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ON THE CERVICAL VERTEBRAE AND THEIR ARTICULATIONS IN FIN-WHALES.

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THE great diversity presented by the cervical vertebrae in Whales gives a special interest to this part of Cetacean anatomy. The differences relate chiefly to the amount of ankylosis and the extent to which the transverse processes are developed. These differences have been a good deal relied on in endeavouring to distinguish genera and species, and have been regarded mostly from that point of view. Yet these various conditions of the cervical vertebrae do not follow the natural affinities within the order, nor can we say that the circumstances which determine them are understood. Sufficient allowance has not always been made for difference of age and for individual variation, which the study of a series of specimens from the same species alone can teach us; and these vertebrae have been but little examined in the light of their relation to the soft parts, although without an examination from this point of view it is impossible to interpret the modifications which bones present. The following remarks are founded on the observation of a series of osteological specimens and on the results of the dissection of the soft parts. I shall first consider the neck in Fin-Whales, arranging my remarks in the following order.

1. Fin-Whales examined.

(A) In Great Fin-Whales:

2. Transverse Processes viewed in relation to function.
3. Ligaments of the Transverse Processes.
4. Ligaments of the Spines, Laminae, and Articular processes.
5. Articulations of the Bodies of the vertebrae.
6. Articulations between the Axis, Atlas, and Occipital bone.

The Cervical Vertebrae serially considered.

7. Table of measurements.
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9. Spinal Canal, Laminae, Spines.
10. Articular Processes.
11. Inferior Transverse Processes.
12. Superior Transverse Processes.
13. The lateral Rings.
14. Recognition of the five posterior vertebrae.
15. The Axis.
16. The Atlas.

(B) In the Lesser Fin-Whale:

17. Transverse Processes and their Ligaments.
18. Bodies and their Fibro-Cartilages.
19. Articulations of the Axis and Atlas.
20. Occipito-Atlantal surfaces.
21. Explanation of the drawings.

1. FIN-WHALES EXAMINED.—The specimens to be considered belong to the following Whales.

(*a*) Great Fin-Whale (Balaenoptera musculus, Ptero-balaena communis, Razorback) stranded alive near Wick, Caithnessshire, June 1869. Male 65 or 66 feet in length. Mature or aged. Soft parts dissected[1].

[1] I am indebted for information regarding this whale, and for the parts of it, to the kind exertions at Wick of Captain C. Cox, and Dr R. MacCalman, and afterwards, at Golspie, to Dr John Gunn, and Dr Soutar of Golspie. The carcase after being flensed near Wick, drifted south to Golspie. The information kindly furnished me by Dr Soutar and Captain Cox leaves no doubt that it was the same carcase. The total length according to one account was 72 to 73 feet, but Captain Cox's careful measurement, with a tape line, from the tip of the upper jaw straight along to the middle of the hinder edge of the tail, reduced this to 65 or 66 feet. I am indebted to the kindness of that gentleman for the following information. It was alive when stranded, and he saw it an hour after, quite fresh and uninjured. Skin on the under half plaited and white, or just a shade darker than white. The bristly part of the whalebone was white, and the solid part adjoining it had nearly the same colour, becoming slaty and then dark at the outer part. Length along the outside of the solid

(*b*) Great Fin-Whale (B. musculus), November 1871, at Stornoway, Lewis, Western Islands of Scotland. Male 60½ feet in length. Mature or aged[1].

(*c*) Great Fin-Whale (B. musculus), June 1871, at Peterhead, Aberdeenshire. Male 64 feet in length. Not quite mature. Soft parts dissected[2].

(*d*) Atlas and Axis of another Great Fin-Whale (B. musculus), Norway, 1872. Mature[3].

part of a plate sketched by him for me, 21 inches, of the longest bristles 10 inches, of the shortest 5 inches. Tail-fin 15 feet or more. The lower jaw, now in my possession, is 14 feet 8 inches in length straight, along the outer side 15 feet 10 inches; greatest depth of curve 2 feet; coronoid process high and curved, height along middle 7 to 8 inches, height of bone to tip of coronoid 22 inches. (The upper half of the right coronoid process is fractured, with ligamentous union, the fracture crossing obliquely and breaking off more of the outside than of the inside, with irregular bony surfaces at the fracture. How had this fracture been produced?) The pectoral fin had the usual lance-shape, and was 8 feet 8 inches in length from the head of the humerus. These characters determine this Whale to have been *B. musculus*. As to age, even the distal epiphyses of the radius and ulna are united, an irregular and incomplete furrow ¾ inch from the end marking the place of union. The os magnum and unciform have coalesced on the two surfaces but not deeply, and there is a small trapezoid bone concealed in the cartilage. This Whale was therefore mature or probably aged. The cervical vertebrae are large.

[1] This Whale was found dead about 14 miles off Stornoway, into which it was towed by the fishermen. I am indebted for obtaining the parts to my brother, Dr James Struthers of Leith, and to Mr Methuen of Leith, and for information regarding it to Mr A. Mackenzie and Dr Millar of Stornoway. Their kind attention and replies to my inquiries leave no doubt that it was a characteristic specimen of *B. musculus*. Length according to a public statement 63 feet, according to Mr Mackenzie's measurement, taken along the side, 60 feet 5 inches. Length of pectoral fin 6 feet (taken I infer along the upper border); length of bones of left paddle from head of humerus to tip 7 feet 1½ inches, but tip is malformed apparently from an old injury, somewhat shortening the paddle. Tail-fin from tip to tip 11 feet. Tail part of trunk thin, like a double-edged knife. Dorsal fin falcate and well marked. The usual furrows on the belly and sides. Belly and sides white, with dark patches of cuticle still adhering on the side. Whalebone, longest plates 30 inches; colour dark externally, cream-coloured on the internal bristly surface. Length of lower jaw 15 feet. As to age, all trace of the line of union of the epiphyses has disappeared on the cervical and three anterior dorsal vertebrae, in my possession. The same of both epiphyses of the humerus. The pisiform is partially ossified. This whale was therefore mature, if not aged.

[2] I gave an account of this Whale, and of certain rudimentary structures which I found in it, in this *Journal*, for November 1871. I was indebted to the kind assistance of Dr Jamieson of Peterhead in obtaining the parts of this Whale and for his help when I was engaged on it there. It was a well-marked *B. musculus*. As to age, the epiphyses of the humerus were united, no traces of the line of union remaining. The epiphyses of the vertebrae are united, the traces of the line of union being variously visible on the following vertebrae which I have—on hinder ends of 6th and 7th cervical (slightly also on fore end of 7th) and 1st dorsal; both ends of three succeeding dorsal, of a middle dorsal, and middle lumbar; while all trace has disappeared on an anterior caudal vertebra. Therefore, although longer than the Stornoway one, this Razorback was less mature than it, and the state of the cervical vertebrae agrees with this.

[3] These were among some of the bones of two Great Fin-Whales, brought

(*e*) Lesser Fin-Whale (Balaenoptera rostrata, Pike-Whale) stranded alive at Aberdeen, July 1870. Young female, 14½ feet in length. Soft parts dissected[1].

I shall first consider the great Finners, distinguishing them by their localities (Wick, Stornoway, Peterhead, Norway), noticing afterwards the peculiarities of the young Pike-Whale.

(A) In Great Fin-Whales.

2. Transverse Processes in the Great Finners viewed in relation to function. The most striking feature in these vertebrae is the enormous mass of the transverse processes, completing a great lateral foramen (see Fig. 4) so large that it is more than half the size of the body of the vertebra, and is twice as capacious as the spinal canal; at once suggesting to the observer that a complete vertebrate segment is entitled to be regarded as presenting not merely two, but four rings. What is the function of these great rings? Contained within them is the *rete mirabile* representing the vertebral artery. This is a vast plexus. To realize the bulk of it, the block of vertebrae now empty should be turned up, the atlas resting on the ground. The series of rings, together with their connecting ligaments, are then seen to form on each side of the vertebral bodies a great lateral canal, like a deep well. This canal is completely filled by the vascular rete, supported by connective tissue and some fat, except the small space occupied by the nerves which traverse it. The canal is continued backwards, diminishing, along the anterior dorsal vertebrae by the rings, or spaces, between the superior transverse processes and the necks of the ribs, or the ligaments representing the ribs. This really wonderful plexus occupying the lateral canal forms communications in various directions, downwards to the carotid region by the

this year from Aalesund, Norway, for which I was indebted to the kindness of Messrs J. and G. Miller of this city. Although there was no history they are characteristic of B. musculus. Both lower jaws so like each other that they cannot be distinguished. Scapula and radius exactly the size of those of the Peterhead Razorback. Distal epiphysis of radius united, a furrow remaining. The state of the wings of the axis shows it to be more mature than the Peterhead specimen.

[1] This Whale was alive when stranded on our beach. The external characters, measurements, and results of the dissection were noted. The skeleton and various portions of the soft parts are preserved.

passages for the inferior division of the nerves, and also by the sides of the vertebral bodies; upwards, by the passages for the superior division of the nerves; and inwards by the intervertebral foramina, with the primary nerves, giving continuity with the rete within the spinal canal. The spinal canal and its lateral openings, the intervertebral foramina, are much more occupied by vascular rete, with its supporting connective tissue and some fat, than by spinal cord and nerves. While the spinal canal averages 6 to 7 inches in width by about 3 in height, I found in the Peterhead Razorback the tube of dura mater to have a diameter at the fore part of the atlas of about two inches, at the hinder edge of the atlas of about 1½, and at the middle of the neck of about one inch. The rete fills the whole of the rest of the spinal canal, and is therefore many times bulkier than the spinal cord and its membranes. But great as this spinal canal rete is, it is small compared with the rete of each lateral canal. The intervertebral foramina, large enough to admit three or four fingers, are in like manner chiefly occupied by the rich communications between the two lateral and the spinal vascular networks. The nerves are comparatively small, the inferior division about the size of the little finger, the superior several times smaller. Having escaped by the intervertebral foramina, the nerves divide, the superior or dorsal divisions pass immediately up to the dorsal spaces; the inferior or ventral divisions sweep outwards across the upper part of the lateral canal, surrounded by rete, as far as I could decide after it had been removed, and curving downwards a little, escape by the ventral spaces.

Although the protection of this wonderful network may seem a function sufficient to account for the presence of these great rings, this view may be as far from satisfactory as it would be now to regard the double transverse process in man as a provision for the protection of the vertebral artery. In either case the interpretation must be sought not in the idea of a protecting ring, but primarily in the locomotive system, in that of outstanding processes furnishing points of attachment for the muscles and ligaments, the spaces within which are, secondarily, more or less occupied by parts of the vascular system.

The study of the relation of these processes to the soft parts in great Fin-Whales has satisfied me that both upper and lower transverse processes, in their various degrees of development, may be interpreted by dividing them into three stages. (See Fig. 4, also Figs. 1, 2 and 3.) *Lower transverse processes.* (*a*) First or *root stage,* short, directed outwards and downwards, alone present in some. Thick, smooth before and behind. Portions of rete mirabile lie here. (*b*) Second or *tubercular stage.* Directed outwards, extensive, being opposite the inner half or more of the ring; begins by an internal angular protuberance or process, and terminates by an external protuberance; thinner at the upper edge where it bounds the ring, thick and rough below. Besides muscles, this stage attaches a series of strong intertransverse ligaments. (*c*) Third, or *nerve-groove stage,* corresponding to the space left for the passage of the inferior division of the spinal nerve, accompanied by communication of rete mirabile. Process at this stage turns upwards and outwards; groove is on anterior surface, directed obliquely downwards and outwards, broad enough to receive the hand laid flat. The very different thickness of these two stages at their lower part gives, especially where they meet, the twisted appearance which the processes present on their anterior surface.

Upper Transverse Processes. (*a*) First, or *nerve-groove stage,* corresponding to the space for the passage of the upper division of the spinal nerve, accompanied by dorsal communication of rete mirabile. Is opposite the inner third of the ring, reaching from the articular process for three or four inches outwards, broad enough to receive the hand flat. Groove most marked on the posterior surface of the anterior vertebrae and on the anterior surface of the posterior vertebrae. (*b*) Second or *tubercular stage,* opposite the outer two-thirds of the ring; beginning by a marked rough projection on the superior edge, and continuing rough outwards. It attaches a series of superior intertransverse ligaments. (*c*) Third, or *terminal stage;* situated to the outer side of the ring, and curving downwards and inwards a little to unite with the inferior process. It forms the extreme part of the transverse process, is scarcely broader than the processes in adolescence, but in maturity forms a tabular expansion beyond the foramen.

These characters will be recognised if one set of these vertebrae be piled in their natural relation on the table and another set arranged on the floor. Then if the observer, bearing in mind the relation of the human transverse processes to their soft parts, will take an articulated set of human cervical vertebrae and also a separate human cervical vertebra, and compare them in detail with those of the Rorqual, he will recognise an interesting correspondence to the stages above defined, small as the foramen is in man compared with the magnificent rings in the Rorqual. The *anterior process* presents first the root, springing from the body, next the "anterior tubercle," and then comes the groove for the anterior division of the nerve. The successional and functional correspondence is evident though the proportions are different. So also with the *posterior process*. Springing from the pedicle there is, first, a stage across which the posterior division of the spinal nerve passes, corresponding to the nerve-groove stage in the Rorqual; and beyond it the "posterior tubercle," greatly extended in the Rorqual and expanded at the end in the terminal plate.

3. Ligaments of the Transverse Processes.—These processes are very strongly knit together by three series of ligaments. (*a*) Inferior series, uniting the inferior processes; and (*b*) those uniting the superior processes, divisible into superior portion above the rings, and external portion between the parts external to the rings. These are interrupted, or interosseous, ligaments, not longitudinally continuous, although those above and below, especially the latter, are seen on the surface.

(*a*) *Inferior Inter-transverse Ligaments*[1] (Inter-parapophysial) pass between the tubercular stages of the processes. A series of strong ligaments, broader than and as thick as the hand, increasing in breadth forwards and outwards, as the tubercular stages on the bones are seen to do, from the sixth vertebra to the third; from about 5 inches broad on the fifth vertebra to 8 inches broad on the third. They pass between the lower parts of the processes, which are correspondingly rough, while the upper part of the processes is smooth. Between the third and the axis the ligament is larger and

[1] The parts to which these ligaments are attached are seen in Figs. 1 and 2.

changes its direction, passing very obliquely inwards and forwards to the process and body of the axis; forming a great mass of ligament, 8 inches broad and 1 inch thick. The attachments of this great sloping ligament account for the breadth and prominence of especially the outer part of the tubercular stage of the 3rd vertebra, and for the roughness on the inferior process of the axis opposite the foramen (tubercular stage, but not defined as on the vertebrae behind) and inwards to where it joins the body.

On either side of this series of ligaments spaces are left. The *internal spaces*, between the ligaments and the bodies of the vertebrae, opposite the root stages of the processes, admitting one or two fingers, but in the putrid state easily enlarged as the ligament is thinner here. The rete is seen bulging against this thinner part, and, as far as one could judge after the external parts had been cleared away, appears to have sent communications through the passages. The external spaces are the *nerve-passages*, corresponding to the third stage of the processes. They are about 3 inches in breadth and about an inch longitudinally, diminishing outwards as the processes converge, easily admitting three or four fingers flat. The one between the axis and third vertebra is smaller than the others (2½ inches). Their inner boundary is some way internal to the outer part of the tubercular stage, owing to the obliquity of the groove and the position of the ligaments. Their outer boundary, formed by the lowest part of the ligaments which connect the external part of the processes, is about an inch internal to the outer end of the foramina. Besides the nerve, which is not larger than the little finger, they are occupied by communications of the rete.

(*b*) *Superior Inter-transverse Ligaments and Nerve-spaces.* The dorsal nerve-spaces are between the ligaments externally and the zygomal processes and their ligaments internally. Between the 6th and 7th vertebrae their breadth is 2½ inches, increasing forwards to a breadth of 4 inches between the third and the axis; but the spaces of the posterior are wider. The spaces have a compressed triangular form, tapering outwards, and admit four fingers easily. Besides the nerves, which are small in proportion to the passages (though the disproportion is not so great as, for instance, in the posterior foramina of the human sacrum), they are occupied by rete, sending communications through here, as far as one could judge after the external parts were cleaned away. The superior inter-transverse ligaments (inter-diapophysial) may be conveniently divided into superior and external portions. The *superior inter-transverse ligaments,* commencing a hand's breadth from the zygomal processes, occupy the processes opposite the outer $\frac{2}{3}$ of the ring (tubercular stage). They are attached to about the upper half of the processes, which is rough accordingly, and bevelled so as to turn this part of the surface upwards. Where they commence, at the outer end of the nerve-spaces, is well marked on the bones[1]. The bundles as seen on the dorsal surface are both longitudinal and oblique, while the deeper fibres, more interosseous in position, are oblique. The *external inter-transverse ligaments* are continuous with the last, corresponding to the fact that the outer part of the transverse processes is a continuation of the upper process. They are the strongest ligaments of the processes, and so placed in between the processes, here very close together, that it is only after their division that their extent and attachments can be distinctly made out. Stated generally, these enormous ligaments occupy about the upper and outer half of the breadth of the more or less expanded part of the processes external to the rings, but coming down far enough to form the outer boundary of the ventral nerve-passages, the inner half being occupied by loose connective tissue lying on the reticular periosteum. Corresponding rough and smoother parts are seen on the surfaces of the bones. Between the 7th and 6th processes I found a synovial cavity, in both of the great Finners dissected, nearly two inches in diameter, situated on the lower part of the plate, presenting a periosteal surface on the convex 7th process and a reticular fibrous or cushioned surface on the concave 6th process, surrounded by a capsular ligament. The 6th and 5th were very close, but there was no cavity proper between them (or between any of the other transverse processes). The ligament attached to the upper,

[1] A smaller and variable rough mark is seen about the middle of the upper edge of the nerve-groove stage on the three posterior vertebrae. It happens to be strongly developed on the left side in the vertebra represented in Fig. 4.

outer, and under parts of the plates was 1 to 1½ inch thick, and about the same between the 5th and 4th, and between the 4th and 3rd.

The ligaments attached to the hinder surface of the great wing-like transverse process of the axis are of enormous strength. It is not very easy to separate any of these vertebrae, but to separate the axis and third is a matter both of art and strength. With a forcible sawing motion the long slicing knife, with barely room to work, at length makes its way through the dense mass. Besides the ligament from the third, the axis has an external compound ligamentous mass from the converged tips of the 4th, 5th, and 6th processes. (1) That from the third passes downwards and outwards to be attached to the wing of the axis. Taking it and the dorsal interosseous ligament as one, the attachment to the axis is over an extent of 12 inches in breadth by two in thickness, following the curve of the process of the 3rd, its position on the axis being external to the middle of the broad plate and along the superior process above the outer half of the ring. The deeper part of this ligament is disposed differently, its much longer fibres converging forwards and inwards to near the ring of the axis; thus lining this part of the lateral canal, which receives a funnel shape here from the comparatively small size of the ring of the axis, while the two parts of the ligament receive different obliquities. (2) The external ligamentous mass is a compound ligament proceeding from the converged tips of the four vertebrae behind the axis outwards and forwards to be attached, for about five inches, to the most external and inferior part of the wing. This is the part of the great wing which forms the extreme triangular projection, beyond the rest of the outer edge of the wing.

Whatever may be the meaning of this convergence of the transverse processes in the Rorquals, we see not only that the bones converge here, forming the apex of the pyramidal framework, but that the plates in which they terminate, and by which they come almost in contact, are firmly tied together by these strong ligaments. Viewing the ligaments of the transverse processes as a whole, while, locally, they enable the processes to strengthen each other as parts for muscular resistance, the firm binding together of the whole must co-operate with the firm binding of the bodies in giving strength to the unankylosed neck. The convergence must impede especially lateral motion, and the ligaments between the converged plates must act not merely as binders but as interposed cushions. Viewed in relation to the contents of the canal, if this can be considered a function, the ligaments complete the walls of the canal all round, except at the dorsal and ventral nerve-passages.

I regret that the circumstances were such as to prevent me examining the muscles attached to these processes. The neck having been roughly cleaned, I could only recognise the remains of various strong tendons. One can hardly doubt that the primary function of these processes is to furnish points for muscular attachment, the more essential parts being the superior processes and the tubercular stage of the inferior, while their ligamentous, and especially their nerve and blood-vessel relations, are subsequent. We must look to the muscles for an explanation of the thick single transverse process of the atlas; of the vast and strong-rooted wing of the axis, and its backward slope; to the muscles, and perhaps to the mode of attachment of the first rib, for an explanation of the absence of a bony inferior transverse process to the 7th vertebra; and to the adaptation of the processes which support the anterior ribs, for an explanation of the size and forward slope of the superior transverse process of the 7th vertebra. Between these two great converging and dominating processes, the 2nd and 7th, the outer parts of the intervening transverse processes are packed as best they may in the available space; the 5th is level and the most projecting, the 6th must slope forwards, the 3rd and 4th must slope backwards, while their inner parts are adapted to muscular attachments. If the part where the nerve crosses is ossified, then a ring results. The processes are joined by strong ligaments, giving the various functional results above indicated; and in the space thus left by the adaptations to the locomotive functions, part of the vascular system has been enclosed or has been developed.

4. LIGAMENTS OF THE SPINES, LAMINAE, AND ARTICULAR PROCESSES.—In the specimen (Peterhead) in which cervical spinous processes are present, there was a *supra-spinous* ligament; and in between the spines pretty strong *inter-spinous* ligaments,

about half an inch in thickness. The laminae are connected on both aspects by *inter-laminar* ligaments. As seen on the dorsal aspect, the ligament passes from the hinder edge (the thick and overlapping edge) of the lamina to the dorsal surface of the lamina behind. From within the canal a thinner ligament is seen passing from the anterior edge of the lamina forwards to the inner surface of the lamina in front. The fibres of the two seem continuous. The latter corresponds in attachment to the ligamentum subflavum of man, but it is white. Also within the canal there was, at least between the axis and 3rd (the only two vertebrae which had not then been separated), a strap-like interlaminar ligament, $\frac{3}{4}$ inch broad and $\frac{1}{8}$ inch thick, separated from its fellow by a distance of an inch. *Inter-zygomal* ligaments continuous internally with the interlaminar ligaments pass from process to process, covering the processes, and external to them form a considerable longitudinal ligament.

5. ARTICULATIONS BETWEEN THE BODIES OF THE VERTEBRAE.—The inferior and superior common ligaments of the bodies are each about an inch in breadth, and therefore not great ligaments for such bodies. The corresponding marks on the bones are well seen above within the canal, while below there is rather a narrow ridge not running the whole length of the body. There is not much difference in the *fibro-cartilages* between the different cervical vertebrae, though they may diminish a little forwards. Their apparent thickness (length) on the surface is deceptive owing to the bevelling of the edges of the vertebrae, this being exaggerated at the middle line where the bevelling goes so far as to form a notch. This median notch is sometimes nearly filled up by ossification. It is strongly marked on the hinder edge of the axis, while the rest of this edge is less bevelled than the edges of the other vertebrae. The thickness of the fibro-cartilages on the surface is $1\frac{1}{4}$ inch, the real thickness deeply between the bones is less than half this, being about $\frac{1}{2}$ inch; perhaps slightly less between the 4th and 3rd, and $\frac{1}{8}$ inch less between the 3rd and axis.

On section, the fibro-cartilages are seen to correspond very closely in all the spaces, except between the 3rd and axis, where there is a little more of the ligamentous and less of the pulpy part. With a body-surface averaging 12 inches in breadth and

8 in height, the ligamentous or capsular part has an average depth of 1½ inch, dipping in to a depth of 2 inches at the middle line above and below, giving the pulp cavity a slightly figure of 8 form. The print of this attachment is well seen on the bones, with parallel lines marking the attachment of the concentric capsular ligaments. The pulp cavity averages 9 inches in breadth, 4 to 5 in height. An interesting transition is seen from the fibrous to the pulpy, in the form of a floating wedge, projecting ¼ to ¾ inch into the pulp from the fibrous part, and ending in fringes which grade into a tenacious pulp. The bodies where they form the walls of the pulp-cavity are lined by a thin layer of pearly cartilage; the anterior surface of the vertebra slightly convex, the posterior slightly concave. The pulp itself is white and glairy, in some parts tenacious enough to lift with the fingers. It had in part an oily appearance, like soft blubber. Under the microscope it showed chiefly groups of cartilage cells of various sizes, bundles of wavy connective tissue, some free oil-globules, fatty crystals, and crystals resembling those of phosphates, all immersed in a fluid glutinous medium.

The proportion of the fibrous part to the pulpy part, though quite mammalian in contrast with the proportions in the fish, is much less than in man, and still less than in long-necked quadrupeds; but a circular ligament in reality over 30 inches in length and 1½ in breadth is a structure capable of great resistance. The *amount of motion* permitted between the cervical vertebrae, either at the bodies or transverse processes, before the fibro-cartilages have become softened by putrefaction is very limited. The transverse processes may be made to move a little on each other, giving a slight rotatory motion of the vertebrae, and the bodies may be moved on each other a little in any direction. Lateral motion is the least, as it is at once arrested by the transverse processes coming in contact; rotatory motion comes next, and vertical motion is the greatest, but is very little. With the block of the five middle vertebrae still attached (including therefore the united motion of four fibro-cartilages), I could give one end of the block a range of only ¾ inch of vertical motion. It is then firmly and softly checked. On then slicing through the connections between the transverse processes, there was no increase in the extent of the motions at the fibro-cartilages, except a very little in the lateral direction. Although, therefore, the intertransverse ligaments must greatly assist to strengthen the neck, they do not limit the extent of movement at the bodies. Viewing the vertebrae of the Fin-whale's neck as a whole, one could scarcely conceive of any parts more thoroughly bound together than they are, both at the bodies and the transverse processes, into a great fibro-osseous unyielding lump. What then is the functional adaptation? It cannot be strength, as the vertebrae in the ankylosed neck are still more firmly united. When vertebrae are separate a strong binding medium is, of course, rendered necessary, but it would appear that the primary functional adaptation is in the soft cushioning, and that there must be some difference in the actions of the head in the Finners, as compared with the Right-whales, to account for ankylosis not taking place[1].

6. ARTICULATIONS BETWEEN THE AXIS, ATLAS, AND OCCIPITAL BONE.—Besides the ligaments between the spines above, and the continuation of the inferior common ligament of the bodies below, there are strong capsular ligaments enclosing the articular surfaces, and certain internal or central ligaments. The *capsular ligament between the atlas and occiput* (condylo-capsular) are strong ligaments, about ¼ inch in thickness, entirely surrounding each articular surface. Coming in contact in the middle, they form a septum between the two joints, where a median groove marking their attachment is seen on the atlas from its canal to its lower edge. This septum has a corresponding attachment on the occipital bone, between the lower ends of the occipital condyles, with corresponding mark on the bones, which but for this would here run into each other. The septum was imperfect and stringy, but this

[1] Ankylosis had taken place between the bodies of two of the vertebrae, the 3rd and 4th, in the Stornoway specimen, all the other vertebrae in these Fin-whales being free. The ankylosis had been broken up by force before they reached me. A plate of the 3rd had torn off, remaining with the 4th, and exposing the spongy tissue of the 3rd. The ankylosis occupies less than the middle half of the body-surfaces, about 5 inches across and 3½ high, being the central parts of the pulp surfaces. The impression at the attachment of the fibrous part of the fibro-cartilage, and other markings on the unankylosed part of the surfaces, are as usual. Notwithstanding the ankylosis, the articular surfaces between the articular processes of these two vertebrae are not only as well but better marked than those between the 4th and 5th.

may have been from the giving way of parts. In all of the four atlases this median groove is well marked, of varying breadth widening below into a triangular space into which the inferior common ligament dips. The *articular surfaces between the atlas and axis*, on the contrary, run into each other inferiorly, forming one great horse-shoe articular surface on both vertebrae, more or less notched at the middle line inferiorly[1]. The cartilage on the articular surface of the front of the axis, and on both aspects of the atlas, was about $\frac{1}{8}$ inch in thickness. In the Peterhead specimen, and there was an appearance of the same in the Wick specimen, the cartilage along the rim of the cups of the atlas assumed a fibrous appearance, and gave off fringes, half an inch to an inch in length, like a fringed marginal fibro-cartilage, the cartilaginous surface being again smooth for half an inch to an inch beyond the margin, until the attachment of the capsular ligament was reached.

The central ligaments, made out with considerable difficulty, are—(*a*) The transverse ligament of the atlas; (*b*) pair of check ligaments, interosseous between axis and atlas, and two longitudinal ligaments; (*c*) an inferior, the ligamentum suspensorium dentis; and (*d*) a superior, a prolongation of the superior common ligament of the bodies.

(*a*) *Transverse Ligament* (see Fig. 5). This great ligament is attached as in man, but has no contact with the odontoid process, and is flattened in the opposite direction. It divides the canal into two parts, the upper and larger part for the spinal canal, while the lower, narrower and pointed inferiorly, is occupied by ligaments. This explains the peculiar form of the canal of the atlas, the most constricted part corresponding

[1] In the Wick specimen, however, there is an appearance (see Fig. 5) of a median separation, by a narrow furrow in the lower part, continued along the upper half as a slight irregular depression, still less marked on the axis. In dissecting this joint, as the cartilage had begun to peel off, I could not be certain that it was continuous across the middle line. In the atlas of a fifth great Finner in my possession (afterwards referred to), a larger one than any of the others, and presenting a very wide median groove between the anterior articulating surfaces, there is no trace of median separation of the two joints on the posterior surface. In the axis of a fifth (young) great Finner (afterwards referred to) the horse-shoe surface appears as if divided by a faint median elevation. These appearances I believe to be deceptive, not implying that the cartilage and synovial membrane were not continued across in these as in the other specimens.

to where the attachment of the ligament begins superiorly. It is a thick flat ligament, measuring when fresh 2 to 2½ inches from border to border, half an inch to an inch in thickness, as thick and nearly as broad as three fingers laid flat; its breadth is about 2½ inches, corresponding to the width of this part of the foramen. Its upper border is concave, bounding the spinal canal, its lower border bounding the canal through which the suspensory ligament passes. Its attachment to the atlas is as far back as possible on the wall of the canal, but there is still left a space between it and the odontoid large enough to admit the fingers flat, though its upper edge comes close to the summit of the odontoid process, when, as in the Peterhead specimen, that process is better marked. It is composed of dense transversely arranged fibres, passes straight across, and is a tight strong resisting structure. Functionally viewed, this ligament is here adapted to serve as a great fibrous beam, presenting its posterior surface as a continuation of the area for the attachment of the check ligaments, while its edges afford attachment to part of the longitudinal ligaments.

(*b*) *Check Ligaments* (Alto-odontoid). This pair of ligaments forms the chief retaining structure between the axis and atlas; attached behind to the side of the odontoid area, in front to the crescentic depression on the atlas internal to its articular surface. An examination of the bony surfaces will enable their attachments to be readily understood. On the axis, bounded by the articular surfaces at the sides and below, and by the spinal canal above, is a large non-articular area, from 5 to 6 inches across and about 4 inches vertically. The whole of this area forms a gentle elevation, rising below the middle into a low conical eminence. While the whole may be termed odontoid area, the latter may be distinguished as the odontoid process. The summit of the process is situated at the junction of the lower and middle thirds of the area. To this process, and to the rough slope below it, is attached the ligamentum suspensorium; while, laterally, along the base of the process and the side of the area, is attached this great check ligament, the convexity of its semilunar attachment not going to the outer part of the area, and its horns approaching those of its fellow above and below. On the posterior aspect of the atlas the attachment is well marked, as a depressed crescentic surface between the articular surface and the edge of the canal (see Fig. 5), varying from 1 to 1½ inch in breadth, tapering upwards and downwards. The check ligament, itself crescentic in section, is attached to this rough crescentic surface; its lower part converges to join its fellow at the middle line below the canal, and is attached also to the neighbouring part of the wall of the canal; its upper part reaches inwards upon the transverse ligament, to which it has a true and extensive attachment. The check ligament is over 3 inches in height, its greatest thickness about 1½ inch. The fibres are longitudinal, direction forwards and a little outwards, length half an inch to an inch. The shortness, size, and interosseous position of this great ligament, explain why the motions between the atlas and axis are so very limited. The dissection of these check ligaments in the great Finners is very difficult. When the atlas is separated forcibly from the axis, they tear off from the axis, leaving the odontoid area bare and a few tufts attached to the process; and the lower part of the canal of the atlas is seen to be blocked by a dense pre-odontoid fibrous mass, below the middle of which is a conical recess into which the tip of the odontoid had sunk, the recess being now the hollow base of the suspensory ligament.

(*c*) *Ligamentum suspensorium dentis* (Occipito-odontoid). This ligament, about the size of a thumb, arises from the tip and lower slope of the odontoid, passes through the aperture below the transverse ligament, shows itself free for about 3 inches between the atlas and occiput, is here compressed laterally (vertically 1 inch, transversely $\frac{4}{8}$ to $\frac{5}{8}$ inch), and passes forwards to be inserted into the triangular fossa between the occipital condyles. The appearance of the lower part of this ligament being attached to the atlas, on its way forward, is due to its fibres being continuous with those of the check ligaments where they meet in the middle line below. There is the appearance as if it afterwards received an accession of fibres at the sides from the atlas and above from the lower edge of the transverse ligament, but this is not easily determined as its circumference is not isolated as it passes through the aperture below the transverse ligament. The occipital condyles are for about 5 inches separated only by a deep narrow fissure, attaching the septum formed by the condylo-capsular ligaments, and above this they diverge upwards, leaving a triangular fossa 3 inches in length, ¾ inch deep, and 1½ to 2 inches wide at the base where it is bounded by the foramen magnum. In this triangular fossa the suspensory ligament and the superior longitudinal ligament have a continuous insertion.

(*d*) The *Superior longitudinal ligament* (Occipito-axoid), a prolongation of the superior common ligament of the bodies of the vertebrae, a pretty strong flat ligament, passes from the upper surface of the body of the axis forward, partly joining the upper part of the transverse ligament but mainly continued on above that ligament, and now expanding passes to be inserted into the intercondyloid fossa with the suspensory ligament, to which it has previously adhered. Tracing these two ligaments backwards, they are separated by the vertically extended transverse ligament, to the edges of which they partly adhere, the lower passing to the odontoid, while the upper passes to the axis proper. The soft parts which occupy the middle line between the occipito-atlantal joints are the following, from the lower edge of the body of the atlas up to the spinal canal. 1, Median septum for 5 inches, formed by the close-together condylo-capsular ligaments. 2, Ligamentum suspensorium. 3, Mass of rete mirabile, in the triangular space between this and the next ligament and between the now diverging capsular ligaments on each side, giving this part a bulky appearance. 4, Superior longitudinal ligament.

Viewing these ligaments homologically and functionally, the transverse ligament is recognised, fully developed, and adapted to assist in binding the axis to the atlas by the attachment which it affords to other ligaments; the superior longitudinal ligament is as in man, and partly adheres, as it also does in man, to the transverse ligament; the inferior longitudinal ligament is a true ligamentum suspensorium dentis, connecting the odontoid and occipital centra; the check ligaments correspond to the lower check ligaments of man greatly developed; while the upper, or occipito-odontoid, check ligaments are suppressed, or converged and united with the suspensory ligament.

THE CERVICAL VERTEBRAE SERIALLY CONSIDERED.

I have examined these vertebrae closely with the view on the one hand of determining their more essential characters, and on the other hand of observing the differences which they present according to age or individual variation. The series of specimens were compared when arranged in position, as seen in Figs. 1, 2 and 3, and when arranged separately, and it will be observed when the remarks refer to them specially when in position and when separate. It is to be borne in mind that of the three whales to which these observations chiefly refer, the Peterhead one was scarcely mature, the other two being mature or aged. From the much greater size of its vertebrae the Wick whale might have been supposed to have been a much larger animal, but its length was only one or two feet greater than that of the Peterhead whale (65 to 66 against 64), while the mature Stornoway whale was only 61½ feet. Even when the length is ascertained by careful measurement with a tape line, there may be different results. Had I gone by the measurement along the back, the length of the Peterhead whale would have been stated as 68 instead of 64 feet; but the measurement ought always to be straight along the side, giving the length of the ground over which the animal extends. But making due allowance for this source of variation in the statements as to length, no reason appears why full-grown whales of the same species should not vary as well as men, some inches in the one being the equivalent of some feet in the other. Although variation in length in man may depend chiefly on the lower limbs, the enormous elongation of the caudal part of the trunk, the locomotive equivalent, in whales gives ample scope for trunk variation.

7. MEASUREMENTS.—The measurements given in the table were made with care, and may be useful for consultation. They show points of correspondence and variation besides those referred to in the remarks. The transverse measurement of the transverse processes (No. 2) is taken from the middle of the side of the body; taken from the anterior edge of the body would give nearly half an inch less. The length of the spinous pro-

TABLE OF MEASUREMENTS OF VERTEBRAE OF FOUR

	Atlas.				Axis.				3rd.		
	Peterhead.	Stornoway.	Wick.	Norway.	P.	S.	W.	N.	P.	S.	W.
1. Greatest width	26	28	27¼	27	39½	42½	46	42	31¾	36	38
2. Width of transverse processes. R. L.	6½ "	7¾ "	7 "	7 "	15 17¼	20 "	19½ "	18 18¾	10½ "	13½ 13¼	14 "
3. Breadth of plate beyond ring. R. L.	... ...	... ...	... ...	... ...	9 10½	13 "	13 "	11½ 12¼	2½ 2	5¼ 5	5½ "
4. Transverse diameter of rings. R. L.	... ...	... ...	... ...	... ...	6 6¾	7 "	6½ "	6½ "	8 8½	8¼ 8¼	8½ "
5. Greatest height of rings, vertically. R. L.	... ...	... ...	... ...	... ...	3½ 3⅞	4 4⅛	3¼ 3½	3¾ 4	6¼ 6½	6¼ 6⅜	6½ "
6. Circumference of rings. R. L.	... ...	... ...	... ...	... ...	15 16¾	18 "	15⅜ 16	17 "	25¾ 26¾	25¼ 25½	26 26½
7. Length of body.	4⅜	4	4½	4	4 2¾	3¾ 2¾	3¾ 3⅛	3½ 2¾	2⅝	2⅝	2⅞
8. Width of body: At anterior surface. At middle of side.					 ... 11	 ... 10½	 ... 12	 ... 11¼	 12½ 11½	 12 12	 13 12
9. Height of body.	...	4	4	3½	6½	7¼	7½	7½	6¼	8	8¾
10. Height of spinal canal.	...	7¾	8	8	5¾ 4½	5¼ 4	5½ 3¾	5⅛ 4⅛	4	3½	3¼
11. Width of spinal canal.	4¼	4½	4⅛	4⅜	6¼ 7⅛	6 6⅞	6 7⅛	6¼ 6⅞	6¼	7	6¾
12. Circumference of spinal canal.	...	...	...	...	19	17½	17¼	17¼	16½	17⅛	16¾
13. Length of spinous process.	1¼	¾	¾	?	3½	1	2¼	½	½	⅛	⅛
14. Greatest height of vertebra.	14¾	14¼	14½	...	16½	13¾	16	14	13	12¼	12¼
15. Weight. Pounds. Ounces.	19 11½	19 8	20 ...	... ...	23 10½	22 15	27 6	22 ...	8 13	7 9½	8 11

GREAT FIN-WHALES OF SAME SPECIES. (B. Musculus.)

4th.			5th.			6th.			7th.			1st. Dorsal.		
P.	S.	W.	P.	S.	W.	P.	S.	W.	P.	S.	W.	P.	S.	W.
32¾	36¼	38	34	37¾	38¼	32¼	36¼	36½	30	32	34¼	32	32	34
10½ 11	12½ 12¾	13½ ,,	11½ ,,	13½ 14	13¾ ,,	11 ,,	12¾ 13	13 13¼	11 11¼	11¾ 11	13 ,,	12½ 13½	11¼ 11¼	13 12¾
2½ 3⅛	4¼ 3¾	5½ ,,	4¼ 4	5 5¼	6¾ ,,	4 3½	4¼ ,,	5 5¾	2¾ 2¼	3 2½	... ...	... ...	... ...	... ...
7⅞ ,,	8¼ 9¼	8 ,,	7¼ 7½	8½ 8¾	7⅛ ,,	7 7½	8½ 8¾	8 7½	8¼ 9¼	8¾ 8½	... ...	... ...	... ...	... ...
6 ,,	6½ 6¼	6 ,,	6 ,,	6½ 6¼	5¼ 5½	7 ,,	... ...	6 ,,	... ...	... ...	... ...	... ...	... ...	... ...
25¼ 25	26¼ 27½	24⅛ 24¼	23½ 24	24½ 25¼	21⅛ 21⅝	24 25¼	26¾ 27¾	22½ 21½	... ...	... ...	... ...	... ..	... ...	... ...
2¾	2⅞	3	3	3⅛	3⅛	3¼	3⅜	3½	3¾	3⅞	4	4¼	4⅜	4½
12¼ 11¼	12 11½	12¾ 11¾	12 11	11½ 10¾	12¼ 11¼	11¾ 11	11¼ 10¾	12 11½	11¾ 11	11¾ 11	12½ 11½	12¼ 11¼	12¼ 12	13 12½
7½	8¼	9	7¾	8½	9½	8	8½	9½	7¾	8½	9½	7½	8¼	9
3¾	3¼	2½	3¾	3	2¼	3¾	3	2⅜	3¾	3⅛	2⅜	4	3⅛	2¾
6⅛	7⅛	7½	6¼	7⅓	7½	6¼	6⅞	7¾	6	6¾	7⅝	6	6¾	7¼
15¾	17⅛	17⅜	16	17¼	17⅜	16	16¾	18⅛	15¾	16¾	18	16	16½	17½
1	½	⅜	1¼	1	¼	2¼	1¼	¾	3¼	2¼	1½	2¾	2	1½
13½	12½	12½	13½	13⅛	12½	14¼	13¼	13	16	14½	14	15	14	14
7 4	8 ...	7 11	8 6½	9 6	9 7	8 2	8 6	9 15	10 6	11 15	13 3	14 6½	14 8	14 15

cesses (No. 13) is taken from within the canal, afterwards deducting the thickness of the lamina; the difficulty of fixing on the point of commencement of the spine rendering all other methods liable to fallacy. The distinction of right and left in the lateral measurements (the right always given first) shows the frequent a-symmetry, and that, when there is a difference on the two sides, there is no general preference of one side more than the other, as will appear farther from the remarks on parts not noticed in the table.

8. BODIES.—The bodies diminish in length (thickness) forwards, from the 7th to the 3rd. They gain in width, and lose in height, forwards, from the 6th to the 3rd. Longitudinally, they are grooved all round, except where the groove is interrupted by the median ridges and filled up by the roots of the inferior transverse processes. If the measurement of the width is taken at the middle of the groove it will generally give from $\frac{3}{4}$ to 1 inch less than if taken at the edges. The bodies are marked below, above, and on the sides by vascular foramina, largest below and smallest on the sides, more or less arranged in two rows, especially on the sides, one row going before the other behind the roots of the transverse processes. The breadth of the articular surfaces greatly exceeds the height, the proportion averaging that of 3 to 2 (see Fig. 4). The form of the surfaces varies in the three series, suggesting the semilunar in the Peterhead, the square in the Stornoway, and the oval form in the Wick series. The fundamentally square form arises from the projections where the inferior transverse processes and pedicles spring, forming lower and upper lateral angles. By the former being placed farther out, a greater breadth is given to the lower than to the upper part of the body, but the broadest part is generally a little below the middle. If the body is concave to the spinal canal, and the pedicles more internal, the semilunar form is given; if it rises up so as to be convex to the spinal canal, and the lower median ridge be also broadly developed, as in the Wick vertebrae, the form is changed to the oval. The posterior surfaces are, transversely, a little concave from the axis to the 5th, decreasing backwards; while the 6th is flat, the 7th and 1st dorsal a little convex. The anterior surfaces are convex transversely (and also a little convex verti-

cally), diminishing backwards, but distinct on the 6th and 7th. The striated ring, about 1½ inch broad, for the attachment of the capsular part of the fibro-cartilages, is well marked for an inch in breadth, and is convex, owing chiefly to the bevelling at the edges of the bodies; the inner half inch is concave and the concentric lines are less distinct. The contained somewhat figure-of-8 space, corresponding to the pulp, presents generally a central elevation, with a large shallow depression on each side bounded by a raised enclosure (see Fig. 4). The central elevation is seen on both surfaces, best marked perhaps on the front surfaces especially of the anterior vertebrae, while on the hinder surfaces it is better marked on the posterior vertebrae. Hence the bodies are thickest in the centre, where the measurements given in the table were taken. They measure ¼ inch less at the ring just within the bevelling, and about ¾ inch less at the extreme bevelled margins.

9. SPINAL CANAL, LAMINAE, ANAPOPHYSES, SPINOUS PROCESSES.—In my account of the Peterhead Razorback[1], I alluded to the high arches and well marked spines in it, compared with the low arches and scarcely present spines in the Wick specimen. Also in the latter, to the extreme thinness of the anterior border of the laminae, indicating atrophy. In both these respects the Stornoway specimen is intermediate, although in regard to shortness of spinous processes it more resembles the Wick specimen. The difference in the *shape of the spinal canal* is great, being triangular in the Peterhead and semilunar in the Wick series. The semilunar form is owing partly to the raising of the floor of the canal, the bodies (at their edges and median ridge) having become convex instead of concave to the canal; partly to the neural arches being very low. But the capacity of the canal, as the measurements of circumference show, is not less, being extended laterally by the pedicles being placed farther out on the bodies. On the four posterior vertebrae, while in the Peterhead specimen the height is more than half the breadth, in the Wick specimen the height averages less than a third of the breadth. The one is fully 1¼ inch greater in height, while the other is 1¼ to 1½ greater in breadth and 1½ to 2 inches greater in circumference.

[1] In this *Journal*, Nov. 1871, p. 120.

The lowness of the arch is not owing to shortening of the pedicles, but to the laminae turning across with very little rise, and forming no angle at the middle. The semilunar form is less marked on the 3rd, the body being a little concave and the arch a little raised at the middle; behind it all the bodies are convex, increasingly so backwards; the arches rise a little at the 6th and 7th, being lowest at the 4th and 5th; at the 5th the curves of the body and of the arch are almost parallel. In the Peterhead series all the bodies are concave and all the arches triangular.

The *laminae* of the posterior vertebrae do not overlap, leaving more or less open, in the Wick specimen the two, in the Peterhead three, and in the Stornoway specimen the four posterior spaces; most open in the Peterhead, elliptical and unsymmetrical in the other two specimens; and in the Peterhead and Wick specimens there is a median space between the laminae of the axis and third. In each there is a series of well marked processes projecting backwards (*anapophyses*) from the outer part of the laminae, near the articular processes. In the Wick specimen (see Fig. 3) they are 1 to 1½ inch in length, about two inches in breadth (about one-third of the lamina transversely), directed backwards and a little upwards, taper to a blunt rough point, and evidently receive their soft attachments from behind. On the 3rd, 4th, and 5th vertebrae they are much larger and longer than the atrophied spines, which are mere narrow median roughnesses, with a slight peak posteriorly. On the three hinder vertebrae they are considerably longer on the left than on the right side. In the Peterhead specimen (in which the spines are well marked) these anapophysial processes are more internal and less marked, though quite distinct, except on the 6th and 7th, on which they are obscure. In the Stornoway specimen they are intermediate. In front, they commence strongly marked on the axis, while posteriorly, on the 7th, they merge with the posterior articular process; but along the neck they are internal to and quite distinct from the articular processes.

10. ARTICULAR PROCESSES.—These processes are in a very reduced condition for vertebrae of this size. The anterior face nearly straight up, but with a little inclination outwards and

also forwards, the posterior the reverse. The size of the cartilaginous surfaces varies a good deal from the 3rd to the 6th, averaging 1½ to 2 inches by 1, the ellipse or oval being placed transversely, or rather obliquely upwards inwards and backwards, nearly in the direction of the laminae, on which most of the facet of the posterior is placed, the anterior being more on the "process," which projects from about ¾ inch on the 3rd and 4th to from 1 to 1½ on the 6th and 7th vertebrae. They become longer and more oblique between the 6th and 7th, and still more so between the 7th and 1st dorsal. Between the axis and 3rd they are nearly twice the size of those of the succeeding vertebrae, and present in all the four specimens irregularities and pits, giving a worm-eaten appearance to the surfaces. When well formed, the surfaces of the anterior processes are from within outwards first convex, then concave; those of the posterior the reverse. They are best marked in the Peterhead, and least in the Stornoway series.

11. Inferior Transverse Processes.—Those of the 3rd, 4th and 5th, complete in all the specimens, may be first compared. The *root* springs from the lower part of the side of the body, placed nearer the anterior than the posterior surface, varying in the amount of forward and backward expansion which it undergoes in joining the body, the 4th being thinner than the 3rd and 5th. The root has a broad attachment vertically, like the pedicle which supports the superior process, and as broad as it, but thicker in accordance with the greater thickness of the inferior processes. The roots are concave and smooth on both surfaces. The *tubercular stage*, nearly on the same line internally, increases in length forwards to the 3rd. The projection of the inner angles, besides being downwards is also forwards on the 3rd and 4th, especially on the former, but backwards on the 5th (and on the 6th also, if the process is present), except in the Wick specimen, in which the projection on the 5th is forwards. The tubercular part rather diminishes outwards on the 4th and 5th, but increases on the 3rd, terminating in a great though variable projection, giving the 3rd the longest and largest tubercular stage. The *nerve-groove stage* is well marked in all, best on the 5th. The twist seen on the anterior surface of the processes is owing, internally, to the

tubercular stage being much thicker below than above, while the grooved stage is thin below as well as above; and, externally, to increased thickness and less inclination of the terminal plate. The posterior surface of the processes is inclined obliquely upwards to the lateral canal, nearly uniformly so on both the tubercular and the grooved stages.

When in position, the process of the *third* is seen, after rising forwards a little at the root, to slant very obliquely backwards, parallel to the lower edge of the process and wing of the axis, and to bulge more downwards than the axis in the Peterhead specimen and at the outer part on the left side in both of the other specimens. The *fourth* has less obliquity backwards, and is more slender throughout, than the 3rd. The *fifth* is nearly horizontal, is the process to which the others converge, and is the stoutest, especially externally, having to support the widest and thickest terminal plate. The conditions of the *sixth* in these three necks illustrate well the liability of the inferior transverse process of this vertebra to be more or less deficient. In the Wick specimen, it is complete on the left side, the stages well marked, but on the right side it is wanting at the nerve-groove stage; in the Peterhead specimen it is wanting at the nerve-groove stage on both sides; and in the Stornoway specimen a large part of the tubercular stage also is wanting, on both sides, on the left side little more than the root-stage being present. When this process is incomplete in length, it also wants the upper part (that which gives breadth to the other processes) partially at the root, but more especially at the tubercular stage. Hence the process is flattened in a direction the reverse of those in front of it, and appears to spring from the body farther in than the others, and the capacity of the ring is thereby incidentally increased. The incomplete process generally tapers outwards to a narrow round point. The other end of the gap is formed by a flattened pointed process which the upper transverse process sends inwards more or less. The appearance as if the two ends would not meet if prolonged, is owing partly to the natural twist of the grooved stage, partly to the two pointed ends not belonging to corresponding parts of the plate which would have united them had it been developed. In the Peterhead and Wick specimens, in which I had the opportunity of dissecting the soft parts, the processes were represented at these gaps by ligament between their cartilaginous tips[1].

The *seventh* shows, as usual, at most a mere rudiment of the root stage of the inferior process. It is seen in the Wick and Stornoway specimens; is better marked on the Wick 1st dorsal, less marked on the Stornoway 1st dorsal; not at all on the Peterhead 7th, but well enough marked on the Peterhead 1st dorsal. It is placed where the lateral and lower surfaces of the body turn round to each other, and is little more than a slight rough projection where the ligament was attached. It may occupy most of the length of the body, but is mainly on its posterior half.

12. SUPERIOR TRANSVERSE PROCESSES.—The *pedicles* from which these processes arise, about an inch farther in than the lower process, are opposite the fore part of the bodies, coming quite to the level of the anterior surface, and expanding backwards so as to occupy $\frac{1}{2}$ (Peterhead specimen) to $\frac{2}{3}$ (in the other two specimens) of the length of the body. They average $1\frac{1}{2}$ inch in length along the middle to the zygomal process; increase in width backwards from the 3rd to the 7th; are grooved before and behind to form the intervertebral foramina; are directed upwards and outwards; and the inner half may be said to belong to the support of the neural arch and articular process, while the outer half sweeps outwards into the superior transverse process, serving as its root. Viewed in position, the *superior processes* converge outwards to the 5th, which is nearly level. Unlike the inferior processes, they gradually increase in strength backwards, the increase becoming more marked on the 6th, and greatly more on the 7th. At first, at the *nerve-groove*

[1] In the *Wick* specimen the right inferior process is $4\frac{1}{2}$ inches in length; after forming a forward and then a backward-projecting inner angle, it tapers rapidly outwards; gap now $3\frac{1}{2}$ inches. Terminal expansion of upper process not so broad as on left side; pointed process sent in $\frac{1}{2}$ inch internal to outer end of ring. In the *Peterhead* specimen both processes are $4\frac{1}{2}$ inches long; inner angles developed backwards, left less than right; left more flattened, from greater deficiency of upper part, than right. Gap on right side $1\frac{1}{2}$, on left 1 inch. Plate of upper process most expanded on right side; extent to which narrow process turns in, right side, $1\frac{3}{4}$, left $2\frac{1}{4}$ inches. In the *Stornoway* specimen the inferior process is $2\frac{1}{2}$ inches long on right side, $1\frac{1}{2}$ on left; left process flattened and tapering to blunt point; right much thicker than left, rounded and does not taper much; gap on right side $7\frac{1}{4}$, on left side $8\frac{1}{4}$. Plates of superior processes turn in for about $\frac{1}{4}$ inch, process on right side the most distinct.

stage, the surfaces are more directly forwards and backwards, giving the processes a slender appearance here, and leaving wide spaces between. The length of this stage increases forwards from the 7th to the 2nd. The *tubercular stage,* from the rough prominences which mark its commencement to opposite the outer end of the ring, has its surfaces inclined, the posterior looking obliquely downwards to the lateral canal. The anterior, looking obliquely upwards, is, in its upper half, rough and bevelled so as to look very much upwards, and is broadened so as to overlap the process behind it before the outer end of the foramen is reached. The inclination of these processes is most strongly marked on the 3rd and 4th, extending also to their nerve-groove stage; a little less on the 5th; on the 6th to a variable extent in the different specimens, in the Peterhead specimen throughout, in the Wick specimen scarcely at any part. On the 7th, on the contrary, the surface which looks obliquely to the canal is the anterior. This process is so thick as to present a third surface, looking upwards and rough, corresponding to the rough bevelled part on the anterior surfaces of the processes in front of it.

The general inclination of the posterior surfaces of both upper and lower processes, from the 2nd to the 6th inclusive, continued externally at their junction, gives the double transverse process the appearance of the section of a cone, the inner circumference, at the ring, being farther forwards than the greater circumference. It is seen on a large scale on the processes and wing of the axis. Although the most striking result of this is the presentation of a series of oblique surfaces, instead of narrow edges, as a bony wall to the lateral canal, it is to be regarded rather as the result of adaptation to the attachment of the ligaments and muscles on the under and upper aspects of the neck.

Viewed in series, the superior processes in the Peterhead and Wick specimens, from the 4th to the 6th, are nearly on the same level in point of height; the 3rd rises a little higher, the 7th rises higher throughout, and prominently so at its outer end. In the Stornoway specimen, the five posterior are on the same level, the 7th scarcely rising, except at the outer end.

The *terminal plates* are a little inclined towards the canal in their inner portion, continuing the inclination of the posterior surfaces of the processes above and below, but the inclination is less. The outer portion, when expanded, is less inclined, but the whole posterior surface has more or less of a concavity, increasing backwards, especially marked on the 6th and 7th; the anterior surfaces being correspondingly convex. The size of the terminal plates varies much according to age and the vertebra. They are much less expanded in the less mature Peterhead specimen than in the more aged Wick specimen. They increase in width backwards to the 5th (except in the Stornoway specimen in which the 3rd are as broad), which is in all the most projecting; and they diminish backward from it. In the Peterhead specimen the 3rd and 4th are blunt-pointed triangles, not much broader than the processes, the 5th forms a larger triangle. The 3rd, 4th, and 5th, in the Stornoway and Wick specimens, have expanded vertically as well as transversely to form more or less square-shaped plates (Fig. 4), the outer edge oblique, the lower angle the more prominent,—as seen on a large scale in the wing of the axis. The upper angle may not be developed, the plate retaining the triangular form, or so much developed that there is a hollow between the two angles. The 6th in all tends to broaden upwards, as a relation to the 7th, though the lower part is still the most prominent point. The extent to which the terminal plates may vary is well illustrated on the third vertebra; in the Peterhead specimen their breadth is 2½ inches (only ½ inch broader than the processes near them), while in the other two specimens they have expanded so as to present a breadth of 5 to 5½ inches, and a height, vertically at the inner part, of 6½ in the Stornoway, and 8 inches in the Wick specimen. The transverse process of the 7th forms a more or less square-shaped terminal expansion. In the Stornoway specimen it is very square-shaped, nearly at right angles to the rest of the process, the upper angle being, at least on the right side, the most extreme point. In the other two specimens it is rhomboidal, directed obliquely downwards and outwards, the lower angle the most extreme point, and less expanded in the Wick than in the Peterhead specimen. The outer edges present the rough unfinished appearance of ossifying bone; in the Peterhead specimen at the broadening points; in the more expanded Stornoway and Wick specimens, all along the outer edge and round the upper and lower angles, most marked in the Wick specimen[1].

Viewed in position, the 5th vertebra is, next to the axis, the most projecting, and its terminal plate is not only usually the broadest but is thicker, especially its lower part, than those of the 3rd, 4th, and 6th. It is the horizontal process, to which the others converge. The 7th is the least projecting in all. Next to the 5th in projection are the two next it; in the Stornoway specimen these two are equal; in the Peterhead it is the 4th on the left side, the 6th on the right; while in the Wick specimen it is the 4th, but in it the 3rd projects as far as the 4th. When the bodies are separated to the same extent as they are naturally by the fibro-cartilages, the terminal plates, though near each other, are not in contact; the thin wedge-shaped spaces diminish outwards until there may be only from $\frac{1}{8}$ to $\frac{1}{4}$ inch between the tips; but they may be made to touch by a little lateral flexion, or the more slender ones by their flexibility when the tips are pressed with the fingers. The following measurements of the Wick and Stornoway specimens indicate the amount of the convergence. At the roots of the inferior processes the extreme distance between the third and sixth is 10 to $10\frac{1}{2}$ inches; between the tips, including the thickness of the four plates, $2\frac{1}{2}$ inches. Including the axis and the 7th, the extreme distance between their superior roots averages 18 inches, while externally they reach the same level.

13. THE RINGS.—The characters of the rings (foramina) are seen when the vertebrae are laid in series on the floor. In *form* they are between a triangle and a semi-oval, the inner boundary obliquely convex, the upper and lower concave; the upper angle acute, the lower obtuse, the outer rounded off (Fig. 4).

[1] The *thickness* of the terminal plates, when expanded, as in the Wick and Stornoway specimens, from the 3rd to the 6th, averages about half an inch, at the middle; the 4th is the thinnest, the 5th the thickest. They are generally rather thinner internally towards the ring, and thicker towards either the upper or lower margin, towards the upper in the 3rd and 4th, towards the lower in the 5th. The fifth in the Wick specimen is $1\frac{1}{4}$ to $1\frac{1}{2}$ inch below, $\frac{1}{4}$ to $\frac{1}{2}$ inch above; in the Stornoway specimen there is marked a-symmetry (Fig. 4), on the right $\frac{7}{8}$ below, $\frac{1}{2}$ above; on left side 1 inch below, $\frac{3}{4}$ above. The 6th in the Wick specimen is $\frac{3}{4}$ inch thick on the side on which the inferior process is complete, and much thicker below ($1\frac{1}{4}$) than above ($\frac{5}{8}$), while on the right the plate is under $\frac{1}{2}$ inch and nearly uniform. The 7th is thicker (1 to $1\frac{1}{4}$) and less expanded than the others.

The oval form is more marked in the anterior, the triangular form in the posterior vertebrae. The upper margin is the longest, partly from the pedicle being set on the body about an inch farther in than the inferior transverse process is, partly from the outer end of the ring being below the level of the transverse axis of the body. This margin does not rise higher than where it begins, but curves gradually outwards and downwards. The lower margin is generally the most bent, varying a good deal (from $\frac{3}{4}$ to $1\frac{1}{4}$ inch) in the degree to which it is bent down at the tubercular stage; and the outer half varies in the degree of its curvature, in some turning up more abruptly so as to give the appearance of an angle on the lower edge of the ring, in others having a more continued concavity. The greatest vertical height of the rings (as given in the table) is at about the junction of the inner and middle thirds, and is about $\frac{1}{4}$ to $\frac{1}{2}$ inch greater than at the middle of the ring. If the line of the transverse axis of the bodies be prolonged, it intersects the rings variously; in the 2nd, $\frac{2}{3}$ are above the line; in the 3rd, there is rather more above than below (except in Stornoway right, most below); the 4th is about equally divided (except in Stornoway left, most above); in the 5th most below (except in Stornoway left, rather most above); in the 6th most (from $\frac{3}{5}$ to $\frac{2}{3}$) below. A line intersecting the outer ends of the rings (foramina) leaves on an average $\frac{2}{3}$ of the rings above it, and intersects the bodies so as to leave $\frac{3}{5}$ above (on the sixth $\frac{2}{3}$) the line. The extreme tips of the transverse processes are below the line of the transverse axis of the bodies, and are mostly below even the transverse line intersecting the outer ends of the rings, but the tips generally are on a line with the general axis of the foramina and double transverse process, the direction of which is outwards and downwards. The *size* of the rings generally decreases a little backwards from the 3rd to the 5th (except in Stornoway 3rd, in which it is not so large as in the 4th), as the measurements given in the table show. The slight increase in capacity at the 6th is chiefly owing to the deficiency in the height of the root of its inferior transverse process. It will be observed, from the measurements given, that the expansion of the terminal plates is not, as in the case of the axis, accomplished at the expense of the foramina; for, although the foramina are a little less in the Wick than in the Peterhead specimen, they are (except in the 3rd) larger all through in the Stornoway than in the Peterhead specimen, while in the latter the plates are much less expanded than in the other two. The gain is by outward growth beyond the rings. The table of measurements shows frequent want of symmetry in the diameters and capacity of the rings on the two sides of the same vertebra.

14. RECOGNITION OF THE FIVE POSTERIOR VERTEBRAE.—These vertebrae may be distinguished from each other by the following characters.

The *third* and *fourth*, from the others, by their transverse processes slanting obliquely backwards. The articular processes indicate front and back, the anterior facing upwards. The *third* is known from the *fourth* by the greater slant of the transverse processes, making it like a bow when resting on the floor, and by the far out position and great development of the outer end of the tubercular stage of the lower transverse process. The *fifth* is known by its transverse processes being directed nearly horizontally outwards. The *sixth* by the transverse processes being directed a little forwards, but more readily by the inferior transverse processes being usually more or less incomplete. The *seventh* is known, from the sixth, by its robust superior transverse process, and the almost entire absence of a bony inferior transverse process; and from the first dorsal, by its transverse process being less robust, and being flattened, especially at the outer end, while the ends of the first dorsal are thick and rounded.

15. THE AXIS.—(*a*) *Transverse processes.* This enormous process, when fully developed, may be divided into three parts of nearly equal length,—the processes and foramen, the broad square part of the wing, and the tapering part of the wing. The *ring* is so small as to be scarcely equal in circumference to the spinal canal of the vertebra, except in the Stornoway specimen, in which it slightly exceeds it. It is ovoid, the lower boundary the most curved, the outer end rather the most pointed. The smaller size of the ring of the axis is owing to the increase of the processes and inner part of the wing at the expense of the ring. The extreme height of the processes opposite about

the middle of the ring is very little greater than that of those of the 3rd vertebra, but they are so developed both in height and thickness that they are twice the breadth (height), and two or three times greater in circumference. The increase is greater relatively on the superior process, but the inferior process is actually the greatest, corresponding to the greater extent of the lower part of the wing. The *wing* corresponds to the terminal plate of the vertebrae behind, enormously expanded. Although it presents very various forms with age and individual variation, definite characters may be recognised. From having been square-shaped, it has become prolonged at the lower part, giving the outer border a very oblique direction, and rather a triangular appearance to the wing. In a young specimen in my possession[1] the processes are as yet flat, the lower twice the height of the upper, the plate beyond the ring is only half the length of the ring, and a line is seen running across it, from the outer end of the ring, where the two have united, leaving much the broadest part of the wing opposite the inferior process. In the four grown specimens the prolongation of the axis of the ring leaves $\frac{2}{3}$ or $\frac{3}{5}$ of the breadth of the wing opposite the lower process, except in the Peterhead specimen, in which the division is about equal.

When the wing is developed, the *outer border*, oblique and undulating, presents more or less of a concavity which may (as in the Peterhead specimen) be partially subdivided by a prominence. The *inferior border* is thick and rough on the process opposite the tubercular stage of the vertebrae behind, and then sweeps outwards to the tip with a general convexity downward. The *superior border* presents first a well-marked stage corresponding to the nerve-groove stage of the other vertebrae, terminated externally by a tubercle where the border is rolled upwards and forwards, corresponding to the series of tubercles on the processes behind, and before to the hinder projection of the transverse process of the atlas. The atlo-axoid intertransverse

[1] Without history, but it is evidently that of a young great Finner. It has the following dimensions. Greatest height 12 inches; greatest width $23\frac{1}{2}$; width of lateral ring, right $3\frac{3}{8}$, left $3\frac{5}{8}$; height of lateral ring, right 2, left $2\frac{1}{4}$; circumference of lateral ring, right 9, left $9\frac{1}{2}$; width of plate beyond ring, right $2\frac{1}{2}$, left 2; width of spinal canal, anteriorly 5, posteriorly 6; height of spinal canal, anteriorly $4\frac{5}{8}$, posteriorly $4\frac{1}{4}$; circumference of spinal canal, $15\frac{1}{2}$.

ligament was found to be attached here in the dissection of the lesser Fin-whale. This tubercle is at the broadest (highest) part of the wing, and is nearly opposite the outer end of the ring. From the tubercle to the upper angle is the tubercular stage of the process and wing; it is rough and bent backwards, forming a considerable concavity transversely, giving a very undulating appearance along the upper edge of the process and wing (see Fig. 3).

The extent to which the wing is expanded varies in both directions. The length outwards to the superior angle is nearly the same (12 to 13 inches, from the edge of the inferior surface of the body) in all the four grown specimens, except on the right side of the Wick specimen, in which it is 2 inches more. The length to the inferior angle varies in these four, from 15 inches in the Peterhead (right side, left 17¼) to 20 in the Stornoway specimen. The broadest part of the wing is nearly opposite the outer part of the ring, where the processes are tubercular, especially the upper; but the breadth (height) is not very much greater than that of the processes farther in, being about 2 inches greater in the Wick (height of wing 12½), 1 to 1½ in the Peterhead (right wing 10¾, left 11), 1 in the Norway (10), ½ to ¼ in the young (8¾, 8½), and in the Stornoway specimen 1 inch on the left side, none at all on the right (10¼, 9¾). From this point, to opposite the upper angle, being along the inner half of the wing, the breadth diminishes somewhat at both borders, and on the outer third rapidly by the obliquity and concavity of the outer edge. The outer 5 inches in the fully grown Stornoway specimen is abruptly marked off as a nearly equilateral triangle, rounded at the tip, and is bent backwards so as to give this part a much greater slant than the inner part. It is at the same time twisted, so that its posterior surface looks partly upwards. The processes and their wing are curved transversely, concavity backwards, the depth of the curve, from the ring outwards, being about an inch when the tips are much bent. The wing is also curved vertically, depth of curve 1 to 2 inches, influenced by the amount of bending of the margins, but well marked over both the surfaces, convex in front, concave behind. The thickness of the wing at the middle is about an inch, increasing inwards, diminishing outwards to from ¾ to ½ inch at the tip.

When *in position*, the wings of the axis, in the Stornoway specimen, are seen to pass outwards beyond the tip of the transverse process of the 5th more than two inches; and backwards as far as fully to the level of the tip of the transverse process of the 7th, and to the level of the junction of the anterior and middle thirds of the body of the 6th. In the Peterhead specimen the wings extend two to three inches (over 2 on the right, over 3 on the left) outwards beyond the 5th; but backwards only to the level of the tips of the transverse processes of the 4th, and to the level of the hinder edge of the body of the 4th. In the Wick specimen (as accurately as can be determined in the partially injured condition of the extreme tips) they reach outwards four inches beyond the 5th; and backwards to the level of between the tips of the transverse processes of the 6th and 7th, and to the level of the hinder part of the body of the 5th, but they may have been longer. Taking all the five specimens, the distance to which the slant of the wings carries their tips back from the level of the hinder surface of the body, is, in the Stornoway specimen 10 inches, Wick apparently 8, Norway 8, Peterhead $5\frac{1}{2}$, young specimen $1\frac{3}{4}$ inch. Vertically the inferior transverse process is seen to project less downwards than the tubercular stage of the process behind it, and the superior process scarcely if at all projects above the level of the inner stage of the superior processes behind it, but all beyond these points the wing and upper process of the axis project beyond the processes behind them, upwards, downwards and outwards, forming a great sloping shield in front of them.

(*b*) The region of the *spinous process* of the axis presents very great variety. The Wick and Stornoway specimens resemble each other in presenting a large square-shaped mass, partially bifurcated in the former, while, in the Stornoway and Norway specimens, this part is flat with two low widely-separated longitudinal ridges, or crests, in the valley between which there is a low median ridge. The mass is apt to be regarded as a greatly developed and more or less bifurcated spine, but the central ridge must be regarded as the true spine, the lateral ridges being processes on the laminae, serial behind with the anapophysial processes, and anteriorly forming projections on which there may be true articular facets for articulation with the atlas. Hence the spine appears in the table of measurements, in one, ½ an inch, in another, 3½ inches in length. We have here a striking illustration of how easily one might be misled in endeavouring to found distinctions of species on the conditions of the bony processes[1].

(c) *Anterior aspect of the body of the axis.* There is considerable variation in the depth of the articular surfaces, in the form of the odontoid area between them, and in the form of the odontoid process. The greater depth of the *articular cavities* is owing to the greater rising up of the outer sides. In the Wick and Peterhead specimens the greatest depth on each side, as given by a line laid on between the outer edges at their fore part, is 1¾ inch; in the Stornoway specimen ¾, in

[1] We can see how the one form may grow into the other. In the *young* specimen, the lateral ridges, or crests, rise about an inch, are 4 inches apart, diverge backwards, and in the valley between them there is a low median spine. In the *Norway* specimen the lateral crests are two low irregular convex ridges, 5 inches apart, rising scarcely half an inch, except forwards, where they support articular facets, while the median ridge, in the very shallow valley, rises at most half an inch. The anterior part of the crests and valley begin to meet the posterior part at an angle, and the posterior part is the roughest. In the *Stornoway* specimen, the crests, 4½ inches apart, have increased both in height and thickness, especially forwards, the valley is an inch in depth at the fore part, much less behind, and there is a low median ridge; and the angle between the fore and back parts is increased, but is still very obtuse. In the *Wick* specimen (see Fig. 3) the crests are largely developed forwards, but still more backwards, the valley between them being at the same time well filled up. The angle between the fore and back parts of the crests and valley has risen up to a right angle. The valley in the fore part is nearly filled up, while in the back part it presents a very rough excavation. The whole has the appearance of a great square-shaped mass partially bifurcated backwards and with a tendency to bifurcate upwards, without median ridge anywhere. In the *Peterhead* specimen the change is carried farther, the angle is carried upwards and backwards to an acute angle, the fore part is quite filled up, the back part concave and rough. The square lump of bone thus formed presents sloping lateral surfaces, giving a width of 6 inches to the process at the middle; a square-shaped superior surface looking forwards as well as upwards, about 4 inches square, projecting more on the left side than on the right; a thick anterior border; and posteriorly, marked off from the fore part by a sharp transverse overhanging edge, an excavated surface, looking backwards and a little upwards, 5 inches across by 3½ vertically, excavated to a depth of 1¼ inch, very rough, and with a median ridge.

This great variation is not a matter of age, for the form presented by the young specimen is retained by two of the mature specimens, while the more developed form is presented by the mature Wick and the scarcely mature Peterhead specimen; unless we suppose that this part having begun as in the young specimen, progresses under muscular action to the condition of the square-shaped mass presented in the Peterhead specimen (in which the other cervical vertebrae have the spines most fully developed), and afterwards becomes reduced with age to its early condition, the three other specimens showing stages of that reduction. But in the Wick specimen, in which the spines of the vertebrae behind have nearly disappeared, this part of the axis presents the next best instance of massive development. These differences must therefore be regarded mainly as exhibitions of individual variation.

the Norway specimen intermediate. This difference is strikingly seen from below when the bodies are in position, the atlas appearing in the two former to sink into a deep cup in the axis, while the depression is comparatively shallow in the Stornoway specimen. This gives the appearance of considerable difference in the length of the body at the sides, while at the middle below they are mostly the same, as seen in the table of measurements. Together with greater depth of the lateral cavities, there is a sharpness of finish all round the edges of the horse-shoe surface, in marked contrast with the Stornoway specimen. The articular edges in the latter are over half an inch lower than the odontoid, in the Norway specimen ⅜ inch below it, in the Peterhead and Wick specimens nearly (Peterhead scarcely, Wick rather above) level with the odontoid, but the odontoid is actually the longest in the Peterhead specimen. The upper of the two series of measurements of the length of the body given in the table are taken at the odontoid, and show it to be 3¾ inch each in the Wick and Stornoway, and 4 in the Peterhead specimen.

The *odontoid* appears to the eye to vary a good deal in length, but this is mainly owing to its form. In the Peterhead specimen, in which it appears long, it rises to a height of an inch from the edge of the odontoid area; in the other specimens about ¼ inch less. In the Peterhead specimen the area and process together form a cone, rising well but not abruptly at the process; in the Wick specimen the area is less raised, the process rather more defined at its base; in the other two grown specimens there is only a low general cone, rising to a blunt summit, lowest in the Stornoway specimen. In the young specimen the cone rises better, and is terminated by a blunt excavated apex. In all of them the summit is below the middle of the area (at about the junction of the lower and middle thirds) but above the middle (nearly as high as the junction of the upper and middle thirds) of the general body of the axis. In height, the odontoid area is nearly the same (nearly 3¾ inch) in all, except in the Norway specimen in which it is fully 4½, but it varies a good deal in breadth. The following are the breadths of this area, and, given within brackets, the breadth of the entire anterior surface of the body—Peterhead 4½ (15), Stornoway

5 (13½), Wick 5¾ (15), Norway 6¼ (15), young specimen 6¼ (12½). The area is much rougher on the inner half or two-thirds than on the outer part, and is especially rough on the process and below it. In the Stornoway specimen, in which the articular surfaces are shallow, the edge between them and the odontoid area is not so sharply defined as in the others.

16. ATLAS.—(*a*) The *posterior surface* presents differences corresponding to those noticed on the anterior surface of the axis. The transverse convexity of the lateral *articular surfaces* is strongly marked in the Wick and Peterhead specimens, the surfaces of the latter being specially prolonged outwards and terminated by a raised edge, so that they become concave externally. In the Stornoway specimen, the surfaces are much more flat, the internal convexity is low, and the external concavity is distinct, although the outer edge, instead of being prolonged, is so deficient that its upper half is bounded by a concave instead of a convex line, and is so low as to be nearly on a level with the transverse process. The *crescentic ligamentous surface*, internal to each lateral articular surface, varies in breadth with that of the odontoid area, to which the two crescentic surfaces and the odontoid division of the canal correspond, and also in sharpness of definition. In the Stornoway specimen it reaches 1 inch in breadth, and is not much depressed; in the Wick specimen (see Fig. 5) 1¾ in breadth, and is abruptly depressed more than ¼ inch; in the Norway specimen fully 1¾ in breadth, and is obliquely depressed.

(*b*) The *anterior articulating surfaces* vary in the state of their edges, in their depth, and in the breadth of the median groove. In the Peterhead and Wick specimens the edges are sharp, giving the cavity a depth of 3 inches; in the other two specimens the cavity is nearly half an inch less in depth, the edges being lower and more rounded, sinking especially at the sides to the level of the transverse processes. All show the furrow round the outer side for the attachment of the capsular ligament. The median groove is narrowest in the Wick and Stornoway specimens, broader (⅜ inch) and more defined in the Peterhead, broadest (⅝ inch) in the Norway specimen. In all it widens out triangularly below, and also a little above, being narrowest at or above the middle, but in the Norway specimen it remains widely open, and presents a double furrow in its floor, indicating the separate attachment of the two capsular ligaments. The measurements of the cups of the atlas are; greatest height and breadth (diameters) of each, Peterhead specimen 11 by 6 inches, Stornoway 10¼ by 5¼ (wanting an inch in height at the upper part from not extending up over the roof of the transverse foramen, as the others do), Wick 11¼ by 6, Norway 11 by 5⅜; distance between the outer edges of both cups, given in the same order, 13½, 12½, 13½, 12¾.

(c) *Parts on the neural arch. Occurrence of articular processes between the axis and atlas.* The spinous process is distinct in all as a median ridge, most marked posteriorly, very little marked on the anterior half in the Stornoway and Wick specimens. It is most developed in the Peterhead specimen in which the axis is so greatly developed here, but it is on the whole scarcely more pronounced in the Wick than in the Norway specimen, in which the spine of the axis is so differently formed. On each side of the spine, about the middle of the lamina, rough lateral ridges occur, serial with the crests on the laminae of the axis, increasing and diverging forwards (see Fig. 3). The ridge runs forwards into the process which arches over the nerve-notch of the atlas and usually converts it into a foramen, and backwards more or less into a posterior articular process for the axis. True *articular processes* between the axis and atlas, situated above the nerve-escape, existing normally in reptiles and birds but not in mammals, are present, more or less, in at least four of these five great Fin-whales[1]. They are present on both sides in the Norway and Stornoway specimens, on the right side in the Wick (see Fig. 5) and the left side in the Peterhead specimen, and seem to have existed on both sides on the young axis. On the axis they are situated on the lower part of the anterior end of the crest-like ridge, above the middle of the lamina, and from their position the facet is very liable to be rubbed off and overlooked. The facets on the atlas in the Norway specimen are symmetrical, 1½ to 1¾ inch transversely by about 1 inch longitudinally; in the Stornoway specimen they are elliptical pits, that of the left side divided into

[1] I find them still better developed in some male Narwhals, on one or on both sides.

two, into which corresponding projections of the axis sink. From the greater development of the crest on the axis making it overlap the atlas, the facet is seen on the upper aspect of the lamina of the atlas, but in the Peterhead specimen it is on the under aspect, as the atlas is here the overlapping bone. In the Peterhead specimen this functional articular facet ($1\frac{1}{4}$ by $\frac{1}{2}$ inch) is situated high up where the spine and lamina join and partly on the spine, on the left side, owing to the great upward projection of especially the left side of the square-shaped mass of the axis. On both sides in the Peterhead specimen, and on the left side in the Wick specimen, there are low projections on the laminae of both bones, not meeting, corresponding to the ligamentous boundary superiorly of the intervertebral foramen. This foramen thus marked off above, of an oval form, admitting from three to four fingers, is rather larger than the two succeeding foramina, but not larger than the foramina between the three posterior cervical vertebrae.

(*d*) The *transverse foramen of the atlas* is incomplete on both sides in the Stornoway specimen; on the left side half an inch is wanting, on the right side $\frac{1}{8}$ inch. The posterior process is short especially on the left side, four-fifths of the nearly completed foramen being opposite the anterior process, which curves back from the end of the articular cavity. It is triangular in form, the deficiency in the roof being on the inner side, leaving the internal aperture unformed; and the articular cavity does not reach upon this part as it does in the other specimens[1]. The breadth of the arch of bone roofing over the foramen (giving also the length of the foramen or canal) is, in the Wick specimen, 2 inches on the right side, $2\frac{1}{2}$ on the left; Norway specimen, right $1\frac{3}{4}$, left 2; Peterhead specimen, right $1\frac{3}{4}$, left $1\frac{1}{2}$. The thickness in the Wick specimen is 1 to $1\frac{1}{2}$ inch, in the other two specimens $\frac{1}{4}$ inch less[2]. In the Stornoway specimen

[1] This variety resembles that often seen in the human atlas by the more or less complete ossification of the ligament which normally arches over the nerve and artery. The serial correspondence of the posterior process to an articular process is evident, but it joins in front with a process of the same vertebra. The same arrangement is seen in the axis of some mammals, the anterior notch being converted into a foramen. In some the posterior notch in the dorsal region is converted into a foramen, the articular processes being also present.

[2] The articular cup being prolonged on this arch as far up as to opposite the middle of the foramen, the edge of the bone receives a forward curve in its upper

the recurved process is an inch in breadth at the middle, and $\frac{1}{3}$ inch thick. In dissecting the Peterhead specimen I found the roof to be naturally continued outwards for over half an inch by a ligamentous arch, thick where attached to the bony edge, becoming thinner to the crescentic margin in which it terminated externally. The broad groove issuing from this foramen is continued outwards to the anterior surface of the root of the transverse process, and a narrower groove is seen to pass nearly straight backwards from the outlet of the foramen to a notch on the lower edge of the lamina at the intervertebral foramen between the atlas and axis (see Fig. 3). The foramen contained, besides the atlantal nerve (about the size of the human great sciatic), a plexus of small vessels, one as large as a crow-quill, but no large vessel. The foramen is less than a third the size of the intervertebral foramina; roughly, it will admit a thumb. It is smallest at the inner end, which is oval in the Wick specimen (long axis longitudinal and nearly 1 inch), smaller and round in the Peterhead, intermediate in the Norway specimen. In the Stornoway specimen, in which the roof is incomplete, the oval is vertical and the capacity greater.

(*e*) The *transverse process* of the atlas is in series with the superior process of the axis. Internally, the process is flattened, the surfaces forwards and backwards, but thick enough to present upper and lower surfaces, the expanded root situated opposite the upper half or two-thirds of the articular surface, or so-called body, of the atlas, the downward extent of this attachment varying, and being at first so gradual that it is not easy to define its commencement. Externally, it is flattened in the opposite direction, the surfaces inferior and superior, with upper, lower, and external borders. Variations are seen in the different specimens, as observed both in vertical and antero-posterior views. *Observed in front*, the processes in the Wick specimen (as seen in Fig. 5, representing a posterior view) stand out transversely, as stout triangular or conical processes, the right broadest (highest) externally, the left broadest at the root, which passes down $1\frac{1}{2}$ inch below the middle of the body. In the

third, making the length between the posterior and anterior surfaces about an inch more above than below in the specimens in which the arch is complete. When the vertebrae are built up vertically, the upper third of the cup is consequently seen to rise to a higher level than the rest.

Peterhead specimen they pass straight out, are much thinner in the outer half, the upper margin forming a general concavity along its outer three-fourths, and the root is opposite very little more than the upper half of the cup. In the Stornoway specimen the root is opposite the upper $\frac{2}{3}$ of the cup, passing $1\frac{1}{2}$ to 2 inches below the middle, but, as the upper inch of the cup is not developed, the middle is a lower point in this specimen than in the others, and the processes therefore extend fully to the beginning of the lower third of the cup. It widens out sooner on the left than on the right side. A little more filling up about the middle of the lower margin would give these processes the form of triangular masses set opposite the upper $\frac{2}{3}$ of the cup; and I should have great hesitation in accepting the extent of this attachment as a character in distinguishing species. The upper margin of the process is sigmoid, first broadly convex, where the other two specimens show only the internal tubercle, and then concave on the outer $\frac{2}{3}$ to the turned up tips. Thus in the antero-posterior view of the Stornoway specimen the processes are stouter at the root than in the other two, are more compressed in the outer half than in the Wick specimen, are turned up at the tips, and are about an inch longer than in the other two specimens. A line between the middle of the outer parts of the transverse processes intersects the cup so as to cut off, in the Wick and Peterhead specimens, the upper 3 of the 11 inches, in the Stornoway specimen the upper 2 of the 10 inches, and intersects the base of the process, so that in the Peterhead specimen about 3 inches are above and a little more below, while in the Stornoway specimen about 3 inches are above and 5 below. The following are the height and girth at the middle of the transverse process in the three specimens—Wick, $4\frac{1}{2}$ and $11\frac{1}{2}$ inches; Stornoway, right $3\frac{1}{2}$ and $10\frac{1}{2}$, left 4 and $11\frac{1}{2}$; Peterhead, $2\frac{3}{4}$ and 10. The process in the Norway atlas is too much injured to admit of accurate conclusions being drawn.

Observed from above, differences are seen (see Figs 1, 2 and 3). At the back part of the root there is a rough tubercle (internal tubercle) from which a ridge passes obliquely across the process towards the fore part of the tip. This ridge is much more developed in the Wick specimen, rendering the process much less flat than in the Peterhead specimen. Another tubercle (external inter-transverse tubercle) is developed behind the tip in each, rendering the outer part, antero-posteriorly, an inch more than the inner part, and making the posterior margin internally much more concave than the anterior. The outer margin is convex in the Wick, nearly straight in the Peterhead specimen, and the extreme point in both is the anterior angle. In the Stornoway specimen the extreme point is the posterior angle, which is prolonged backwards and outwards, the outer margin rounding off to continuity with the anterior margin, giving the processes a backward droop externally. Farther, the surfaces of the process are much twisted beyond the root, so that the inferior surface looks obliquely forwards, the superior obliquely backwards, and the oblique ridge, noticed on the upper surface in the other two specimens, remains as the upper border of the twisted process[1]. In the Peterhead specimen the surfaces are directly up and down, superior flat, inferior convex; but in the Wick specimen, especially on the right side, an approach to the twisted form is seen, the increase downwards at the root giving the anterior surface some obliquity, and prolonging the inferior surface of the root outwards, so as to give the process a somewhat triangular figure. The differences in form between the transverse processes in the Peterhead and Stornoway specimens are certainly remarkable.

Seen in position, the processes stand nearly straight out in the Wick and Peterhead specimens, but in the Stornoway specimen they have a backward droop externally. The distance between the nearest part of the tips of the transverse processes of the atlas and the surface of the wing of the axis behind them is, in the Wick specimen 6 inches, Peterhead 5, Stornoway 2½ to 3; the distance is nearly an inch less to the tubercle (inter-transverse) of the axis, in the Wick and Peterhead specimens, from its being turned forwards towards the atlas, while the little development of this tubercle in the Stornoway specimen is probably related to the unusual prolongation, above noticed,

[1] This twist of the transverse process is an approach to the condition in the lesser Fin-whale, in which this character is strongly marked. The same obliquity may be seen in man and in various other mammals.

of the tip of the process of the atlas. The tips pass out beyond the foramen of the axis for an inch or more in the Peterhead and Wick, for about two inches in the Stornoway specimen. Their lower margins, except quite at the base, are nearly on a level with the upper edge of the foramen, except in the Stornoway specimen, in which they project down in front of the upper fourth of the foramen, and more internally towards the base.

(*f*) *Canal of the Atlas.* The constriction indicating the division into two parts varies. The width at the constriction in the several specimens is, Peterhead 1¼, Wick 2⅛, Stornoway 2¼, Norway 2¾, but the appearance of constriction is most marked in the Stornoway specimen. The general form of the odontoid division of the canal is, in the Wick specimen, that of a blunt-pointed triangle with gently concave sides (greatest breadth 2¾); in the Stornoway specimen it is bulged at the sides and more pointed below (breadth 3); in the Norway specimen it is like the lower two-thirds of an ovoid (breadth 3); in the Peterhead specimen the ligaments still remain filling it up, but it most resembles the Wick specimen. The projection sustains, as in man, the most internally projecting part of the articular surface behind it, but more immediately attaches the upper part of the transverse ligament, the attachment of the ligament continuing down to where the opening begins to contract, leaving a triangular odontoid opening, bounded above by the concave edge of the ligament. The neural division of the canal varies a little in width in the different specimens (see table), and its form above is influenced by the curvature of the neural arch, which is less in the Norway specimen than the others, giving it more distinct upper lateral angles. The general form may be defined as square-shaped, with rounded angles, and contracting downwards, or as triangular with a very blunt apex below. Vertically, it measures about 4½ inches to the concave edge of the ligament, 4¼ to the bony projections, which are situated below the middle of the general opening; its greatest breadth is about the same when taken anteriorly (as given in the table), but posteriorly the canal is much wider; near the intervertebral foramen in the Wick and Norway specimens it is 6 inches, in the Peterhead 5¾, in the Stornoway specimen 5½.

(*g*) *Sub-axial process.* The peak on the hinder part of the atlas, the development of which has been regarded as a character of specific import, is present in various degrees in these specimens. The horse-shoe articular surface recedes here for $\frac{3}{4}$ inch in the Norway and Peterhead specimens, $1\frac{1}{2}$ in the Wick and Stornoway specimens, leaving a median triangular notch. The upper part of this notch is a rough depression, while from the lower part a pointed process projects more or less backwards. In the Peterhead specimen, though forming a projection from where it begins, it does not reach so far as the edge of the atlas itself; in the Stornoway specimen it projects half an inch behind the rest of the atlas and in below the axis, as a median conical process, occupying the whole height of the notch; in the Wick specimen it projects transversely, as a tongue-like process, from the lower part of the notch, $\frac{1}{2}$ inch in length, $2\frac{1}{2}$ inches in breadth, but, although larger than in the Stornoway specimen, it barely reaches to below the axis[1].

(B). IN THE LESSER FIN-WHALE[2] (B. Rostrata).

17. TRANSVERSE PROCESSES.—(*a*) *Completion of the rings.* It may be considered as determined that the various degrees of

[1] This process is much more developed in a portion of the atlas of a great Finner in my possession, which came I believe from Orkney. It is a larger atlas than either of the above. The lateral portions have unfortunately been sawn off through the outer parts of the articular surfaces. It has the following dimensions. Greatest height, spine being away, $15\frac{3}{4}$ inches; height of canal $9\frac{1}{8}$; greatest width of canal, anteriorly $4\frac{3}{4}$, posteriorly $7\frac{1}{4}$; width at constriction $2\frac{7}{8}$; below this the canal slightly diminishes downwards to a very blunt rounded lower end. Length of articular cup, now $11\frac{1}{2}$, probably 12; breadth $6\frac{1}{4}$; median groove between cups very broad, narrowest (at an inch from lower end) $1\frac{1}{8}$, at middle $1\frac{3}{4}$, near canal $1\frac{7}{8}$. Transverse canal small, length $3\frac{1}{4}$; inner end oval antero-posteriorly, long axis scarcely $\frac{3}{4}$; outer end vertically oval, long axis $1\frac{1}{4}$; thickness of its bony roof $1\frac{1}{2}$. On posterior aspect, crescentic ligamentous surfaces scarcely $1\frac{1}{2}$ in breadth and moderately depressed; lateral articular surfaces, length $10\frac{3}{4}$, moderately convex, united in one great horse-shoe surface. *Sub-axial process* greatly developed, amount of projection as seen from above, 1 inch, from below $1\frac{3}{4}$ inch, breadth at base $5\frac{1}{2}$, rising gradually, greatest to right side; thickness $1\frac{1}{4}$, coming close up to horse-shoe surface, which is $3\frac{3}{4}$ inches in height at the middle line.

[2] These vertebrae in B. rostrata have been described in a nearly full-grown specimen by Prof. Flower (*On a Lesser Fin-Whale, recently stranded on the Norfolk coast:* Pro. Zoo. Soc. May, 1864), who has also given notices of specimens which he examined in the Museums of Leyden, Brussels and Louvain (*Notes on the Skeletons of Whales in the principal museums of Holland and Belgium*, P. Z. S. Nov. 1864); and by Drs Carte and Macalister of Dublin (*On the Anatomy of Balaenoptera rostrata*, Trans. Roy. Soc. 1868) in a young specimen nearly the same length as mine. Their various conditions of ossific

ossific development of the rings is a matter chiefly of age, partly of individual variation. In this 14½ feet long specimen none of the rings are ossifically complete. That of the axis wants ⅜ inch at the outer edge of the ring. The terminal plate of cartilage by which it is completed is only an inch in breadth, the ovoid ring almost two inches. In the fœtus, Eschricht found the 5th and 6th with complete rings; and Van Beneden and Gervais, speaking of B. musculus, remark: "On peut admettre que dans cette espèce, comme dans la *Balænoptera rostrata*, ces anneaux sont toujours complets, à l'état de cartilage, dans le jeune animal, et que les différences ne sont que le résultat d'une ossification plus ou moins complète." Drs Carte and Macalister mention "fibro-cartilage" as completing the rings in their young specimen, and in my notes of the dissection the completing structure has been recorded as ligamentous. The bony processes were succeeded by a cartilaginous stage, and this again by a fibrous stage, completing the canal. The cartilaginous stages varied in length; on the superior processes of the 4th and 5th they were ⅛ inch; on the inferior processes of the 5th, the most ossified of all the inferior processes, they were on the left side ½ inch, and ¾ inch on the less ossified right side. The ligamentous prolongations, beyond the cartilages, were quite distinct from each other for some distance, but, owing to the convergence of the processes, they became confluent at their outermost part, and could not be traced round to meet the corresponding process. This was more especially the case with the third, the fibrous part of which became intimately connected with the thick periosteum of the overlapping wing of the axis; and with the sixth, owing to the superior process of the 7th slanting forwards so much against it. Even the 4th and 5th could not be traced round, the fibrous part of the lower process of the 4th appearing to end on the (farther out) cartilage of the lower process of the 5th. The fibrous parts of the processes may be looked on as portions of that thick periosteum which encloses the bones

development are remarked on in the *Ostéographie des Cétacés*, of Van Beneden and Gervais, p. 160, and they are figured in Pl. 12 and 13 of that valuable work. Dr J. E. Gray has also figured some of them in P. Z. S., May, 1864, and in *Cat. Seals and Whales, Brit. Mus.* 1866. My remarks relate to some farther points in the osteology illustrated by this young specimen, and to the articulations.

and cartilages in the cetacea, from within which fœtal cartilage has been absorbed, or within which ossification is advancing.

The lower transverse process of the 7th vertebra was nearly altogether represented by a ligament, attached internally to a short pointed bony process (over ½ inch in length), externally to the cartilaginous tip of the superior process; the ligament 1¾ inches in length, and flattened in the same direction as the bony processes[1]. This fibrous representative of the inferior transverse processes of the 7th vertebra is serial with the ligaments sent in from the heads of the anterior ribs, and from the tips of the corresponding dorsal transverse processes, to the sides of the bodies of their vertebrae[2].

[1] Prof. Turner found in the fœtus of one of the great Fin-whales (B. Sibbaldii) the inferior transverse processes represented by cartilage, completing a cartilaginous ring. See this *Journal*, 1871.

[2] These were examined on the three anterior dorsal segments, and are still seen on the dried preparation, and I may here note the arrangement. The 1st rib rested generally on a fibrous cushion interposed between it and the converged tips of the transverse processes, from the axis to the first dorsal, more precisely against the 7th cervical and 1st dorsal, but also on the 6th cervical (end of its lower transverse process), its chief ligamentous connection being with the 6th. From its short capitular process a ligament passed in to join the outer part of the ligamentous representative of the inferior transverse process of the 7th cervical vertebra, while from the tip of the 1st dorsal transverse process a separate ligament passed in to the body of the first dorsal vertebra, where it is attached to a conical bony parapophysis, like that on the 7th cervical. The 2nd rib, after being connected by a ligamentous cushion to the second dorsal transverse process, sends in a pretty long capitular process, going about half way in to the body, from which a strong ligament is prolonged to the 2nd and 3rd bodies, and to the fibro-cartilage between. The deeper part of this ligament is a prolongation from the second transverse process along the upper edge of the capitular process of the rib, so that the ligament passing in to the bodies is in its upper part parapophysial and in its lower part pleurapophysial. The 3rd rib repeats this, but having scarcely any capitular process, the two parts of the ligament are identified earlier. These parapophysial ligaments prolong the lower wall of the lateral canal of the neck backwards into the thorax.

In both of the great Fin-Whales this part was so mutilated, as it is very apt to be in dividing the carcase, that I could only infer the presence of a ligamentous representative of the inferior transverse process of the 7th cervical vertebra from portions which remained, showing a ligament as thick as two fingers laid together. From the dissection of the Peterhead Razorback I inferred that such a ligament, connected to the body of the seventh cervical vertebra, 7 to 9 inches of it remaining, had been connected externally to the movable capitular process of the first rib, and along it to the transverse process of the 7th cervical vertebra. These ligaments will vary with the extent to which the ribs develop capitular processes. I may note here that in the Stornoway Razorback the three anterior pairs of ribs all develop long capitular processes, and that if the movable capitular process which I figured on the first rib of the Peterhead Razorback (see this *Journal*, 1871) were ankylosed and a little enlarged, it would represent very well the form which both first ribs present in the Stornoway specimen. I was able to examine the connection of one of the first pair of ribs to the transverse processes in the Wick specimen. It rested in a socket on the transverse processes, formed in (*b*). The *bony inferior transverse processes* differ from those of the great Finner in being relatively stronger and in having a more downward direction. They are present as half-inch-long conical processes on the 7th cervical and 1st dorsal vertebrae. The tubercular stages of the next four (6th, 5th, 4th, 3rd) increase in length forwards to the 3rd, on which they are twice the length of those of the 6th, and are directed outwards and downwards, unbent, as far as their outer prominence, which is strongly marked. These processes, therefore, descend below the level of the bodies more than in the great Finner forming the sides of a sub-vertebral space, the depth of which at the 3rd is twice that at the 6th, while in the great Finner it may scarcely increase in depth forwards. The nerve-groove stage then turns upwards and outwards, tapering, and is variously ossified,—on the 6th full-length on the right side, half-length on the left; on the fifth, nearly full-length on the left, under two-thirds length on the right; on the 4th, just beginning on the left side, not begun on the right; on the 3rd the process continues robust to the end, no part of it turned up. The processes of the 4th are the most horizontal, those behind them inclining forwards. Those of the 4th and 3rd are not directed backwards, as they are in the great Finner by the greater slant of the wing of the axis, but slant a little forwards, that of the 3rd consequently coming very close to the wing of the axis, and it is the most robust of all the inferior transverse processes. The different states of the inferior transverse processes of the 6th vertebra in the two groups forms a marked contrast, the grooved stage being more or less unossified in the great Finners, while in this lesser Fin-whale this stage is better developed than in any of the other cervical vertebra, shooting out to near the end of the superior process of the 7th, the

front by the 7th and partly by the 6th cervical, behind by the 1st dorsal. Its chief ligamentous connection was to the 7th cervical. Between the rib and the cervical part of its socket was a great fibrous cushion on which it rested, while between it and the dorsal part of the socket was a quasi-synovial cavity about 2 inches in diameter, with periosteal surfaces on the rib and on the first dorsal transverse process, the ligaments forming a kind of capsule around it. On the 2nd dorsal transverse process the attachment of the 2nd rib was indicated by a thick capsular cushion with central cavity bounded by soft irregular walls. No synovial cavity existed in connection with any of the ribs in the young Pike Whale, although the separation of the perichondrium is at first apt to deceive the dissector in regard to this.

two forming a strong arch for the support of the first rib. The *ligaments* between the inferior transverse processes (inter-parapophysial) are oblique in different directions; an external series running between the tubercles forwards and outwards, strongest behind; and an internal series, the largest, passing from the tubercles forwards and inwards, increasing forwards, and of great size between the 3rd and axis and between the axis and atlas.

(*c*) The *superior transverse processes* are well ossified; the 7th fully, like the first dorsal though not so robust; the 3rd, 4th, 5th and 6th, in their first two stages, of nearly equal length, and much more slender than the corresponding inferior processes. The distinction between the nerve-groove and the tubercular stages is marked on these four more distinctly than in the great Finner, by the presence here of a series of triangular processes directed forwards, between which the inner part of the superior inter-transverse ligaments passes. On the 7th cervical and 1st dorsal vertebrae these processes (meta-pophysial) are placed more internally, close to, or almost on, the anterior articular processes.

(*d*) The *lateral canal* formed by the rings of the transverse processes differs in this young lesser Fin-whale from that of the great Finner both in relative capacity and in form. Taken at the fourth vertebra, it is transversely less than half the breadth of the body, and its capacity is not much greater than that of the spinal canal, their circumferences being respectively 7 inches and 8. In form, instead of being transversely triangular or ovoid, it is vertically ovoid or rather semilunar, the blunt end downwards and outwards, owing to the more downward direction of the transverse processes, a line prolonged from the transverse axis of the bodies leaving a much larger proportion of the ring below than in the great Finner.

The neural arches are high and triangular, with rounded lateral angles. At the 4th, the breadth of the spinal canal is $2\frac{5}{8}$, the height $1\frac{11}{16}$. Below the 4th it increases in breadth and diminishes in height; at the third with about the same breadth as at the fourth the height is 2 inches; while at the axis the height and breadth are each $2\frac{1}{4}$. The laminae are thin on their anterior, thick on their posterior edges, overlapping a little but nowhere in contact. The spines are mere rudiments on the 3rd, 4th, and 5th, on the 6th half an inch in length, on the 7th longer.

18. BODIES AND THEIR FIBRO-CARTILAGES.—There was very little motion between the cervical vertebrae in any direction, the motion, small as it is, becoming more limited forwards. The rotatory motion taken at the zygomal processes was not over $\frac{1}{16}$ inch in extent. The thickness (length) of the fibro-cartilages, not including the rim of cartilage belonging to the epiphyses, was—behind 2nd dorsal, $\frac{1}{2}$ inch; behind 1st dorsal and 7th cervical, each $\frac{1}{4}$ inch; behind 6th, 5th, and 4th cervical, $\frac{1}{6}$th; behind 3rd, over $\frac{1}{8}$; behind 2nd, $\frac{1}{8}$ inch. The bodies of the 3rd, 4th, and 5th vertebrae are from $\frac{4}{8}$ to $\frac{5}{8}$ inch in thickness, those of the 6th and 7th are about $\frac{1}{8}$ inch more. When divided, the fibrous part was seen to reach half an inch inwards above, a little more below, dipping in to $\frac{3}{4}$ inch at the middle line above and below, the measurements of the body surfaces being,—breadth, at the third $4\frac{1}{8}$ inch, at the sixth $\frac{1}{4}$ inch less; height, at the third $2\frac{1}{2}$, at the sixth $\frac{1}{4}$ inch more. Before and behind the 3rd, although the pulp surfaces are as extensive as at the other spaces, there was very little pulp, owing to the nearness of this vertebra to those next it. The body surfaces are, especially in the transverse direction, a little convex in front, a little concave behind, better marked the farther forwards. The middle of the anterior surface of the bodies, corresponding to the centre of the pulp, is rough, rising into a faint prominence on the posterior vertebrae. The epiphyses want from $\frac{1}{8}$ to $\frac{1}{6}$ inch of reaching the edge of the bodies. The thinnest part of the body is at each side of the pulp space, so that, in the macerated bones, the sides of the bodies come in contact, leaving thin spaces between the surfaces, deepest at the middle line, both above and below; this being also due in part to the curvature of the bodies just mentioned.

19. ARTICULATIONS OF THE ATLAS AND AXIS.—(*a*) The *articular surfaces* are continuous across the middle line below, forming one great horse-shoe cartilaginous and synovial surface. There was a faint median depression in the cartilage, though no interruption to its continuity, and through the dried cartilage is now seen a median furrow on both bones, which in fully

macerated bones has led to the surfaces being reckoned distinct. The odontoid rises higher than in the Razorback and is at the same time broader and less abrupt, the whole area rising gently to a rounded prominence, the summit of which is near the upper part, towards the transverse ligament. (*b*) The *transverse ligament* (see Fig. 6) is, in this whale, flattened in the same direction as in man, but is somewhat prismatic; upper surface flat and a little concave transversely, forming part of the floor of the spinal canal, in line with the body of the axis; anterior border thick; lower surface applied obliquely against the odontoid process, which in this whale rises a little above the level of the ligament. But the transverse ligament is not free; its hinder edge joins the periosteum on the upper surface of the axis, and its lower surface is attached to the odontoid as it crosses.

(*c*) The *check ligaments* (Atlo-odontoid) have essentially the same connections and function as I have described in the Razorback, but from the greater prominence of the odontoid, and the greater width of this division of the ring of the atlas, they are less interosseous in position, and their fibres have less of a forward direction. Its attachment on each side to the atlas is to the narrow crescentic surface between the posterior articular surface and the edge of the ring, meeting its fellow in the middle line below; while its upper fibres, attached inwardly to the upper aspect of the odontoid, outwardly to the atlas, are continuous with the deeper fibres of the transverse ligament, giving that ligament its connection to the odontoid. In the Razorback the lowness of the odontoid required these fibres to pass forwards some distance to reach the posterior surface of the transverse ligament; while here the transverse ligament is so close that, besides attaching ligamentous fibres from the odontoid, it gives direct support to that process, its surface being adapted accordingly. Concealing, from before, the lower part of the check ligaments, there is a fibrous structure like an *inferior transverse ligament,* embracing semicircularly the odontoid below as the transverse ligament does above. The deeper part of this inferior fibrous girdle is continuous with the lower part of the check ligaments, as the transverse ligament is with their upper part, and superficially it forms a fibrous cushion, levelling up the lower part of the odontoid division of the ring of the atlas and giving a soft flooring for the inner part of the occipital condyles, which here project inwards beyond the inner edge of the atlantal cups. Between these two fibrous girdles the odontoid is seen for a breadth of $\frac{3}{4}$ inch, with the remains of the ligamentum suspensorium attached to it.

(*d*) I was able to examine the *superficial ligaments* between the atlas and axis more satisfactorily here than in the great Finner in which they had been injured. Below, besides the inferior longitudinal ligament of the bodies, a strong inferior oblique ligament, serial with the inferior inter-transverse ligaments but much stronger, passed inwards and forwards to the atlas from the transverse process of the axis. There was a well marked capsular ligament round the outer side of the articular surfaces, also well marked on the inner side of these surfaces, above the position of the transverse ligament, but below this identified with the check ligaments. Above, besides the interspinous ligament, the interlaminar ligament was a strong membrane, leaving between it and the upper end of the articular surfaces a space for the passage of the second nerve; and a strong ligament (superior inter-transverse) passed from the upper transverse process of the axis to the transverse process of the atlas, serial with the superior inter-transverse ligaments behind. On either side of this ligament was a space from which the contents had been removed, apparently the spaces through which the superior and inferior divisions of the second nerve had passed.

Notwithstanding the extent of the synovial articular surfaces between them, the *motions* of the atlas on the axis were very limited. Vertical and lateral gliding motions were not over $\frac{1}{20}$ inch in extent. Rotatory motion was checked before the tip of the transverse process (which is 4 inches from the centre of rotation) had moved $\frac{1}{8}$ inch. All the external ligaments help to check, but after their division the rotatory motion remained as limited in extent as before, and as long as the check ligaments were undivided the atlas could not be lifted $\frac{1}{20}$ inch off the axis. These extensive synovial surfaces, usually in other animals an adaptation to extensive motion, must, therefore, be regarded as rudimentary here, so far as their synovial condition is concerned. The amount of yielding and elasticity is not greater than that which fibro-cartilages allow, and their retentive power is inferior.

20. OCCIPITO-ATLANTAL SURFACES.—On applying the atlas on the occipital condyles, the lower end of the condyle is seen to project about an inch ($\frac{1}{5}$ part of the whole length) below the cup, and this part of the condyle is more abruptly curved. The atlantal cups are seen to project a little laterally beyond the condyles, while the condyles approach each other internal to the cups, so that over half an inch of the breadth of each condyle is seen through the odontoid division of the ring of the atlas. The distance to be traversed by the ligamentum suspensorium, from the odontoid to the fissure in the floor of the inter-condyloid fossa, does not exceed half an inch. The neural division of the canal of the atlas corresponds in form to the foramen magnum but is somewhat larger, being transversely nearly $2\frac{5}{8}$, vertically $1\frac{7}{8}$, while the foramen magnum measures transversely $2\frac{3}{8}$, vertically $1\frac{6}{8}$. The odontoid division of the canal is relatively much wider than in the great Finner, measuring transversely at its widest part near the transverse ligament $1\frac{6}{8}$, vertically $1\frac{2}{8}$ inch; total height of canal of atlas $3\frac{2}{8}$. The position of the transverse ligament is a little below where the distinction of the two parts of the canal appears on the bone. The transverse foramen for the atlantal nerve, between the lamina and the upper end of the cup, is completed by bone on both sides, and is about the size of a goose-quill.

21. EXPLANATION OF THE DRAWINGS. Plates I and II.—The drawings are from photographs kindly taken by my pupil, Mr J. Shearer. The outlines taken from these were carefully filled in and shaded from nature, in my presence, by Mr Gibb. In taking the first three views the vertebrae, built up on the table, were separated to the extent to which they are naturally separated by their fibro-cartilages. The two front views are placed above and below for more ready comparison.

Fig. 1. Under-aspect of the cervical vertebrae of the *Peterhead* Razorback. The distinction between the tubercular and nerve-groove stages of the inferior transverse processes is well marked. It shows a deep atlo-axoid articulation; greater length of the left than of the

right wing of the axis; a great development of the tubercular stage of the inferior transverse process of the 3rd; a nearly symmetrical deficiency at the nerve-groove stage of the inferior transverse processes of the 6th; traces of the posterior body epiphyses of the 6th and 7th vertebrae, indicating that the animal, though of full length, was not quite mature; &c.

Fig. 2. Under aspect of the cervical vertebrae of the *Stornoway* Razorback. Comparing this fig. with Fig. 1, it shows a different form of transverse processes of atlas; a shallow atlo-axoid articulation; a more projecting sub-central process of atlas; the wings of the axis greatly developed, backwards to the level of the tip of the transverse processes of the 7th, and also downwards so as to show part of the surface of the wing, while in Fig. 1 only the border is seen. The undulations of the wing are seen, the internal eminence, opposite the tip of the transverse process of the atlas, is just external to the ring. The rudimentary state of the inferior transverse processes of the 6th, although it was a mature animal, will be observed; also the distinction between the tubercular and nerve-groove stages on the inferior processes of the 3rd, 4th, and 5th vertebrae, though not so strongly marked as in Fig. 1; and the transverse process of the 5th is seen to be horizontal, and, after that of the axis, the longest and the most projecting.

Fig. 3. Upper aspect of the cervical vertebrae of the *Wick* Razorback. On the atlas is seen the oblique ridge roofing the foramen in front, and supporting an articular process behind; the two grooves proceeding from the foramen; and some a-symmetry of the transverse processes. The axis shows great development of the crests in the region of the spine (still more developed in the Peterhead specimen), the right crest articulating with the atlas. On the wings, opposite the tip of the transverse process of the atlas, is seen the strongly marked and turned forward inter-transverse tubercle, and, bounding the concavity external to it, the upper angle of the wing, farther out on the right than on the left side in this specimen. The superior transverse processes appear thin at their inner third (nerve-groove stage) from the direction of their surfaces, and external to this (tubercular stage) are seen to be bevelled and rough, and to begin to overlap. The inferior processes are seen in deep shading beyond, that of the 3rd of great size on the left side, that of the 6th complete on the left side, and partly deficient on the right. On the laminae of the five posterior vertebrae are seen the very rudimentary spines; the more developed anapophysial processes, serial with the crests of the axis; and the partially cribriform condition of some of the laminae from their extreme thinness near their anterior margins, in this mature or aged animal.

Fig. 4. Front view of *fifth* cervical vertebra of the Stornoway Razorback. On the body, externally, is seen the streaked ring where the capsular part of the fibro-cartilage is attached, and within this the figure-of-8 surface where the pulp lies, somewhat raised at the

middle. The laminae show, about the middle, a non-symmetrical anapophysial process; the spinal canal is intermediate between the triangular form presented by the Peterhead specimen, and the elliptical form presented by the Wick specimen. Spine also intermediate in length. On the lower transverse process (*a*) is the root stage; (*b*) the tubercular stage, with its outer and inner angular prominences; (*c*) the nerve-groove stage, the groove seen to be directed obliquely outwards and downwards. On the upper processes, (*d*) is the nerve-groove stage. At the inner part of this a small tubercle is seen (as it so happens, unusually developed on the left side of this vertebra) on the upper edge, the grooving being on the surfaces; (*e*) is the tubercular stage, marked off from the nerve-groove stage by an angular elevation, but the tubercular character of this stage, owing to the bevelling, is visible only in an upper view (see Fig. 3); (*f*) is the third stage of the superior process, the terminal plate, developed in the mature animal. It is seen to be less developed on the right side, the upper angle not having been yet formed. The rings in this specimen present the semi-oval form.

Fig. 5. Hinder aspect of the atlas of the Wick Razorback. The transverse ligament (*a*), flattened in the opposite direction to that of man, is seen dividing the canal into an upper or neural division, and a lower, odontoid or ligamentous division. On each side of the lower division is seen the crescentic surface where the atlo-odontoid check ligament is attached, unsymmetrical in this specimen. The articular facet, by which it articulates with the right crest of the axis, is seen on the right lamina above the groove for the nerve-escape. The internal inter-transverse tubercle, at the upper edge of the root of the transverse process, is seen to be more developed on the left side, and the external tubercle, behind the tip of the process, to be also unsymmetrical. A median groove is seen dividing the articular surface into two, but the two are naturally continuous, the presence of the groove being exceptional in this specimen.

Fig. 6. Front aspect of atlas of young (14½ feet long) Pike Whale (B. rostrata). Transverse ligament (*a*) not flattened as in the Great Finner, but prismatic. Both upper and odontoid divisions of canal are proportionately wider than in the Great Finner. Median groove seen between condyloid cups, where ligamentous septum is attached. Transverse foramen for atlantal nerve already roofed over. Transverse processes incompletely ossified, but the twist is seen.

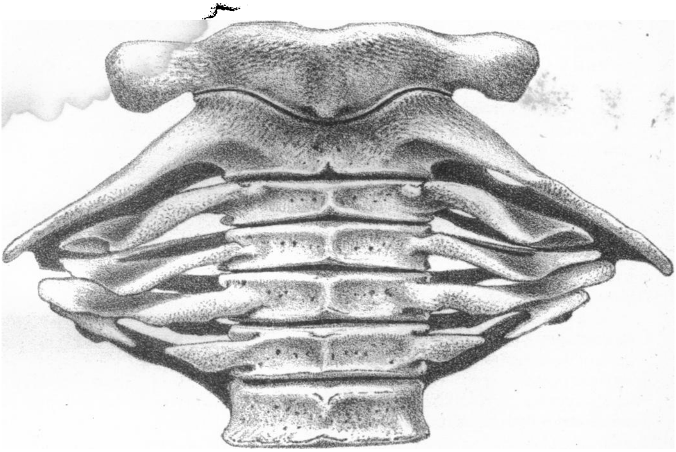

FIG. I.
Cervical Vertebrae in Balænoptera musculus, Peterhead, 1871. Under aspect. $\frac{1}{12}$.

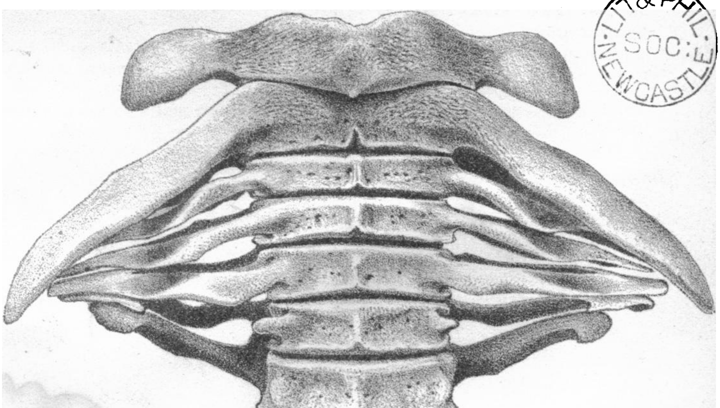

FIG. II.
B. musculus. Stornoway, 1871. Under aspect. $\frac{1}{12}$.

CERVICAL VERTEBRAE AND THEIR

Keith & Gibb. Lithrs Aberdeen.

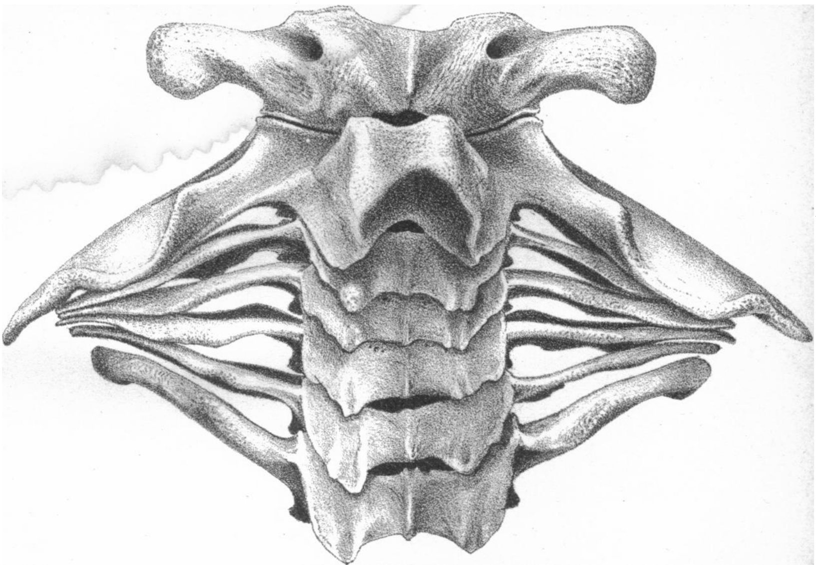

FIG. III.
B. musculus. Wick. 1869. Upper aspect $\frac{1}{11}$

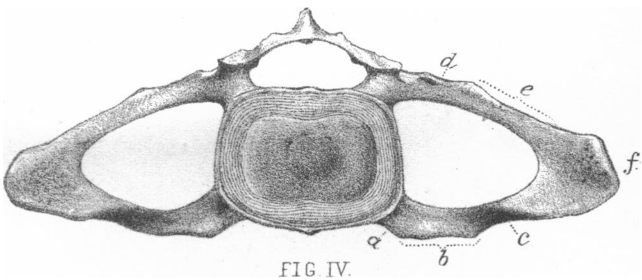

FIG. IV.
Fifth cervical vertebra of B musculus (Stornoway Fig 2) Front aspect $\frac{1}{12}$

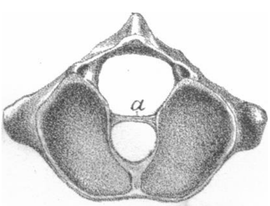

FIG. VI.
Atlas of young B. rostrata, with Transverse ligament. Aberdeen. 1870. Front aspect $\frac{1}{6}$

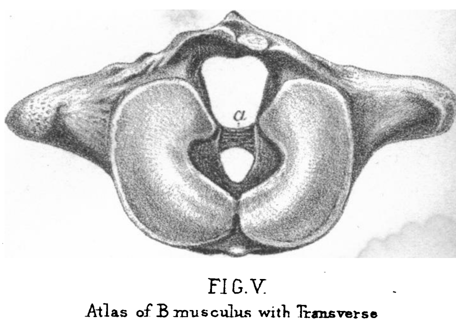

FIG. V.
Atlas of B musculus with Transverse ligament (Wick Fig. 3) Hinder aspect $\frac{1}{12}$

ARTICULATIONS IN FIN-WHALES.