THE DEVELOPMENT AND VARIETIES OF THE SECOND CERVICAL VERTEBRA. By Professor A. MACALISTER, F.R.S. (PLATES IX., X.)

I. DEVELOPMENT.

IN the history of the growth of the axis, as in that of any of the other vertebræ, two successive processes of growth are to be observed, that of chondrification and that of ossification.

The former begins at the end of the second week; first, by the formation of cartilage in certain parts of the *membrana reuniens* on each side of the neural canal; and secondly, in the perichordal sheath.

The first centres of chondrification appear as two lateral masses, one on either side of the neural cord. These extend backwards in the *membrana reuniens*, and ultimately unite with each other posteriorly, so as to form a cartilaginous neural arch.

The ventral ends of the lateral masses become also united together by the formation of a hypochordal bridge of cartilage (the "spange" of Froriep). In this way a gristly ring is formed which incloses the notochord and its sheath as well as the embryonic spinal marrow.

I have not succeeded to my satisfaction in tracing the successive stages of this process in the human embryo. It is not hard to follow them in the sheep embryo, or in the ox, as Professor Froriep has done. As far I can see, the hypochordal bridge of the axis is smaller than that of the atlas, but larger than that of the 3rd vertebra in the human embryo.

External to the point at which this lateral mass narrows into the hypochordal bridge, there arises from it a lateral cartilaginous outgrowth on each side, which projects into the embryonic tissue of the inter-muscular system between the muscle plates. The longitudinal anastomotic vessel which connects the several inter-protovertebral arteries, and which becomes the vertebral artery of the adult, passes along the lateral face of this outgrowth, dividing its extremity into dorsal and ventral portions. In the axis the former is the larger, the latter being very small and at first with difficulty recognisable.

As the indefinite blunt point in which each of these terminates grows outwards, it engirdles the artery by joining with its neighbour so as to complete the cartilaginous boundary of the arterial canal.

While the formation of this vertebral ring is in progress, a small centre of chondrification appears on each side, in the embryonic tissue sheathing the notochord. These appear on the caudal side of the hypochordal bridge, and by uniting around the notochord they form the cartilaginous body of the second cervical vertebra, and ultimately this coalesces with the hypochordal bridge.

A similar perichordal body has likewise originated in the atlantic segment, but it remains discontinuous from the large hypochordal bridge of the atlas, as the intervening embryonic tissue becomes partly fibrous while a considerable portion of it disappears, especially in front and behind, thus forming articular clefts on the dorsal and ventral surfaces of this somewhat conical body-element.

The base of this perichordal body of the atlas becomes united on each side by a continuous chondrification, with the hypochordal bridge of the axis at the region at which that bridge is attached to the lateral mass of that gristly vertebra. Medially the body of the atlas becomes attached to the cephalic surface of the perichordal body of the axis, by a layer of embryonic tissue which speedily becomes hyaline cartilage.

These processes have taken place by the end of the sixth week, at which period the cartilaginous vertebra, as yet showing no sign of ossification, presents the following parts,—a complete neural arch, having at each side of its base a thick lateral mass from which transverse and costal processes jut outwards. The body, which is medio-ventral, is formed by the union of three elements—the hypochordal bridge of the axis, the perichordal body of the axis, and the perichordal body of the atlas—the last named forming the cartilaginous *dens*.

The first signs of ossification appear late in the seventh week. In several sixth-week embryos there was no sign of any bony depositions; but in all that I have seen over eight weeks, ossification has well begun.

The history of its bony development may be divided into the following 11 stages:—

1. *Development of the neural arch.*—The first bony granules appear in the lateral mass during the seventh week, and, from these points, ossification extends into the neural arch. In an 11th-week fœtus there is in each half of the arch a slightly-curved, club-shaped rod 2 mm. long (fig. 1), slightly flattened at its hinder end.

In a 12th-week fœtus these rods are thicker and longer than are the corresponding parts of any other vertebra. Their anterior extremities appear bilobed, an outward spur projecting into the lateral process, and an inner projecting towards the body.

In two bones of the 16th-week the hinder ends of the neural rods have become distinctly thickened and flattened. The fore ends are more strongly incurved towards the body, and the inferior articular processes are partially ossified, forming distinct joints with the third vertebra; ossification has extended to some extent into the short transverse process.

2. *Development of the body.*—In the 16th week bony growth has begun in the body of the axis, in the form of two contiguous nodules. In a 17th-week axis, these have coalesced to form a bilobed body nucleus.

3. *Ossification of the dens.*—In the 19th week, in one specimen, two unequal centres of ossification appear in the cartilage of the dens near its base, above the body nucleus, which is rapidly growing. In this case the right nucleus is large and rounded, the left small and irregular. In another of somewhat later age, the left centre is large and the right is a rudimental speck. In another, at the 22nd week, the dens-nuclei are equal, rounded, and symmetrical. In a 6th-month fœtus these are asymmetrical rounded nodules, the left larger than the right, and together they make a bony mass 3·5 mm. wide and 1·7 mm. high, placed on a bony axis-body, which is 3·25 mm. wide and 2 mm. high, and faintly bilobed below, with a central dimple corresponding to the place of the vanished notochord. The arch in this vertebra contains a curved bony rod on each side, 9 mm. long, and it is slightly grooved on its cephalic surface for the second cervical nerve. The vertebra in this stage is about 17 mm. in sagittal diameter, and about 10 mm. in coronal. Its arch is gristly in front and behind as well as at its lateral process.

4. *Coalescence of the nuclei in the dens* takes place usually during the latter half of the sixth month. The resulting bilobed mass is faintly grooved along the anterior line of junction, deeply grooved along the posterior line, and wider than the subjacent body (averaging 4 mm. by 2·5, while the body averages 3·5 by 3). There are some varieties in the time of this fusion. In a 7th-month axis I have found the dens nucleus as a rounded mass, while in the axis of a child of five months old the two dens-centres were separate as large oblong bony masses placed side by side (fig. 5). This condition is very exceptional.

The part of the arch which abuts on the body in these specimens is nodular, showing that ossification is here in active progress. Above this end is a plate of cartilage continuous with the lateral angle of the dens. This, in a macerated axis at this stage, becomes easily detached from the underlying end of the neural arch, and appears as a lateral flap at each side of the dens. The upper surface of this plate articulates with the under side of the lateral mass of the atlas, the articular cleft between them being visible at the fifth month, probably much earlier.

Although I cannot find any other structural differentiation between these cartilages and the underlying end of the lateral mass of the axis, it is yet probable that this layer is genetically connected with the dens rather than with the arch cartilage. I am satisfied that Froriep is right in describing the articular slit of the inferior atlanto-axial joint of the ox as being between the lateral mass-cartilage of the atlas and the expanded base of the dens, so that the joint is intra-atlantic not atlanto-axial. The lateral parts are more flattened and the dens is more columnar in Man than in the quadruped, but their relation seems to be the same. A considerable portion of this cartilage, both in Man and Ox, is ossified from the arch centre.

In 7th-month fœtuses the dens has grown larger than the body beneath it, the former averaging 5 mm. by 3·5, the latter 4 by 3. There is still a groove on its hinder surface, and medial notches filled with cartilage above and below. The widest part of the dens-nucleus is at the front of the base; from this it narrows to its notched apex. The widest part of the body-centre is behind and below. The arterial foramen at this time is bounded by bone behind as well as internally.

At birth the bony dens averages 9 mm. broad by 7 high. Its rounded and expanded base abuts on the upper half of the inner face of the arch, the body occupying the lower half. There is no ossification in the apical cartilage. The spinal end of the lamina is dilated, its outer angle swollen, laying the foundation of the bituberculate spine. The costal process is cartilaginous, except in one specimen, in which it contains a minute bony granule. Otherwise both it and the transverse process ossify as outward extensions from the arch-centre.

5. *Consolidation of the body of the axis with the arch* takes place during the second year, beginning usually at the hinder side. In my specimens from children over three years of age, this union is complete.

6. *Closure of the neural arch* by the median union of the laminæ takes place in general before the end of the third year. In one of my specimens it has been completed at twenty-eight months, while in another it has just began at forty-five months. The hinder aspect of the immature neural arch shows a lateral tubercle at each end of a median flattened area. By the end of the tenth year these tubercles have extended downwards on each side as the lateral tubercles of the spinous process, and they bound between them a triangular notch. I have found no trace of a terminal spinous epiphysis comparable with that of the thoracic or lumbar vertebra, but, as will be hereafter noted, there is sometimes an ossicle on the under side of each lateral tubercle

which may become consolidated as a depending cornu, and may represent the spinous centre.

7. *Union of the lateral margin of the dens with the arch of the axis*, in my specimens, begins posteriorly in the 3rd year, and is completed in my specimens of 4½ years.

8. *Ossification of the wedge-shaped cartilage* which occupies the summit of the dens, takes place in general by an extension of bony growth from the underlying centre, but sometimes an apical nucleus forms in the front and upper part of the cartilage. Sir G. Humphry figures a specimen of this from the Berlin Museum, and describes another from the Museum at Prag. In Cambridge we have six examples, one from a child aged 45 months, in which the arch has not completely fused with the dens and body on the left side. This nucleus is very small, and in the centre of the cartilage. In a second of 4 years, the centre is larger; a third, at 5 years, has a wedge-shaped ossicle at the bottom of the apical notch; a fourth, from an ancient Egyptian child, has a large rounded nodule of bone here. In the fifth, the nucleus is ankylosed to the dens, but its margin is still distinct; and in the sixth it is apical, as in Sir G. Humphry's figure (*Human Skeleton*, pl. vii. fig. 4). This is doubtless the homologue of an apical epiphysial nodule, such as that which I have figured in *Balænoptera rostrata* (*Phil. Trans.*, 1868, pl. vi. fig. 2). In all these the region of the dens from which the occipito-axial ligaments spring, is ossified by extension from below, not from this centre.

9. *Closure of the arterial canal* takes place at a variable period, and in a variable manner. In one of 4 years old it is closed; in one of 10 years it is yet open; while in some it never closes. Most commonly, however, it closes at about 5 years of age, by the extension of ossification forwards around the artery from the hinder crus. In one or two, ossification seems to have proceeded at nearly equal rates in the fore and hind crura, while in one the anterior crus has ossified more rapidly than the hinder. It thus sometimes happens that the terminal tubercle is sometimes ossified from the posterior, sometimes from the anterior crus.

I have found no specimen with a terminal epiphysis on the transverse process, such as I have described on the atlas. In one example only was there an independent bony granule in the pre-arterial crus.

10. In five specimens, two from children a little over 1 year old, one from a child aged 3, one from a child of 4, and one from an ancient Egyptian child, probably about 5, there is an additional nucleus present on each side at the under part of the base of the pedicle in front, just where it abuts on the body of the axis, and underlying the overlapping base of the dens. This extends to the inferior surface of the pedicle, but does not extend backwards as far as the arterial foramen, from which it is separated by the inner end of the pedicle (figs. 7 and 8).

The tissue in which this centre forms corresponds to the part of the cartilaginous axis which is derived from the lateral angle of the hypochordal bridge, and therefore this centre is strictly homologous in position with that in the anterior arch of the atlas. This relationship was foreseen by Sir G. M. Humphry long before the researches of Froriep had shown that there was a hypochordal element in the axis (*Human Skel.*, p. 130). It is noteworthy that although I have only found this element in four out of thirty-one axes (about 13 per cent.), yet in others in which it was not present, there is along the upper and lower surface of the ossifying inner end of the pedicle a row of dimples in the end of the bone along the line at which this nucleus, if present, would have abutted on the arch. This centre has, obviously, nothing costal in its nature.

11. *The dens begins to ankylose with the body of the axis* early in the third year by the formation of superficial bands of ossification from one to the other, both behind and in front. By the beginning of the sixth year superficial union is complete in front, and the posterior interval is reduced to a large hole. An irregularly lenticular cartilage persists through life intermediately, as Sir G. Humphry has described. In a child of 10 years this was a considerable plate, limited superficially by a thin skin of bone in front and behind. In an old man of 85 years there was still a speck of cartilage persisting. This is true hyaline cartilage, not analogous to the tissue of the nucleus pulposus. A few bony specks in an irregular line along the lower border of the body represent the inferior epiphysial plate of the axis. This I have seen in an axis at 16 years. They consolidate rapidly, for I have found it fully consolidated at 20.

I have carefully examined the surfaces of the intercalated disk of cartilage between the body and dens, and in three specimens at about 16 or 17 years of age I have found a few bony granules, both at its upper and lower surfaces. These probably represent the epiphysial plates of the contiguous surfaces of atlas and axis, like the laminæ in this region which I have figured in Balænoptera. In no case did these form a definite epiphysial lamella, and they seem to have become completely consolidated with the neighbouring bone by 20 years of age.

It will be noted that my specimens in many respects differ from those from which M. Robin has given his account of the development of the axis, in his *Memoire sur l'evolution de la Notocorde, &c.* (Paris, 1868, p. 95). He had only found single centres in the body and dens, and no apical epiphysis. This is probably due to his specimens not representing the earliest stages.

II. Varieties of the Axis.

Most of the deviations from the common conditions of this bone are in matters of detail, unimportant and easily overlooked. Those which are illustrated by my specimens are as follows :—

A. *Varieties of the Spinous process.*—In the normal axis the spine presents (1) a median superior ridge to which is attached a weak fibrous lamella attached to the ligamentum nuchæ, but consisting chiefly of condensed areolar tissue. To each side of this ridge is attached the origin of the rectus capitus posticus major. On each side is (2) the lateral oblique surface of the spinous process, more or less hollowed and ridged for the origin of the obliquus capitis inferior. At the posterior extremity of the ridge and surface is (3) the posterior surface, often only linear and continuous downwards from the median ridge, prolonged at its inferior angles into (4) the lateral tubercles into which the semispinalis colli is inserted. Between the lateral tubercles is (5) the posterior median notch; and in front of each tubercle at the inferior border of each lateral surface there is generally an inferior tubercle into which, and into the rough surface below and internal to it, is inserted the multifidus spinæ. The relative proportions of all these parts show many varieties. My statistics are taken from 150 bones.

1. The length of the spine is variable: my longest (fig. 11) measures 23 mm.; my shortest (fig. 12) 14 mm.

2. The superior ridge is obsolete in 2 per cent. This is the retention of an immature condition. In a considerable number this edge is sharp, sometimes up-raised above the level of the laminæ. In four specimens there were small friction facets for the under edge of the hinder tubercle of the atlas, on which there were similar facets, a variety omitted in my last paper. This facet in one is at the front, in two near the middle, and in one at the side of this ridge (fig. 15, *f*).

3. The inter-tubercular width is very great, measuring 28 mm. in a Saxon axis, from a secondary interment in Bowl's barrow (fig. 13). This is also a character of immaturity. The narrowest notch is in an Egyptian axis, measuring 7 mm. In this the spine is reduced to a median ridge with closely approximated posterior tubercles. In one the median ridge and the right lateral tubercle have terminally coalesced into one point (fig. 14).

4. The lengths of the lateral tubercles may vary; in general they project little below the level of the lower edge of the lamina, but in three they are long and prominent, becoming in one 18 mm. long (fig. 16). In one they were represented by detached ossicles, as in the instance described by Luschka (*Anatomie*, i, p. 39). In one of mine the right is long and the left short, showing a facet to which probably such an ossicle was attached. In another these tubercles are markedly asymmetrical, the right being lower and displaced to the left underlying the left tubercle. Another has a facet at each end of the posterior surface, to which probably ossicles were attached, but they have been lost. The degree of eversion of these tubercles also varies: in one their points are turned horizontally outwards.

5. In one specimen the posterior surface is a flat triangle, instead of being linear as it is usually.

6. The inferior median ridge, to which a thin elastic inter-spinous lamella is attached, is very sharp and prominent in one, obsolete in another, moderate in the rest.

B. *The lateral process* is normally peculiar in that it is never truly bituberculate. Its single tubercle represents the posterior or true transverse process-tubercle of the lower cervical vertebræ, and gives attachment to the scalenus medius, levator anguli scapulæ, and splenius colli. The anterior or costal tubercle is represented by an obsolete or rudimental prominence in front of the superior articular process, at the outer end of the variable infra-articular ridge. To this point the rudimental intercostal muscle (anterior inter-transverse) is attached. This ridge and tubercle, when present, should therefore be called the *costal ridge.* The continuation of this to the tip of the transverse process is in series with the costo-transverse lamella of the other vertebræ, and it is occasionally channelled internal to its apex for the anterior branch of the second cervical nerve.

The bone may present other grooves for nerves, the chief one being the supra-pedicular groove behind the articular process for the ganglion and trunk of the second nerve. This area is always swollen and often has a definite border. There also may be one on the inferior surface of the transverse process, when that is longer than usual, for the anterior branch of the third cervical nerve. This is rare; I have only two distinct examples. A more common groove is the ascending sulcus between the posterior crus of the lateral process (fig. 17, *i*) and the front margin of the inferior articular facet, for the posterior branch of the third cervical nerve.

The extremity of the transverse process is short and tuberculate in 70 per cent.; longer and with a superior neural groove in 2 per cent.; subulate and decurrent in 15 per cent.; directed strongly backwards and downwards in 5 per cent.; very short and blunt in 5 per cent.; and dilated at the end in 3 per cent.

A line joining the tips of the opposite transverse processes lies behind the plane of the dens, but cuts off the hinder part of the superior articular surfaces in 60 per cent. It cuts both articular surface and dens in 36 per cent.; it is tangential to the articular process and behind the dens in 3 per cent., and lies quite behind both in 1 per cent. In most of my specimens the angle formed by the decurrent costo-transverse process with the vertical axis is about 50°.

When viewed from above, the lumen of the arterial foramen is not visible in 93 per cent.; in 2 per cent. it is visible on both sides; in 5 per cent. it is slightly visible on one side or on both. The *crypto-trematic* or ordinary condition is usually associated with a greater curve in the artery than is found in the *phœnotrematic* condition.

In two specimens the lateral processes are almost completely hidden under the superior articular surfaces: in one (fig. 20) the extreme inter-articular width is 43 mm., and the extreme inter-transverse 45 mm. On the other hand, when the transverse processes are more horizontally placed, and do not project so much backwards, they are more prominently exserted. In one such specimen the inter-articular width is 47 mm., while the inter-transverse is 63 mm. (fig. 19).

The sides of the notch, between the back of the transverse process (fig. 18, *j*) and the front of the inferior articular process (*k*), usually form an angle of 90°, but in about 4 per cent. this is reduced, in one being only 40°. This reduction is due to the greater displacement backwards of the tip of the transverse process (*cf.* fig. 17).

The posterior crus, or real base of the transverse process, is deficient in four specimens. It is completely absent in two (fig. 21), represented by a faint spur in one, by a longer spur in another. This element is very slender in 3 per cent. This deficiency is described by Henle (i. 52). I have never seen the anterior crus deficient in an adult bone, although it is the later part to ossify in the immature lateral process.

C. The upper articular processes are separated from the dens by a sulcus (fig. 19, *l*) in nearly every case, and there is a vascular foramen in this in about 60 per cent. Each of these articular surfaces is slightly concave coronally, but convex sagittally. The tangent line joining the front border of these facets touches the body at the root of the dens in 23 per cent., lies in front of the body in 43 per cent., and cuts the front of the body in 34 per cent.

The shape and curvature of the upper articular processes are similarly constant, as the condition of this joint are subject to such slight variety, it being in all normal cases a laotrope screw joint, as Henke long ago recognised.

D. Thecordiform spinal canal has an averagewidth of 22·5 mm., the range being from 20 mm. (10 per cent.) to 27 mm. (1 per cent.). The sagittal depth on the lower surface averages 15 mm., but ranges from 12 (2 per cent.) to 20 mm. (4 per cent.). The average index, $\frac{\text{sag.} \times 100}{\text{cor.}}$ is 70, the range being from 60 (4 per cent.) to 85 (1 per cent.).

E. Seen from below, the arterial foramen presents certain variations of form, which are reducible to two types. In 80 per cent. the opening is a round hole with a definite margin all round (fig. 17, *g*). In 20 per cent. the opening is an elliptic fossa, with a rounded and distinct anterior margin, but the wall of the fossa posteriorly is undivided for the rest of the under side of the pedicle. In most of these cases the posterior crus is small (fig. 18), and its edge does not extend inwards as a distinct ridge on the pedicle. In these cases there is usually the mark of a very spiral vertebral artery. In one such specimen the artery has deeply indented the side of the vertebral body. In the specimen figured, it touches the side of the body at *m*, but does not indent it (fig. 18). Varieties of size of the foramen are not uncommon. It is very frequently asymmetrical, and in one case is reduced to a fine hole on the right side. This foramen is never double or divided.

F. The front of the body varies chiefly in the degree of prominence of the triangular ligamentous area, in the sharpness of the inferior lateral tubercle, into which, and the ridge above it, there is inserted a strong ascending cervical stellate ligament figured by Luschka (*Anat.*, i. p. 46). This is crossed obliquely by the intercostal muscle ascending from the costal process of the 3rd vertebra (ant. inter-transverse), which ascends obliquely inwards to the lower border of the costal ridge.

The muscular depression on each side of the triangular area is for the accommodation of the longus atlantis muscle. Its depth depends on the forward projection of the costal ridge and the articular process above it.

G. The dens displays few striking varieties. In No. 1558 (*Path. Mus. Camb.*) it has become detached as the result of disease. Cases of detached odontoid without disease have been described by Giacomini and by Romiti, and other instances which were probably pathological are described by Shaw (*Trans. Path. Soc. Lond.*, ix. p. 346) and Turner (*Jour. Anat.*, xxiv. p. 258, 1890). The firmness of the dens, which is so distinctly shown by vertical sections, has been proved by the experiments of Dr Stephen Smith, who demonstrated that the dens was capable of resisting a force sufficient to break the anterior arch of the atlas or the transverse ligament (*Amer. Jour.*, iv., N.S., p. 338).

The average height of dens to height of body is as 17 mm. to 20 mm. in males, as 15 mm. to 19 mm. in females, but the dens may be only 12 mm. or may be 19 mm. high. It is usually short and subulate in such Australians as I have seen (6). The principal varieties are in the shapes and extent of the anterior or atlantic facet, and the relation of the plane of this surface to the vertical axes of the bone. In old bones there is often an *occipital process* at the top of the dens, which extends behind the anterior atlanto-occipital ligament to touch the basi-occipital. In one specimen this is twofold, an anterior lamellar process, and an apical tubercular process, the ossification of the tissue around the suspensory ligament. In one instance of atlanto-occipital ankylosis the dens articulated with two lateral bony processes from the occipital bone, which replaced the check ligaments. The various shapes of the dens may be described as clavate, cylindrical, subulate, or else some form intermediate between these extremes.

H. The inferior articular process is fairly constant in obliquity and size, but may vary within limits as to outline, being sometimes transversely elongated, in others vertically prolonged. The hinder crus of the lateral process starts from the arch in front of the anterior border of this process. Above and behind this, and behind the smooth area on the upper surface of the lamina upon which the second nerve lies, there is usually a vascular hole in a depression, marking the point of junction of the lamina and pedicle: sometimes this spot rises into a little rounded eminence, to which the thickened margin of the areolar posterior atlanto-axial ligament is attached. In one specimen this projects upwards as a kind of rudimental superior articular process, not really articulating with the atlas.

From this point backwards the upper edge of the lamina is thin for the weak atlanto-axial inter-laminar ligament. The inferior laminar ridge for the strong inter-laminar ligament between the axis and 3rd vertebra is much rougher, and differs from those of the subjacent vertebra in that it is at the level of the lower border of the lamina, whose inferior margin is seldom prolonged below it, as it is in the other vertebræ.

Pathological cases of ankylosis of the axis to the third vertebra, of the atlas to the axis, and of both to the occipital bone, are by no means uncommon, and are represented by specimens in our pathological museum. Of other diseased conditions simulating anomalies, the most interesting are those in which, after fracture of the dens, the upper part of that process seems to have become disintegrated, as in the curious case described by Friedlowsky (*Wiener Med. Jahrbücher*, x. p. 232, 1868).

In noticing the literature of anomalies of the atlas in my last paper, I omitted to refer to the cases of divided atlas published by Theile in the *Deutsche Klinik*, 25, 1853, and by Keen in the *Amer. Jour. Med. Sci.* for 1874, p. 412.

EXPLANATION OF PLATES IX., X.

Plate IX.

Fig. 1. Upper surface of axis at 11th week × 5. *a*, cartilaginous body; *b*, bony rod in arch.

Fig. 2. Coronal section of axis at 16th week × 2. *c*, dens; *d*, bony nucleus in body; other letters as last.

Fig. 3. Coronal section of axis at 19th week. *d'*, united body nuclei; *e*, dens nuclei.

Fig. 4. Similar section at 22nd week.

Fig. 5. Unusual case of delayed union of lateral dens centres in infant of 5 months old.

Fig. 6. Axis at birth. *e'*, united dens centres.

Fig. 7. Axis of child 15 months old, seen from below. *f*, hypochordal nucleus.

Fig. 8. Coronal section of axis of 28 months child, showing hypochordal epiphysis.

Fig. 9. Axis of child 45 months old, showing the apical epiphysis, *g*, of the dens.

Fig. 10. Coronal section of adult axis, showing, *h*, the lenticular cartilage between the dens and the body of the axis; and, *i*, the inferior epiphysis of the body.

Plate X.

Fig. 11. Elongated spine of axis, natural size. *a*, median superior ridge; *b*, inferior tubercle; *c*, lateral oblique surface; *d*, posterior surface; *e*, lateral tubercle.

Fig. 12. Rudimental spine in the axis of ancient Egyptian.

Fig. 13. Wide bituberculate spine in axis of Saxon, from secondary interment in Bowl's barrow, Wiltshire.

Fig. 14. Axis with acuminate spine.

Fig. 15. Axis with friction facet on superior ridge.

Fig. 16. Spine of axis with long lateral tubercles.

Fig. 17. Arterial foramen, round variety.

Fig. 18. Axis with exserted lateral processes.

Fig. 19. Arterial foramen, ovate variety.

Fig. 20. Axis with lateral processes under cover of upper articular surface.

Fig. 21. Axis with deficiency of outer wall of arterial foramen.

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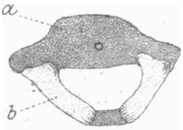
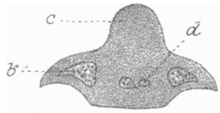
Fig. 1.



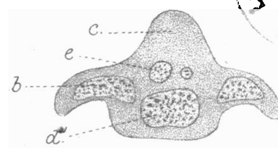
at 11th week
upper surface
× 5

Fig. 2.



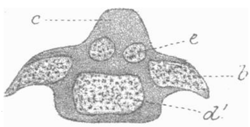
at 16th week
coronal section
× 2

Fig. 3.



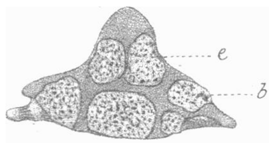
at 19th week
× 3

Fig. 4.



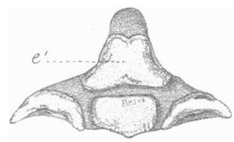
at 22nd week
× 1½

Fig. 5.



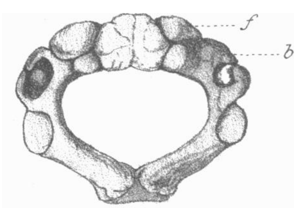
at 5 months
after birth
× 1¼

Fig. 6.



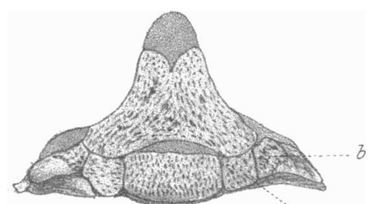
at birth.
× 3

Fig. 7.



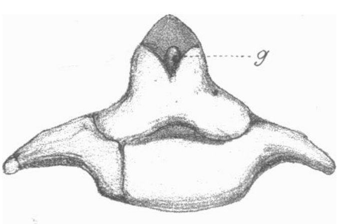
Hypochordal epiphysis
15th months.

Fig. 8.



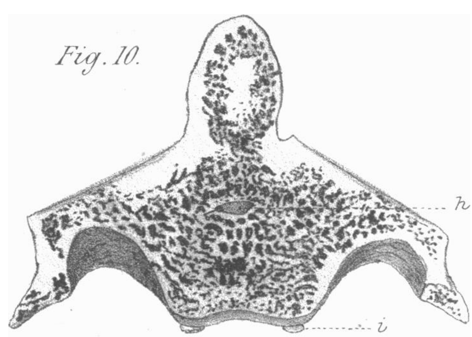
Hypochordal epiphysis
28th months.

Fig. 9.



Apical epiphysis.

Fig. 10.



Coronal section, showing traces
of epiphysial plates.

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DEVELOPMENT OF AXIS.

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Fig. 11.

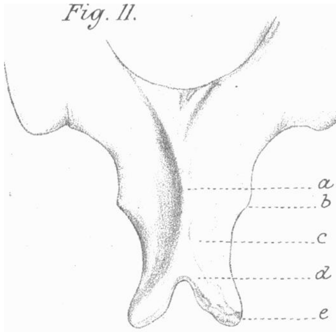


Fig. 12.

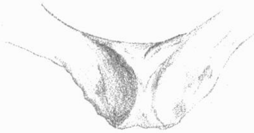


Fig. 13.

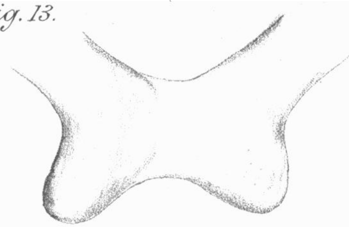


Fig. 14.

Fig. 15.

Fig. 16.

Fig. 17.

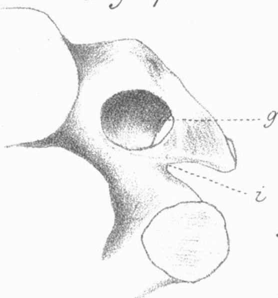


Fig. 18.

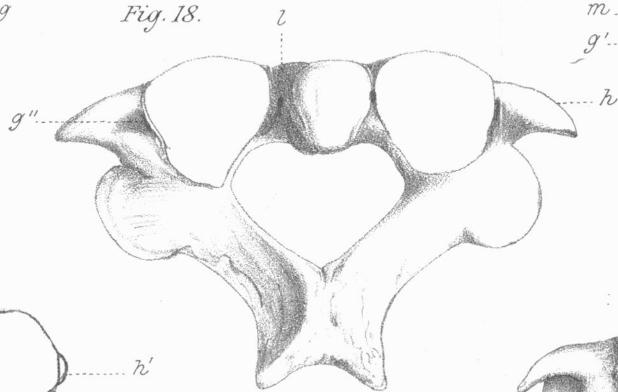


Fig. 19.

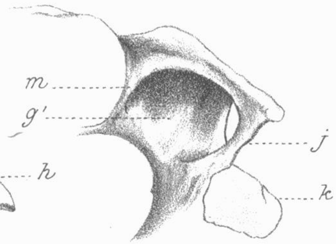


Fig. 20.

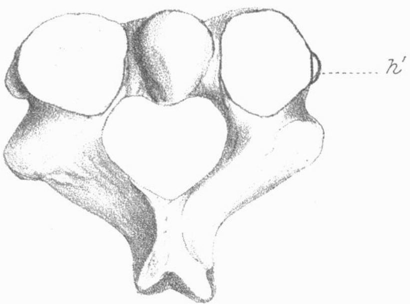
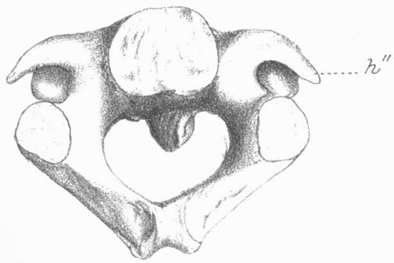


Fig. 21.



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VARIETIES OF AXIS.