professor Thomson ("Sexual Differences of the Foetal Pelvis" - Journal of Anatomy and Physiology/

Physiology, Vol. XXXIII, 1899).

	Model.	Embryo.
Breadth of Pelvis (between widest points of iliac crests)	212 mm.	10.6 mm.
Total height of Pelvis (highest point of crest to most dependent part of ischium)	182 mm.	9.1 mm.
Breadth-height index = $\frac{182 \times 100}{212}$	85.8	85.8
Breadth between antero-superior iliac spines	206 mm.	10.3 mm.
Breadth between postero-superior iliac spines	92 mm.	4.6 mm.
Breadth between ischial tuberosities (all three from outer limits)	91.5 mm.	4.575 mm.
Breadth between ischial spines	55 mm.	2.75 mm.
Greatest diameters of cotyloid cavity vertical	46 mm.	2.3 mm.
transverse	42 mm.	2.1 mm.
Greatest diameters of obturator foramen vertical	33 mm.	1.65 mm.
transverse	24 mm.	1.2 mm.
Subpubic angle	67°	67°
The sides of the pelvis are inclined towards each other at an angle of about (measured by the lines passing through the most extreme points of the iliac crests and ischial tuberosities and meeting below)	70°	70°

Dimensions/

	Model.	embryo.
Dimensions of True pelvis :		
Brim - Conjugate diameter (measured from a point above the centre of the first sacral)	84 mm.	4.2 mm.
Transverse diameter	102 mm.	5.1 mm.
Pelvic or Brim index = $\frac{84 \times 100}{102}$	82.35	82.35
Oblique diameters		
left	96 mm.	4.8 mm.
right	92 mm.	4.6 mm.
Cavity of Pelvis Antero-posterior	73 mm.	3.65 mm.
transverse	72 mm.	3.85 mm.
Inferior sagittal diameter (from tip of last sacral to inferior end of Symphysis)	73 mm.	3.65 mm.
Coccygeo-pubic diameter	60 mm.	3 mm.
Intertuberal diameter (between inner borders of ischial tuberosities immediately below smallsciatic notch)	57 mm.	2.75 mm.
Depth of pubic symphysis	27 mm.	1.35 mm.
Depth of pelvic cavity (from brim opposite ilio-pectineal eminence to inner, lower edge of the ischial tuberosity)	72 mm.	3.6 mm.
Interobturator/		

	Model.	Embryo.
Interobturator width (taken from inner margins of thyroid foramina)	30.5 mm.	1.525 mm.
Inter-cotyloid width (taken from the bottom of the cotyloid cavities at the inner end of the upper border of the triangular area)	97 mm.	4.85 mm.
Breadth between antero-inferior iliac spines	163 mm.	8.15 mm.
Dimensions of Individual elements:		
Ilium: (right)		
Height length (from upper corner of rough area at bottom of acetabulum to highest point of crest)	125 mm.	6.25 mm.
Breadth	143 mm.	7.15 mm.
Iliac index = $\frac{143 \times 100}{125}$ =	114.4	114.4
Breadth of Innominate bone (measured from upper end of Symphysis pubis to postero-superior iliac spine)	123 mm.	6.15 mm.
Pubis:		
Length (measured from upper part/		

	Model.	Embryo.
part of rough area in acetabulum opposite ilio-pectineal eminence to Symphysis)	55 mm.	2.75 mm.
Pubo-innominate index = $\frac{\text{Pubic length x 100}}{\text{innominate breadth}}$	44.7	44.7
Ischium:		
Length (measured from junction of upper and posterior borders of rough surface in acetabulum to most depending part of tuber ischii)	61 mm.	3.05 mm.
Innominate Index = $\frac{\text{100 x breadth of Innom.bone}}{\text{Height length}}$ = $\frac{123 \times 100}{182}$ =	67.5	67.5
Ischio-innominate index = $\frac{\text{ischial length x 100}}{\text{pelvic height}}$ = $\frac{60 \times 100}{182}$ =	32.9	32.9
Sacrum = Length	100 mm.	5 mm.
Breadth	114 mm.	5.7 mm.
Sacral index = $\frac{114 \times 100}{100}$ =	114	114
Coccyx:		
Length	57 mm.	2.85 mm.
Breadth/		

	Model.	Embryo.
Breadth (measured across extreme width at base)	46 mm.	2.3 mm.

Professor Thomson found in his foetuses that the breadth of the ilium was, relatively to pelvic height less than in the adult, and he was led to assume that the bone grows more rapidly in breadth than in total height. He gives:-

	Height of Pelvis		Breadth of Ilium.				
(Verneau)							
adult males	220 mm.	:	164	::	100	:	74.5
" females	197 "	:	156	::	100	:	79.1
(Thomson)							
Foetus males	42 mm.	:	29.3	::	100	:	69.7
females	41.1	:	27.8	::	100	:	67.6
Model No. 3 male	182	:	143	::	100	:	78.5

The proportions are thus much what is found in the adult, in the embryo of this age, 11-12 weeks. From this stage on, one would expect that the true pelvis would grow more rapidly than the false so that the proportions of the true to the false would become more as in the adult. This may occur for a time, and so the total depth would be relatively greater than the breadth of the ilium in the foetus than in the adult.

It is interesting to compare the innominate indices in embryo, older foetuses, and adult. The index increases/

increases gradually from the embryo up to the adult, and shows that the growth in width of the innominate bone is proportionately greater than its increase in height.

(Thomson)	Index.
Adult male	87.1
" female	93
Average foetal	
male	73.3
female	74.6
Model No. 3	
male	67.5

Professor Thomson states that the iliac crest is higher in the male than the female. He takes a line from the antero-superior to the postero-superior iliac spines and drops a perpendicular from this to the highest point of the crest.

In the model we find

		embryo.
Left	76 mm.	3.8 mm.
Right	70 mm.	3.5 mm.

Summary of Most Important Facts.

Between the stages of models 1 and 3 there is a marked development of the innominate bones. In model 1 the breadth of the ilium is almost equal to the total pelvic height and thus we get a very high index. This is due to the very low iliac expansions. The depths of the true pelvis is just about half the total height of the pelvis. By the next stage the height has increased whilst the breadth of the ilium has not. In model 3 the iliac expansions have assumed something of the shape of the adult bone. They have grown very much, both in height and breadth. The total height being now nearly three times as much as the depth of the true pelvis. Between this stage and the adult there is a greater growth in the true pelvis, in height, than in the false which grows more in breadth of the ilium.

The conspicuous antero-superior spine has been noted, with the deep notch below it. This notch is narrow in models 1 and 2, much wider in model 3, and still wider and much shallower in the adult. This suggests an interesting manner of growth of this portion of the pelvis. There is a rapid development of this abdominal part of the false pelvis. First the/

the growth affects most the part of the anterior border between the acetabulum and the notch (as is seen in models 1 and 2). Later the growth goes on more rapidly in the upper portion, whereby the notch becomes much wider and shallower, because the antero-superior iliac spine is raised higher up and carried backwards.

The relatively great development of the sacral portion of the ilium has been noted in all these models, and in models 2 and 3 the posterior ends of the iliac expansions are massive, with the spines directed downwards. The postero-superior spine, in the earliest model, is directed backwards.

The development of the adbominal portion of the ilium is greater, between these models and the adult, than of the posterior (see measurements from anterior margin of the great sacro sciatic notch to postero-superior spine, and antero-superior spine).

The short postero-inferior spine of the ilium in the models has been remarked. It evidently increases downwards and extends the sacro-iliac joint to the level of the third anterior sacral foramen.

In model No. 1 the splay of the lower part of the false pelvis is very marked. The upper part is much more vertical. In model 2 the "flaring" of the ilia is/

is slight and the summits of the crests are inturned.

The "flaring" is more marked in model 3, though nothing like what is found in the adult. The amount of splay in the embryo is determined by the pull of the abdominal walls due to the large liver (Petersen); so that the iliac expansions lie in the body wall and do not project as they do in the adult.

The ischial tuberosities are small and undeveloped. In model 1 they are somewhat inturned. In 2 and 3, are perhaps straighter. The ramus of the ischium is very prominent. Between the last embryo and birth there is a marked change in the width between the ischial tuberosities. This is due mostly to the increase in transverse diameter of the pelvic cavity, but even at this age (at birth) there is some slight eversion of the tuber ischii. With the separating of the tuber ischii there is a straightening of the ischial ramii, the tuber ischii apparently moving backwards slightly. The Pubes however moves forwards by the growth in the superior ramii and this brings the descending pubic ramus more into line with the ischial ramus.

By this growth of the pubes forwards, the anterior aspect of the pelvis becomes less flat and the pubic bodies have their anterior surfaces directed outwards and forwards instead of forwards, as in the models.

The/

The thyroid foramen becomes more vertical as it is traced from the earliest model,and assumes the adult direction with the movement forwards of the Pubes and the straightening out of the rami.

The curve in the sacro-coccygeal element of the column has been seen to be, expecially in model 3 (11-12 weeks), mainly in the coccyx and that the sacrum is remarkably straight. In model 1 there is no suggestion of a promontory. In model 2 the first sacral is slightly more prominent. In model 3 there is a distinct connection across the middle line between the posterior ends of the pelvic brim. This may be regarded as a promontory. The first lumbar vertebra is placed at a slightly different angle, so that there is a sacro-vertebral angle of 164°.

The sacrum is large in comparison with the rest of the pelvis. It is much wider relatively to the pelvic breadth in the embryo than in the adult. Its transverse diameter is greater than its vertical. The sacral canal is very large and elliptical in shape in the upper part. Above,it is wider than the bodies of the vertebrae. The arches have developed considerably since model 2, and the coccyx is now (in model 3) connected to the sacrum by its cornua. The sacral canal/

canal is still open posteriorly. The superior articular processes of the first sacral are wider apart absolutely, and relatively to the width of the sacrum in model 3 than in the adult.

The evolution of the posterior aspect of the sacrum from the embryo to the adult has been discussed. It is a very interesting feature. Between the stages of model 1 and model 3 the sacrum has generally developed a more solid appearance. In model 1 the anterior sacral foramina are comparatively large, and the costal processes narrow. In model 3 the costal processes have greatly thickened, and the first one forms a strong, deep, anterior aspect to the ala.

In the true pelvis the sacrum occupies a large part of the pelvic brim. It gradually takes less part in the brim until the adult state is reached. The iliac percentage seems to vary very little, whereas the pubic greatly increases. From this it appears that growth at the brim has been greatest in the pubic element; least in the sacral element; and midway in the iliac element. The great growth in the pubic element accounts for the increase in the antero-posterior diameter of the brim; but this antero-posterior diameter is diminished again by the forming of a definite promontory and the pushing of this/

this forwards. The increase in the transverse diameter of the brim is due to the growth in the iliac portion of the brim, which is more rapid than the growth in breadth of the sacrum. It may be influenced indirectly by the marked growth of the Pubic element.

In the embryo, the sacrum at the base is wider than the transverse diameter of the inlet. This shows that the wide sacrum is the cause of the greater transverse diameter over the conjugate; and this, in spite of the fact that the promontory is not well developed. This last factor however is balanced by the growth forwards of the anterior part of the brim as age advances. Taking the conjugate diameter as 1, we find that the transverse diameter of the brim in the embryo occupies a place about midway between that of the adult and the newly born. This is probably due to the fact that the sacro-vertebral angle in the newly born is not yet marked; so that the conjugate is relatively longer in the newly born than in the adult and the early embryo. (See Petersen's table - after Litzmann).

The true pelvic cavity gradually increases in transverse diameter, as age advances, from the early embryo up to the adult life, (see table). The outlet increases accordingly in diameter also.

Viscera and Pelvic Floor in Model No. 3, (being the Pelvis of a Male Embryo 9-10 weeks old, magnified 20 diameters). (See figs. 4-16 and 37.)

Although the cartilaginous pelvis has been the most important part in this investigation, yet I thought, that a reconstruction of the form of the organs, and in their relation to the hard parts, might be of value. After I had worked through the sections and reconstructed the model of the hard parts and viscera in situ, I was led by certain interesting points in the sections to reconstruct a model of the genito-urinary apparatus in the male specimen. (see figs. 31 and 32.)

Professor Keibel of Freiburg has reconstructed some very beautiful models of the pelvic region of the embryo. One is a model of the pelvis of a female embryo. It shows all the structures from the skin to the hard parts, and is represented in section through the mesial plane. The form of the organs is not shown, since the undifferentiated mesoblast is represented as filling up the space between the viscera. He has also reconstructed a series of models illustrating the development of the genito-urinary apparatus in the female. (The models I have seen are in the Anatomy Department of the Edinburgh University).

To show the organs and their connections better, the/

the pelvis has been reconstructed in two sections, an upper and a lower portion. If this had not been done, the expanded peritoneal cavity above would have hidden the structures below in the true pelvis. The section is made where the cavity begins to expand in the false pelvis. Thus the upper portion contains: the genital glands and their ducts; the upper end of the bladder with the folds of peritoneum enclosing the hypogastric arteries; the pelvic colon; upper ends of the ureters and the expanded peritoneal cavity. The skin and body wall have been reconstructed in part anteriorly. The lower section shows the main contents of the true pelvis. The blood vessels and nerves have not been represented. Thus it contains:- the rectum, peritoneal cavity, wolffian ducts lying side by side in a common envelope, the bladder and lower ends of the ureters, and a supporting tissue lying on either side of the ureters, wolffian ducts and peritoneal cavity. In this portion also are represented the levatores ani, coccygei and obturator internus muscles.

Various coloured pigments have been employed to make the various structures stand out more clearly. Pale blue has been selected for the hard parts to suggest that these are cartilaginous and not osseous.

The Musculature of the Pelvic Floor.

Here, as true a representation is given as was possible; but it must be said that, in trying to reconstruct muscle, it is often very difficult because of the indefinite outline, particularly at this early age. A definite outline is, of course, necessary to accurate work. I was particularly anxious to reconstruct the levatores ani, and these can be taken as accurate, for their outline was quite definite in every section. The coccygeus muscle was not nearly so definite, some sections being quite good, and others apparently not. So that I do not put much weight upon their representation in the model. The only other muscle represented is the obturator internus in its pelvic part.

On the right side the levator ani and coccygeus have been partly cut away to show the curve of the rectum, and the other parts within the pelvis, from the side. On the left side the muscles have been left attached.

Obturator Internus.

Nothing much requires to be said about this muscle except in its relation to the levator ani, and that will be/

be given later. It is seen covering over the obturator foramen internally, and attached to the lateral wall of the pelvic cavity. From below, it is seen forming the outer wall of the ischio-rectal fossa.

Coccygeus.

This muscle is represented on the left side of the model. Its upper and posterior border has a peculiar shape, passing at first straight back from the ischial spine and then dipping before it becomes attached to the sacrum. It may be that the attachment to the sacrum should be represented higher up; but I could not make out such an attachment. The muscle has a comparatively wide origin from the region of the ischial spine and passes backwards, downwards and inwards to be attached to the lower part of the lateral mass and the upper three pieces of the coccyx. There is a hiatus at one part between the lower end of the sacrum and the coccyx. It forms an arch between the two, completing the last anterior sacral foramen for the passage of the anterior division of the last sacral nerve. The attachment of the coccygeus and the obturator internus to the ischium is not well defined along the posterior border of that cartilage. The muscle and hard parts are difficult to represent in their/

their relation to one another here. A more or less accurate outline of the cartilage is represented by the colours.

Levatores Ani.

There is here, I believe, an accurate representation of the floor of the pelvis as it is formed by these muscles. The muscles are practically perpendicular, with their surfaces looking outwards and inwards. In the adult, of course, the surfaces look more outwards and inwards than superiorly and inferiorly; but in the model they are much more so. This is due to the relatively narrow outlet in the embryonic pelvis, which is well shown by the narrow ischio-rectal fossae. Viewed from below, the levator ani is seen arising in the region of the ischial spine. In the sections there was no direct origin from the cartilage. It seemed to arise from the soft parts - coccygeus and obturator internus - though indirectly from the perichondrium. Its posterior end has a peculiar curved appearance, well seen on the right side below, forming the posterior margin of the ischio-rectal fossa. The general direction is antero-posterior until the posterior limit is reached when the muscle curves almost directly outwards to its origin from the ischial region. On the right side, below, the muscle has been cut away to show/

show the rectum; but on the left side it is left intact and is seen surrounding and supporting the rectum below. Below the rectum the muscles meet in the middle line and there fuse together. The muscle, seen surrounding the rectum at its lower end, is the external sphincter in the formation, for it was not yet definite muscular tissue. The anterior margins of the muscles, higher up, support the prostatic urethra and end anteriorly, on either side of the middle line, in rounded thickened ends.

Before considering the ischio-rectal fossae, the upper margin (origin) of the muscle will be considered. The origin posteriorly corresponds to about the level of the middle and lower thirds of the acetabulum. Anteriorly it is much higher, as would be expected. It is therefore somewhat higher than in the adult. Posterior to the pubes it arises from the inner aspect of the obturator internus. This part of the origin extends almost horizontally backwards. It then dips suddenly and is separated from the obturator internus by a definite space filled with areolar tissue. The upper margin, in this part, is therefore free (see fig. 11). This seemed a peculiar feature to me, but Dr. Waterston tells me that it is a recognised condition in the adult. This little space is definitely shut off from the ischio-rectal fossa below.

Ischio/

Ischio-rectal fossae. see fig. 9)

These fossae are, as stated, narrow, owing to the small outlet of the pelvis. On cross section they appear pear-shaped with the narrow end directed backwards, the curve being due to the curve of the levator ani posteriorly. Thus the levator ani forms the inner wall and the posterior limit. The outer wall is formed by the obturator internus. These two muscles come together and form the upper limit of the fossae. They come together considerably below the upper margin of the levator ani. It is probable that the fascia on the outer aspect of the levator ani (anal fascia) becomes attached at this level to the fascia over the obturator internus, (the parietal pelvic fascia). This seems to demonstrate that the ischio-rectal fossa extends up to the origin of the levator ani from the lateral wall; but that it does not extend nearly to its upper margin - indeed only, apparently, half way. No definite fasciae could be made out. It is possible that the ischio-rectal fossae extend higher up in the adult when the outlet widens; for although the anterior part of the levator ani appears to have a wide vertical origin from the obturator internus, yet much of that appearance may be/

be due merely to the close approximation of the two muscles. No space could be made out any higher up than has been indicated in the model; so that the upper limit of the fossa is much below the upper limit of the levator ani.

The relation of the fossae to the lower end of the rectum is interesting. The fossae are placed farther back, apparently, than in the adult. This is only apparent, however, and is due to the rectum opening straight forwards. With the evolution of the anal canal the lower end of the rectum comes to have its proper relation to the ischio-rectal fossae.

VISCERA.

Rectum.

The rectum descends fairly straight, for the full length of the sacrum, keeping about the same distance (5 mm.) from the four lower sacral vertebrae. Opposite the first sacral, it bends slightly forwards and so gradually leaves the vertebral column. This occurs along with the peritoneal cavity. Opposite the last lumbar it bends suddenly to the right and has now a mesentery, and is, therefore, pelvic colon. The mesentery commences opposite the lower edge of the fourth lumbar, to the right of the middle line slightly, and the attachment extends upwards and to the right. The mesentery rapidly increases in length. At the upper end of the fourth lumbar vertebra the mesentery attachment is in front of the right margin of the body of that vertebra. When the rectum (or pelvic colon) turns suddenly to the right it lies above the right testis and in close relation to it. The diameter of the rectal tube increases gradually, but uniformly, from above downwards.

The main interest is in the lower part of the rectum. Below the sacrum it bends almost directly forwards along with the coccyx. But its curve is more acute than the coccygeal because the rectum leaves the column/

column here to the extent of about 16 mm., opposite the third coccygeal vertebra. There is, at this stage, no anal canal, and the rectum opens directly forwards below the genital eminence. There is a slight groove on the inferior wall, about an inch from the anus; evidently the first indication of the backward bending of the lower end of the canal, in the formation of an anal canal.

The rectum must open forwards as it is controlled by the hard parts. The straightening out of the coccyx, and the formation of an anal canal, evidently go hand in hand. The coccyx tends to atrophy and the rectum goes on growing, and thus we get the necessary length of rectum to bring the change about. Associated with the change in direction and position of the lower end of the rectum is the formation of the perineal body. The change in the lower end of the rectum brings it into the adult relationship to the ischial fossae which, at this early stage, lie posterior to the anal opening.

The Peritoneum.

This has been represented in one colour, except where it covers organs which it was desired to map out. A different colour has been used over these organs although they may be covered by peritoneum. In some places/

places a certain thickness of the wax is left for strength; but the inner surface represents the peritoneum. Mostly the peritoneum is in the upper section. The cavity of the peritoneum extends lower down, relatively to the bladder, than in the adult. It reaches a point in the model about a line joining the ischial spines, and this is placed about 20 mm. lower than the opening of the bladder into the urethra. These measurements are only approximate as it is difficult to measure this in the model.

Bladder and Ureters.

Portion of the allantois, which is to form the bladder, is shown in the lower part of this model. Its inner wall was smooth, in this specimen, and not rugose. The posterior wall is vertical, but the anterior slopes rapidly towards the urethral opening. The anterior wall is carried round to the sides to form lateral walls. The trigonum is well seen with the openings of the ureters. These openings are, in this model, about on a level with the upper border of the pubes. The urethral opening, well defined at this age, lies behind the bodies of the pubes, about 15 mm. below the upper border. The anterior aspect is closely applied to the pubic symphysis. In Professor Keibel's models the bladder is well separated from the pubes. The walls of/

of the bladder are comparatively thin above the ureters.

The part of the allantois represented in the upper section (fig.12) will largely become obliterated. It is shown covered by peritoneum in its full extent, and, at the sides, are folds of peritoneum enclosing the hypogastric arteries. These are shown cut across at the level of the umbilicus, and they pass to the upper surface of the allantois before entering the umbilicus. The lumen appeared closed at the umbilicus, and could not be traced into the cord.

The ureters pass from the bladder immediately upwards and backwards. Professor Keibel's models represent the ureters as passing, at first, deeper into the pelvis before ascending on the posterior wall. The genito-urinary apparatus will be described more fully in the separate model. In the model we are describing we see the urethra opening upon the surface at the base of the glans penison the genital eminence. (See fig. 8).

The Testes.

These are large structures and fill up a good part of the lateral aspects of the false pelvis. They lie in the postero-lateral angles of the peritoneal cavity, covered by peritoneum. They are attached to the posterior/

posterior wall by a short mesentery through the epididymes. The left extends higher than the iliac crest. The right is depressed below the crest by the liver, which occupies the lateral aspect of the false pelvis at this age. Its shape is consequently altered, and it appears with its long axis lying more horizontally than in the left. It is also broader and shorter than the left, which is elongated, with its long axis in the sagittal plane. The epididymis on the left side is placed upon the posterior and inner aspect of the organ. On the right side it is mostly behind, but at the lower end the epididymis projects forwards from under the external surface of the gland. The testes are placed high in the false pelvis and their lower ends lie at about the position of the internal abdominal ring. There is no definite pitting of the peritoneum, but the cavity is lowest laterally in the position of the internal ring. So that everything is ready for the descent into the inguinal canal - whether that be passive or active on the part of the testes. (Berry Hart "Descent of Testicle" Journal of Anatomy and Physiology, April, 1909). There is as yet no scrotum, the genital folds being small and narrow.

The wolffian ducts pass downwards and inwards from/

from the lower ends of the epididymes, so that, with a sliding descent, the appearance seen in the adult will be attained. That is, the vasa deferentia will ascend upon the inner side of the epididymes. The ducts pass downwards and inwards across the hypogastric arteries and ureters and are ultimately enclosed in a common tissue (see later). The very beginning of the Wolffian duct crosses the hypogastric artery, so that there must be an enormous elongation of the vas to allow of the descent of the testis into the acrotum.

Reconstruction Model of Genito-Urinary Apparatus. from the same specimen as last, (i.e. 9-10 weeks). figs. 31 and 32).

The kidneys have not been reconstructed. The left testis was chosen since it was evidently least affected by pressure and would give more the proper shape of the organ. This, of course, must vary.

The bladder and allantois, with the complete urethra (as it is at this stage), are shown opened up. Portions of the ureters are attached.

Bladder, Urethra and Ureters.

A good view is obtained now of the full extent of the bladder and allantois above. The posterior wall of/

of the bladder is much the thickest, and this gradually thins off towards the front. Above the actual bladder the anterior wall again thickens as the umbilicus is reached. Nothing outside the muscular coat has been represented in the bladder; so that the external surface of the model is the muscular coat. There is very little diminution in the lumen of the allantois until near the umbilicus. The whole interior has the appearance of a much elongated bladder. The ureters appear, even so early, as if opening obliquely through the bladder wall. They pass from the bladder directly upwards and backwards, and not at all downwards, as in Professor Keibel's female models.

The urethra has been opened by dissection in its full extent. The upper prostatic part is already well formed, but the verumontanum is very large and long, extending the full length of the prostatic urethra. It projects into the lumen as a deep ridge and gives the urethra, on cross section, a semilunar appearance, with the concavity directed backwards and downwards in varying degree. At first this part is directed downwards, and then downwards and forwards into the next portion. At the upper end, the Wolffian ducts open into the urethra upon the verumontanum. Each opens separately on either side of the middle line. In/

In the middle line is a third opening representing the lower ends of the Mullerian ducts. These have fused together and only the lower ends are present. This opening - the uterus masculinus - extends backwards into the posterior wall for a short distance between the Wolffian ducts. In transverse section, just below the openings of the Wolffian ducts, one canal is represented in the section, shut off from the urethra, so that the uteris masculinus forms a cul de sac, with the lower end below the level of the opening into the urethra (see fig. 36). This cul de sac extends for a short distance upwards between the Wolffian ducts. The wide prostatic tube passes forwards into a very narrow portion about half as long as the first part. In front of this it again opens out into a slightly wider part to form the first part of the spongy urethra. At the base of the glans the urethra dips downwards and opens upon the under aspect of the genital eminence. There is no sign of grooving of the under aspect of the glans which ends in a hammer-like extremity.

The urethra is lined by epithelium several layers deep - the deepest cells being columnar. Into the substance of the glans a solid bar of epithelium extends from the under aspect. It forms a narrow septum extending forwards from the base, where it is/

is deep, to a point behind the apex of the glans and where it is not nearly so deep. There is as yet no sign of grooving upon the under aspect of the glans; but there is some tunnelling into the base from behind where the epithelium is continuous with that of the urethra and below with that over the surface of the glans. This tunnelling from the base has been noted by J. E. Spicer ("The Development of the Male Urethra, . . ." Journal of Anatomy and Physiology, April, 1909.

The urethra is surrounded by cellular mesoblastic tissue, deeply staining with haemalum. In the genital eminence this is well supplied with blood vessels. This cellular tissue is represented in the model, in part.

Testis and Wolffian Ducts.

Here the testis is about twice as long as it is broad, though this must vary somewhat. The epididymis is comparatively large and is attached by a short mesentery to the posterior abdominal wall. The Wolffian duct leaves its lower end and passes towards the middle line where it lies side by side with the opposite duct in a common tissue. The Wolffian duct is very short as has been noted. The Wolffian ducts thus/

thus pass down through a structure which is well defined. At first this structure narrows slightly and then widens out again, and so forms an elongated, oval organ, flattened from behind forwards. Below, it apparently becomes absorbed into the posterior thickened wall of the prostatic urethra. Above this it is separated from the posterior bladder wall by a space. Still higher up it lies against the bladder. It extends some distance above the openings of the ureters. (See fig. 31). Four photographs are shown, (see figs. 33-36) of cross section of this organ, and they show the three tubes below. Still lower the single cul de sac referred to is seen. Above, there are only two tubes, lined by columnar epithelium. As yet there are no seminal vesicles. These bud out later from the Wolffian ducts; and I believe the interesting structure just described to be the precursor of the seminal vesicles - from which their mesoblastic coats will be derived.

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Examination of Figures.

The models are all reduced in the photographs. The amount of reduction is stated in each case. The sections, as stated, were magnified 20 diameters, in the three models.

Figs. 1,2,3 are of Model No. 1 (of pelvis from embryo at the end of the second month).

Fig. 1. Lateral view (size - .58 of model)

Fig. 2. From above (" - .58 of ")

Fig. 3. Anterior view(" - .54 of ")

Figs. 4 - 16 are from model No. 2 (of pelvis from embryo between 9th and 10th weeks).

Fig. 4. Right lateral view of upper section showing:- lumbar vertebrae, upper part of right ilium, and expanded peritoneal cavity in front, with part of body wall. (size .58 of model).

Fig. 5. Right lateral view of lower section showing sacrum, coccyx and lower part of ilium, ischial tuberosities turned well forwards, genital eminence and part of body wall behind the genital folds. The rectum is seen deep down. (Size .51 of model).

Fig. 6. Left lateral view. Dark part in front of ilium/

ilium is peritoneum (from without). Anterior to this is skin (lighter colour) (size .56 of model).

Fig. 7. Left lateral view of lower section of same pelvis. Dark parts represent muscle - coccugeus, levator ani, and obtürator internus in thyroid foramen. Anterior to cartilage the body wall is seen in section. (size .54 of model).

Fig. 8. Lower aspect of same pelvis (painted). Shows Rectum and urethra opening on the surface. Muscle attached to coccyx on the left side. (size .47 of model).

Fig. 9. Same (unpainted). Shows curve of sacrum and coccyx. Neural arches well seen. Note ischio-rectal fossae. (Size .47 of model).

Fig. 10. Upper aspect of pelvis (unpainted). Shows:- Hard parts posteriorly and laterally, Peritoneum cut across. Testes lying on either side. Rectum curving to the right. Upper end of bladder anteriorly, with hypogastric arteries. Expanded peritoneal cavity. Part of body wall. (size .502 of model).

Fig. 11. Upper aspect of lower section (unpainted). Shows:- Levator ani deep down, with space referred/

referred to in the text. In the middle line from before backwards:- bladder, Wolffian ducts in common envelope (not delineated), peritoneal cavity, rectum (solid), sacrum, (size .51 of model).

Fig. 12. Lower aspect of upper section (unpainted). Shows:- Ilia and sacrum, body wall in front. In middle line:- bladder, peritoneal cavity. Deep down, the outer aspect of the peritoneum. (size .53 of model).

Fig. 13. Posterior view of upper section (painted). Shows:- Pelvis cut obliquely. Lumbar vertebrae and ilia. Dark - the soft parts. (Size .58 of model).

Fig.14. Posterior view of lower section (unpainted). Shows:- Large sacrum with posterior sacral foramina looking well outwards. Posterior ends of ilia, ischium, etc. (size .53 of model).

Fig. 15. Anterior view (unpainted). (Size .48 of model).

Fig. 16. The same (painted). Shows:- Rectum opening forwards. Thyroid foramina looking well forwards above. Prominent acetabula, and ischial tuberosities directed forwards. Genital eminence. (Size .49 of model).

Fig.17/

Fig. 17. Microphotograph from Embryo No. 1 (at end of 8th week). Section, about the pelvic brim.

Magnified about 11 diameters. Shows:- In middle line - Pubic symphysis, bladder, Wolffian ducts, peritoneal cavity, rectum, sacrum (with notochord), spinal cord. Very large spinal nerve trunks passing from cord between body of vertebra and lateral masses. Venous spaces in cavity, with nerves (dark).

Specimen stained en bloc.

Figs. 18-20. Microphotographs of sections from embryo No. 2. (9-10 weeks).

Fig. 18. Through false pelvis - slightly oblique. Section seen from below - large gland on the right side. Bladder with hypogastric arteries. Rectum in front of the last lumbar vertebra, with ureters and hypogastric arteries lying to the side. Large nerve passing through intervertebral foramen. Shows waxy liver guides. (magnified about 7.4 times.

Fig. 19. Section through true pelvis low down, somewhat oblique, at level between 3rd and 4th vertebrae. Shows:- Urethra passing forwards, supported/

supported posteriorly by the rounded anterior margins of the levatores ani. Posteriorly, lateral masses and neural arches (magnified about 13.7 diameters).

Fig. 20. Section still lower down through last sacral vertebra (oblique).
Rectum opening forwards supported by levatores ani. Farther back, coccygei attached to the sacrum (magnified about 11.5 diameters).

Fig. 21-24 and 26-27 are of model No. 3 (of pelvis from an embryo 11-12 weeks old).

Fig. 21. Lateral view of right innominate cartilage. Shows:- Short postero-inferior spine, and ledge on lateral mass below. Large antero-superior spine. Prominent ischial ramus. (size .5 of model).

Fig.22. Internal view - model in construction. Shows:- sacro-coccygeal curve - mostly on coccyx. Marked spine of ischium turned inwards, with concavity above. (Size .5 of model)

Fig. 23. Anterior view of same pelvis. Shows:- Peculiar base of sacrum. Acetabula directed well outwards. Prominence of the ischial rami. Pubic arch, and notch at upper end of symphysis pubis. (size .52 of model).

Fig. 24. Posterior view of same model. Shows:- The/

The comparatively large sacrum. Arches nearing completion - especially the third sacral. (Last lumbar shown complete, to strengthen the arch - not really yet complete). (Size .51 of model).

Fig. 25. Adult pelvis, to compare with fig. 24. Comparatively small sacrum. (Size .41 of normal).

Fig. 26. Same model from below. Shows:- Prominent ischial spines and rami. Prominent antero-superior spines. (Size .48 of model).

Fig. 27. Same from above.
Note. Base of sacrum. Very prominent ischial spines. (Size .48 of model).

Fig. 28 - 30. Microphotographs of sections from preceding embryo (11-12 weeks).

Fig. 28. Slightly to one side of the middle line. Shows:- Curve of column, and arches cut across. Fifth piece on coccyx. First sacral most prominent. Ossific centres in upper two sacral.

Fig. 29. Section farther cut. Shows:- Articular processes of sacrum. First sacral very prominent. Ischial ramus cut across. Ilio-pectineal eminence above.

Fig. 30/

Fig. 30. Still farther out. Shows:- Lateral mass of sacrum. Ischial spine and, below, the ischial tuberosity. Ilio pectineal eminence above. (All three 28-30, magnified 8.9 diameters).

Fig. 31-32. Models of genito-urinary apparatus of embryo 9-10 weeks old. Models aremagnified 20 diameters.

Fig. 31. Shows cavity of bladder, and urethra in its full extent. Ureters opening into the bladder. Testis and tubes - darker colour. Portion of genital eminence.

Fig. 32. Same from the outside. Shows:- Ureter curving upwards. Posterior to bladder, seminal vesicles with Wolffian ducts separated from the bladder. Light part anteriorly is genital eminence. (size in both, .53 of model).

Figs.33-36. Sections of pelvis (of embryo 9-10 weeks) to show Wolffian and Mullerian ducts.

Fig. 33. Shows:- Wolffian ducts passing down through common structure.

Fig. 34. Shows:- central canal of fused Mullerian ducts.

Fig. 35. Shows:- the three tubes opening separately into the urethra.

Fig. 36/

Fig. 36. Shows:- Cul de sac of uterus masculinus in posterior wall of urethra.
(sections 33-36, from above downwards; all magnified 36 diameters).

Fig. 37. Section of testis, from embryo 9-10 weeks. Note the clear edge, round the organ, of connective tissue - tunica albuginea.
Magnified 50 diameters.

Fig.1.

Fig.2.

Fig.3.

Fig.4.

Fig.5.

Fig.6.

Fig.7.

Fig.8.

Fig.9.

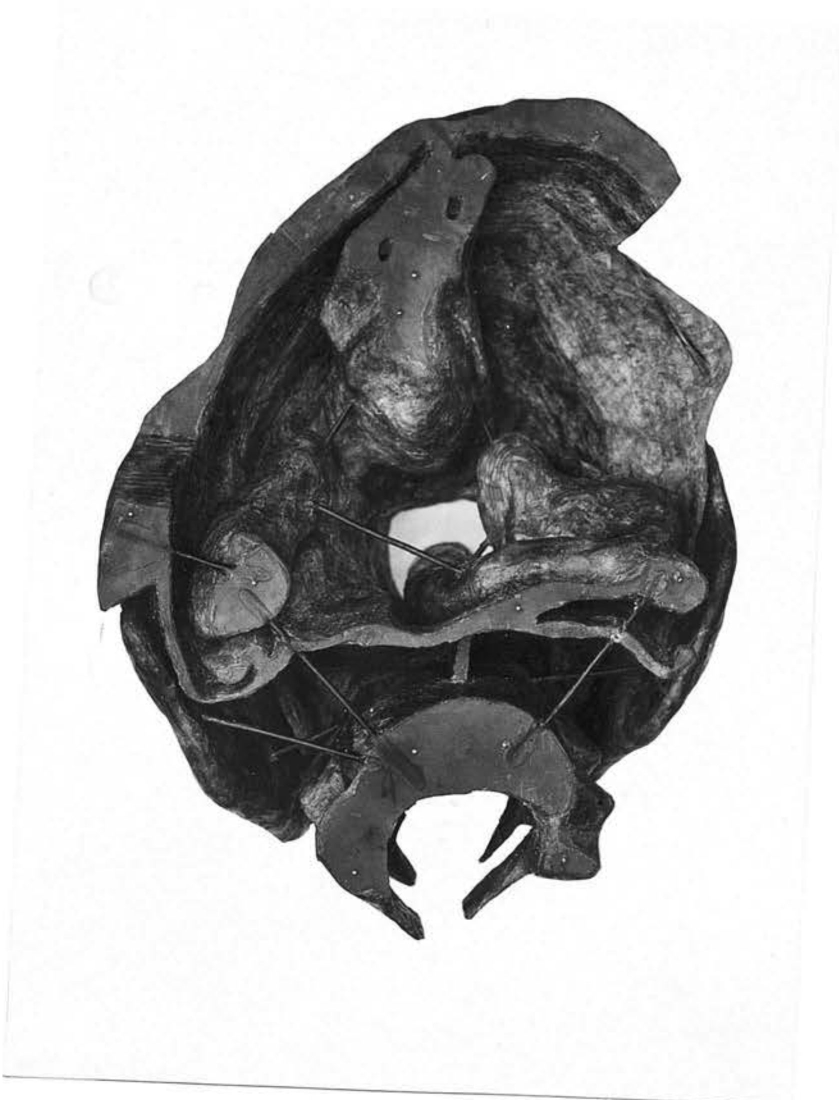

Fig.IO.

Fig.11.

Fig.12.

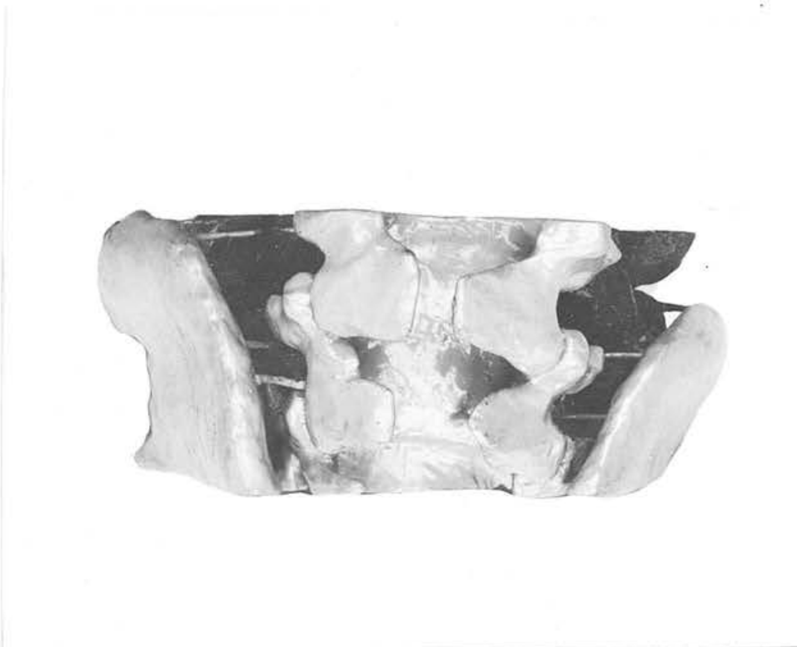

Fig.13.

Fig.14.

Fig. 15.

Fig. 16.

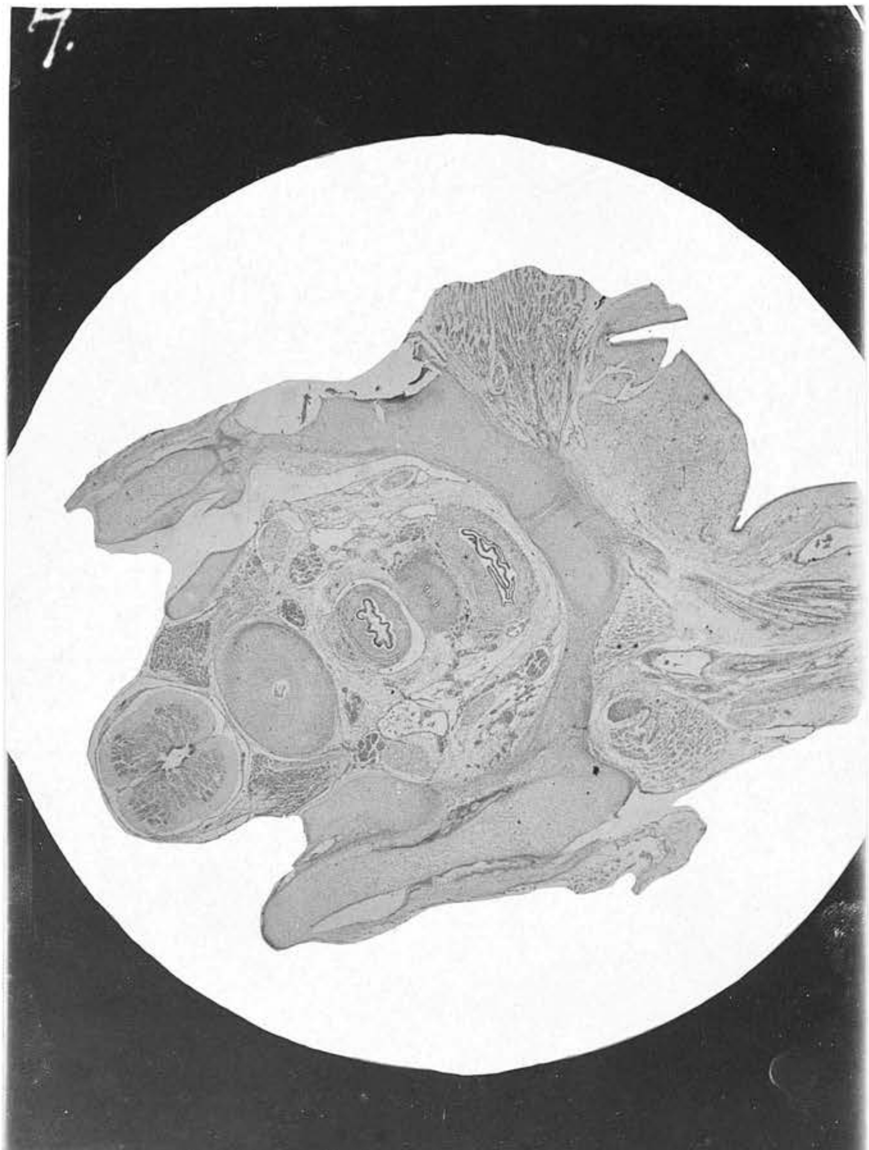

Fig. 17.

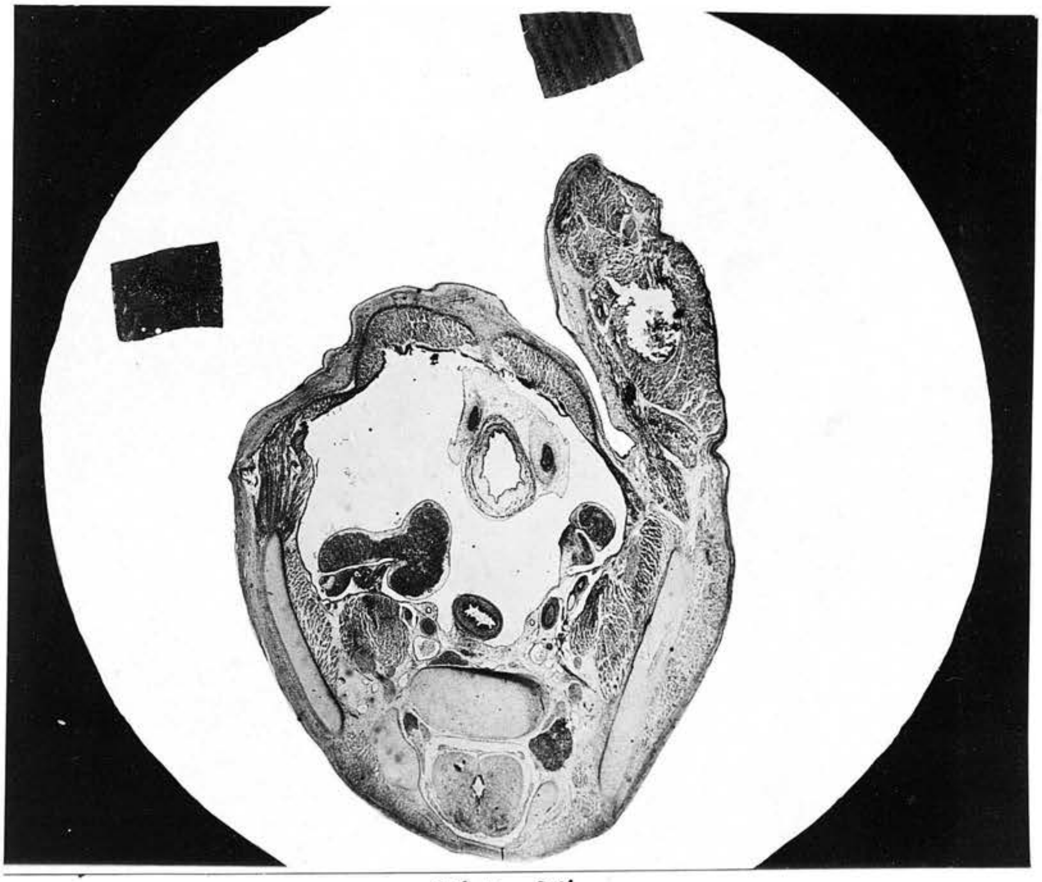

Fig. 18.

Fig. 19.

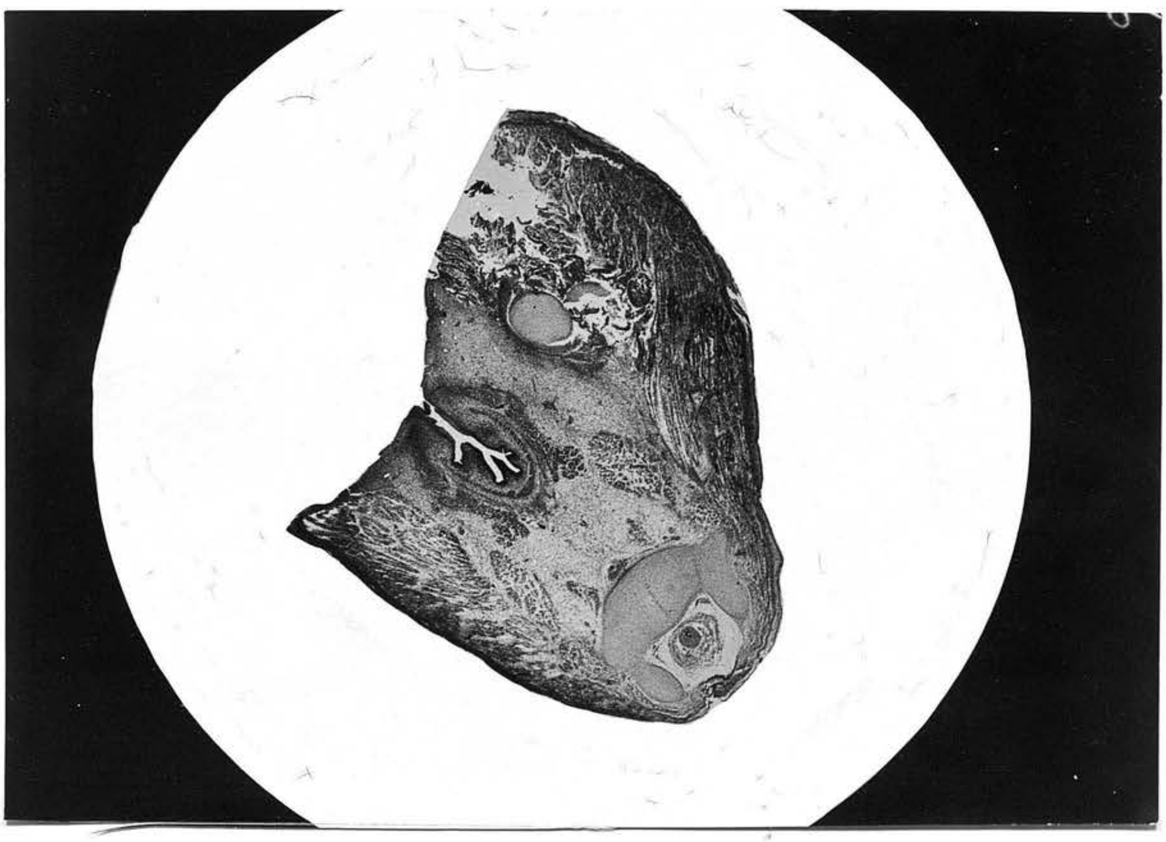

Fig. 20.

Fig. 21.

Fig. 22.

Fig. 23.

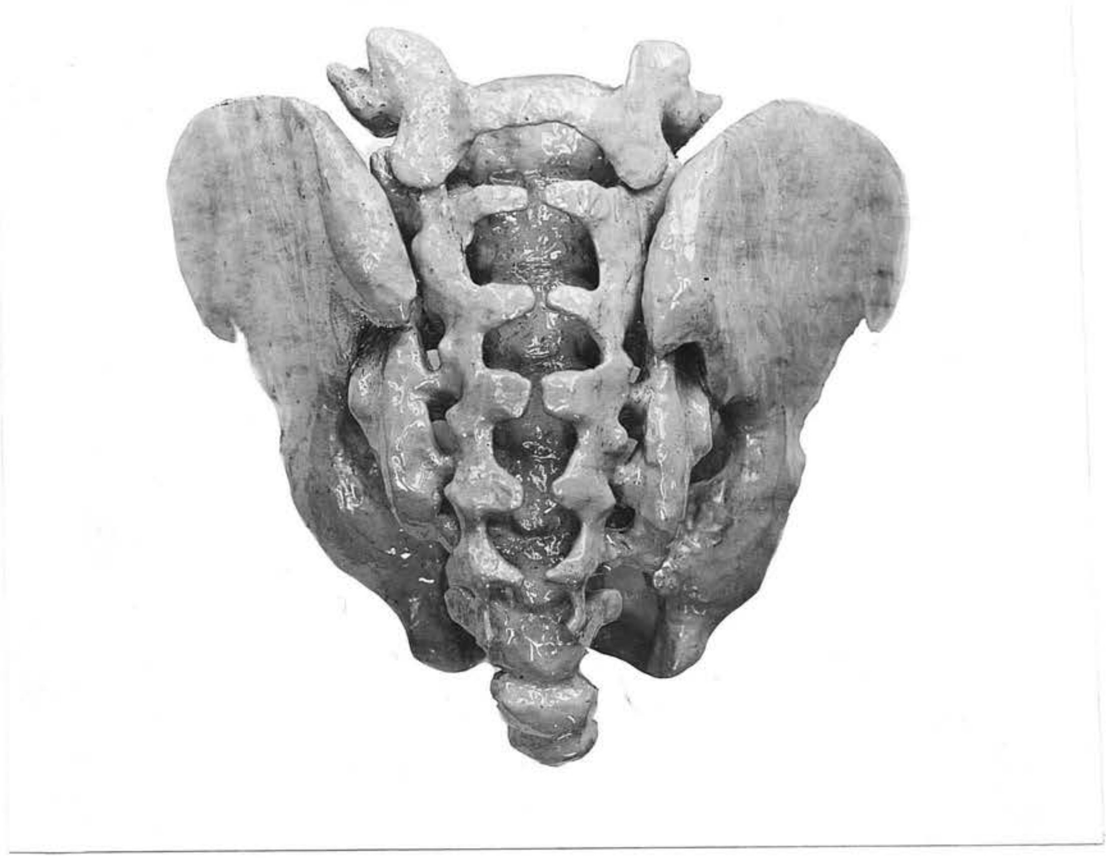

Fig. 24.

Fig. 25.

Fig. 26.

Fig. 27.

Fig. 28.

Fig. 29.

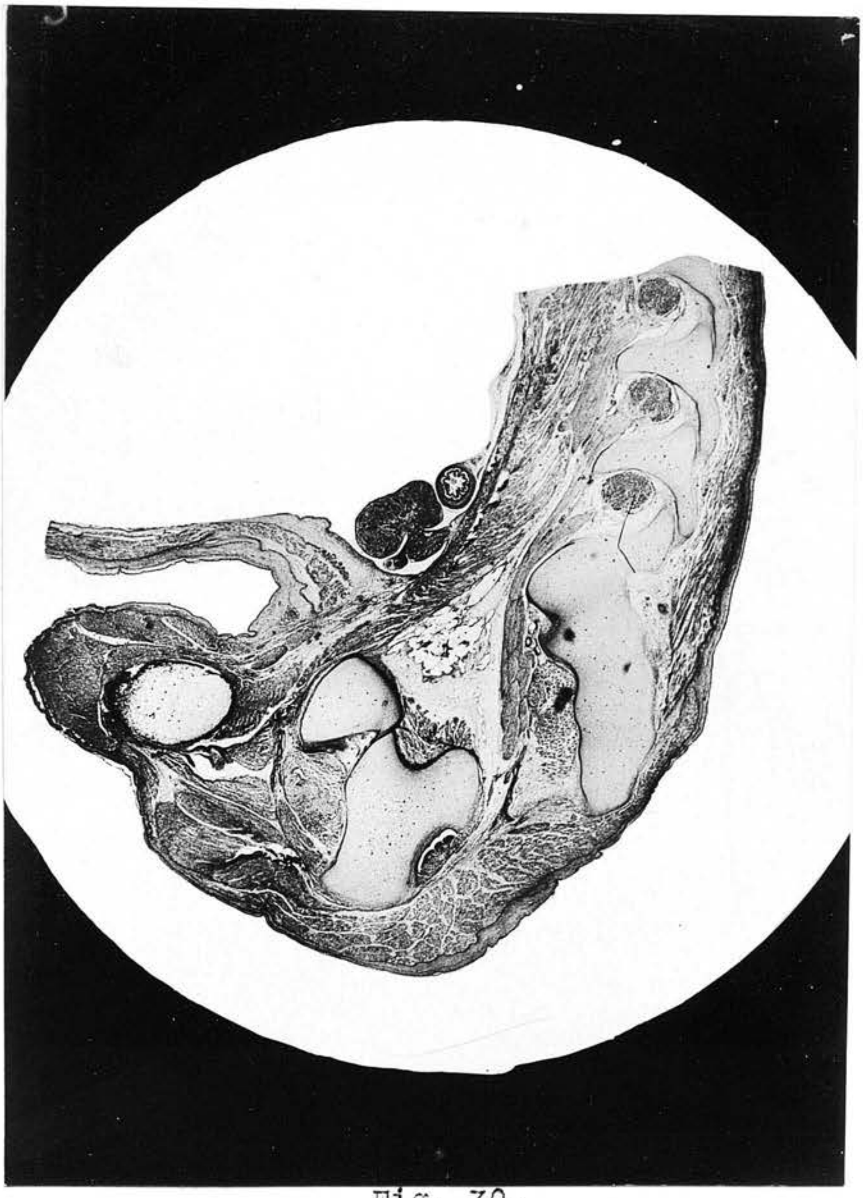

Fig. 30.

Fig. 31.

Fig. 32.

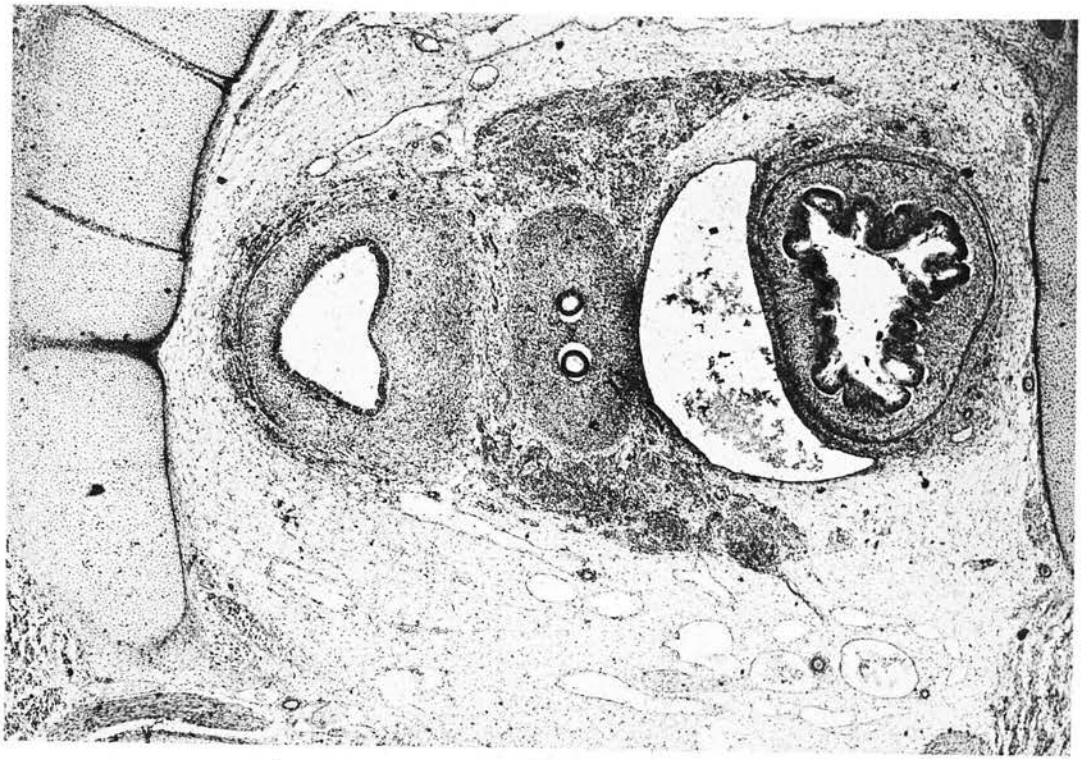

Fig. 33.

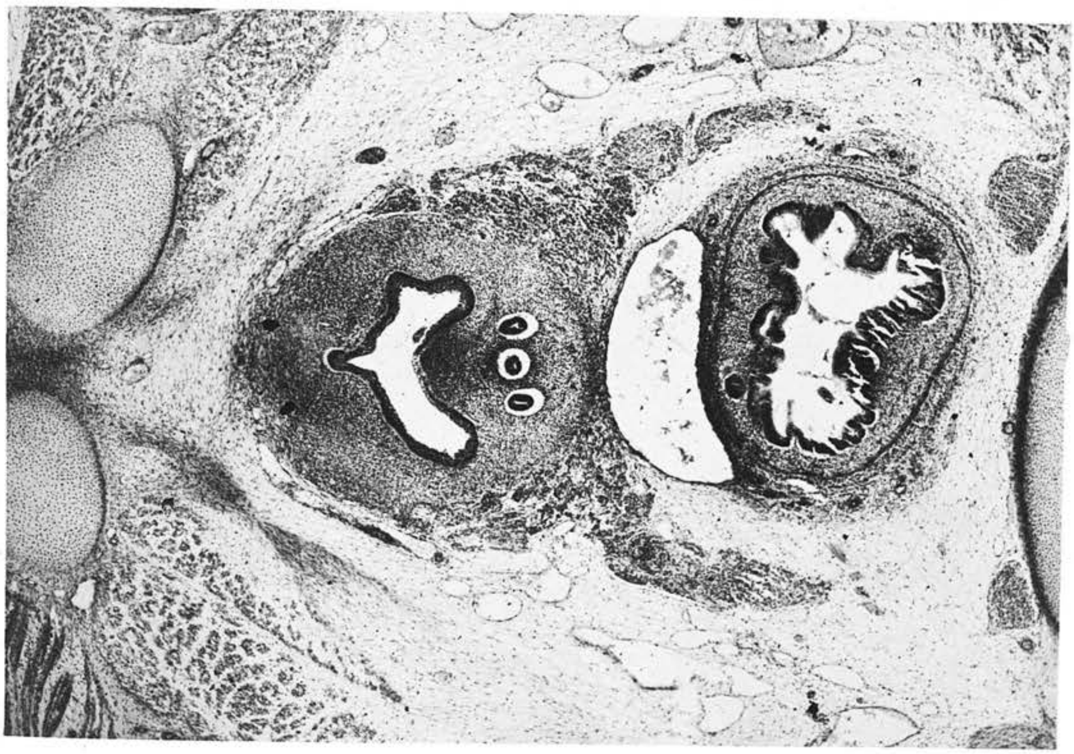

Fig. 34.

Fig. 35.

Fig. 36.

Fig. 37.