RESTORATION

OF

DINORNIS MAXIMUS.

The indications in a former section (pp. 250-253) of an established form of Dinornis surpassing in size those to which the names Dinornis giganteus and Dinornis robustus had been applied have been strengthened by later discoveries, which equally justify the term maximus, and have contributed to the present restoration of that huge species or propagable variety.

Osseous remains, agreeing in their dimensions or proportions with those figured in Plates LXXIX. and LXXX., have been disinterred, chiefly from that notable locality "Glenmark Swamp," in the province of Canterbury, New Zealand; and the abundance of the evidences of this hugest of known birds (recent or extinct) afforded Dr. Haast the materials for a proposition of exchange, in effecting which I obtained a series of bones of the Dinornis maximus which permitted the articulation of the skeleton figured in Plate XCVII., and now in the National Museum of Natural History.

In the present summary of the osteology of the species I shall supplement the former Memoir by details of the vertebral structures. These I propose to combine with comparisons of the homologous bones in the largest living wingless bird, Struthio camelus —to which end the admirable and usefully illustrated monograph by Professor Mivart, F.R.S., "On the Axial Skeleton of the Ostrich"¹, lends peculiar facilities.

In these comparisons I adopt most of the technical terms of aspect and position proposed by Prof. Mivart, in addition to my own, and I subjoin, for the convenience of students, their vernacular equivalents:

\[\text{preaxial} = \text{fore, anterior;}\]
\[\text{postaxial} = \text{back, hind, posterior;}\]
\[\text{dorsal or neural} = \text{upper;}\]
\[\text{ventral or hæmal} = \text{lower, under;}\]
\[\text{neurad} = \text{upward;}\]
\[\text{hæmad} = \text{downward;}\]

antero-posterior or prepostial = longitudinal, fore-and-aft;
dorso-ventral or neuro-hæmal = vertical, high, deep;
lateral = side.
medial = relating to the middle line or mid-vertical longitudinal plane of the body.

ATLAS, or FIRST, VERTEBRA (natural size).

Fig. 1, neural (or dorsal); 2, hæmal (or ventral); 3, preaxial.

The atlas vertebra of *Dinornis robustus* is described and figured (p. 169, Pl. LXII, figs. 4, 5, 6). To the three figures there given, answering to the 2nd, 3rd, and 4th in Mivart's Memoir¹, I here add views of the neural or dorsal, fig. 1, of the hæmal or ventral, fig. 2, and of the 'preaxial,' fig. 3, surfaces of the atlas of *D. maximus*, to complete the comparative illustrations of the bone in the genus *Dinornis*.

The preaxial articular cup (fig. 3, *ac*) for the occipital condyle is formed in great part by the hypapophysis (simulating the centrum), the neural vacuity being supplied by the true centrum of the atlas ('odontoid process,' fig. 4, *ca*): the sides of this vacuity are formed by a pair of articular surfaces developed on the atlantal neurapophyses, homotypal with the prezygapophyses in the succeeding vertebrae. The vacuity is progressively encroached upon by the growth of the prezygapophyses, and, in the atlas of the aged individual of *Dinornis maximus* (fig. 3), it is reduced to the chink *a*. The neurapophyses have met and coalesced above the neural canal, which was not the case in the atlas of the younger, but full-grown, subject of *D. robustus* (loc. cit.).

Assuming the atlas of *Struthio camelus*² to have been from a full-grown and mature individual, a similar confluence of the neurapophyses having taken place, the following differences are chiefly notable between it and the corresponding vertebra of *Dinornis maximus*. In the Ostrich the antarticular vacuity (not marked in Mivart's figures), answering to *a* in fig. 3, remains much more widely open; the hypapophysial surface

(ac) is less deep in proportion to its breadth; its lower border has not the pair of low tubercles (fig. 3, t, t); the hæmal surface of the hypapophysis is produced downward and backward into the quasi-hæmal spine, hy (Mivart, figs. 2–7); this is not present in Dinornis, but is replaced by a pair of low tuberosities, fig. 2, hy (which productions served for the attachment of the 'longus colli' 1), as in Apteryx, but are variable. The difference between Dinornis and Struthio in the relative size of the vertebrarterial foramina v is well marked; the larger size of the canal in Dinornis relates to its better-developed brain: the roof of the neural canal is relatively less extended from before backward in Struthio; it is convex, rough or irregular in surface, with a feeble indication of a medial ridge at the fore part in Dinornis (fig. 1, n), and with a hyper-apophysis (ib. hp) as a low tuberosity above each postzygapophysis.

The postaxial articular surface presents, in Dinornis, a subquadrate convexity, and is not flat transversely in the present species or individual: the upper shortest border is moderately concave; the lower longest border is framed, as it were, by a backwardly extended ridge, of which the pair of tubercles (fig. 3, t, t) form part. The postzygapophysial facets (z, z', fig. 2) look more obliquely backward than in Struthio, where their aspect is almost wholly inward or 'mediad.'

In the general though slight convexity of the postaxial articular surface of the atlantal hypapophysis, in the slenderness of the pardiapophysial bar (fig. 3, pd), defining outwardly the vertebrarterial canal, and in the parial disposition of the hypapophysial tubercles, the atlas of Dinornis elephantopus 2 in the main agrees with that of D. robustus and D. maximus.

In Struthio the neural arch has a less relative antero-posterior breadth, and the same proportional difference prevails in the quasi-centrum; the processes, t, t, in fig. 2, are not developed; the preaxial cup has a wider upper emargination.

The length of the axis in Dinornis maximus (fig. 4) is about four times that of the atlas, and equals about 2 1/2 inches. The preaxial surface of the centrum (fig. 5, cx) is twice as broad as high, and is concave transversely, but less deeply than it is neuro-hæmally. It is not prolonged neurally, as in the Ostrich, "on to each side of the base of the odontoid process" 3; a slight non-articular concavity separates it on each side from the convex articular surface on the under part of the odontoid (figs. 4 and 7, ca, o). This surface is convex, narrower and more produced than in the Ostrich 4. The postaxial surface (figs. 4 and 6, pc) has reverse proportions to the preaxial one, the longest diameter being vertical. It is divided into a pair of narrow vertically concave facets by a still narrower medial tract, the transverse contour being thus rather angular than, as in Struthio and most birds, convex. The under border is nearly straight, and the transverse extent of the neural margin slightly exceeds that of the hæmal one.

1 P. 49, Pl. XIII. fig. 2 and Pl. XIV. a.
2 P. 232.
3 Mivart, loc. cit. p. 391.
4 Ibid. fig. 12, o.
The articulation slopes downward and backward. The hypapophysial process (figs. 4, 5, 6, 7, hy) is relatively more produced hæmad than in Struthio, and descends vertically and slightly backward from the postaxial surface, thus adding to the length of the vertebra.

**AXIS, or SECOND, VERTEBRA** (natural size).

![Diagrams of vertebrae showing aspects and neural canal](image)

Aspects.

Fig. 4, lateral; 5, preaxial; 6, postaxial; 7, hæmal (or ventral).

The neural canal (figs. 5 & 6, n) is half the length of the entire vertebra, and its width is nearly one third of the breadth. Its area is a full ellipse with the long axis vertical, not transverse as in Struthio.
The ridges on the fore part of the hæmal surface of the centrum in *Struthio*¹ are not present in *Dinornis maximus* or in *D. robustus*. The parapophysis is represented by the short obtuse ridge, *p*, figs. 4 & 7; the pleurapophysis (ib. *pl*) by a similar one above, near the middle of the outer wall of the vertebrarterial canal, *v*. From the diapophysial plate (fig. 6, *d*), completing that wall above, a ridge (fig. 4, *r*) extends backward to the postzygapophysis, *z*; this ridge circumscribes externally the vertical canal (figs. 4 & 7, *s*). On the medial side of this canal is the pneumatic orifice (fig. 7, *t*), leading to the cancellous part of the neurapophysis. The canal *s* is not noted in *Struthio*, and in place of one large hole there are irregular pneumatic foramina². The postzygapophysis is thrice the size of the prezygapophysis, but the antero-posterior hardly if at all exceeds the transverse diameter; its aspect is as in *Struthio* and birds generally. The hyperapophysis (figs. 4 & 6, *hp*) is relatively more prominent than in *Struthio*. The neural spine gains thickness as its base extends backward; its summit is broken off in my specimen, exposing the wide-celled pneumatic texture.

In *Dinornis elephantopus* the hyperapophyses (fig. 5, *hp*) are relatively larger and higher; the prezyapophyses are relatively less.

The odontoid process (figs. 4 & 7, *ca*) is less than half the size of the atlantal hypapophysis; its free extremity is obtusely rounded.

The third cervical vertebra, as in *Struthio* and birds generally, gains a transverse breadth of the neural arch, anteriorly, with concomitant size of the prezygapophyses (fig. 11, *z*), fitting the postzygapophyses of the axis. From this gain results a quadrate form of the roof of the vertebra; but, from the less relative length or greater breadth of this part in *Dinornis*, the roof (fig. 11) is a transverse quadrilateral, not so oblong as in *Struthio*: in both birds the angles are rounded off³.

The centrum is a horizontal wedge, with the edge anterior, concave, and formed by the neural border of the preaxial articular surface (fig. 9, *ac*), which, broad and concave transversely, is short and almost flat vertically, but here slopes from the vertical so much backward that it is on a plane with the contour of the hæmal surface of the centrum, as carried back by the hypapophysis (*hy*), and forms a very open angle, with the base-line extended from its hæmal border to the same border of the postaxial surface. Hence, in a direct front view (fig. 9), a little more than the concave fore border of the preaxial surface (*ac*) is seen: while the whole surface is fully in view in the under view of the vertebra (fig. 10, *ac*). It looks almost wholly downward (hæmad) in *Dinornis*, not obliquely downward and forward (hæmo-preaxiad) as in *Struthio*⁴. The postaxial surface (fig. 8, *pc*) much resembles that of the axis vertebra: its transverse contour is sinuous, a medial convexity dividing two concavities; the aspect is more upward than backward; the vertical exceeds the transverse diameter, but in a minor degree than do the reverse proportions of the prcaxial surface.

---
¹ Mivart, *loc. cit.* p. 391, fig. 12, *t*.
² *Ib.* *loc. cit.* p. 393.
³ *Ib.* *loc. cit.* p. 395, fig. 15.
⁴ *Ib.* *loc. cit.* p. 394.
Aspects.

Fig. 8, lateral; 9, preaxial; 10, haemal (ventral); 11, neural (dorsal).
The pleurapophysis (fig. 8, \( pl \)) is more prominently marked than in *Struthio*; a low tuberosity represents the diapophysis (fig. 10, \( d \)); the interzygapophyseal bar (fig. 11, \( r \)) has gained breadth; the interzygapophyseal foramen (fig. 11, \( s \)) is well defined.

On the under part of the centrum (fig. 10) the transverse preaxial articular concave tract is followed by a broad depression beyond. From this begins the medial ridge, which expands into the tuberous hypapophysis (\( hy \)). This is less produced than in the axis.

The chief differences from the Ostrich, besides the shorter or broader and deeper proportions of the entire vertebra, are seen in the more distinct hypapophysis, the better-developed hyperapophyses (fig. 8, \( hp \)), and the more distinctly bifid character of the neural spine (figs. 9 & 11, \( ns \)).

This spine rises a short way before it divides; a ridge extends from the fore and hind margins of each division, and defines the depression (for the insertion of elastic ligaments) in front and behind the undivided base: this, at its summit, is not more than one fifth of the antero-posterior extent of the neural platform. (The specimen figured is from a higher and larger individual than the articulated skeleton.)

The fourth cervical vertebra of *Dinornis maximus* (figs. 12, 13), representing, with increase of size, the proportional characteristics of the third, resembles that of the Ostrich in the greater production of the pleurapophysis, \( pl \), and in the absence of the hypapophysis.

The interzygapophyseal plate, \( r \), not extending to the postzygapophysis, \( z \), does not circumscribe the space forming the foramen, \( s \), in figs. 8 & 11; and the pneumatic foramen (fig. 12, \( pn \)) comes into view. The zygapophyseal articulations, \( z \), \( z' \), become elongated; the posterior outlets of the vertebrarterial canals expand.

There is little, if any, modification of the pre- or post-axial articular surfaces (\( ac \), \( pc \))
of the centrum. The hæmal depression (fig. 13, c) behind the preaxial surface (ac) is deeper than in the third cervical; and the angle between this and the hind half of the centrum, c', owing to the non-development of the hypapophysis, is more marked. The spine (fig. 12, ns) repeats its small basal extent and bifid character.

The diapophysial plate (fig. 12, d) extends its origin from the outer side of the prezygapophysis, z, halfway towards that of the postzygapophysis, pl; the broad outer wall of the vertebrarterial canal (fig. 13, v) thus formed is the 'pleurapophysial band' of Mivart. It sends forward from its lower anterior angle a short obtuse parapophysis (fig. 12, p). The riblet, pl, extends backward from the opposite or hinder angle. The vertical hind border of the 'band' has two semilunar insertional impressions, the angle (fig. 12, a) between which is less produced than in Struthio. The pleurapophysial band has a relatively greater vertical extent than in Struthio; and this relates to the corresponding excess of vertical over longitudinal dimensions in the entire vertebra of Dinornis as compared with Struthio.

In the direct under view (fig. 13) the pleurapophysis extends almost to the vertical level of the postzygapophysis, z' (compare with fig. 24, Mivart, loc. cit.); a more marked difference from Struthio is in the bifid neural spine of Dinornis. There is no medial hypapophysial ridge in D. maximus.

In D. elephantopus the fourth cervical has the hinder half of the lower surface of the centrum relatively wider than in fig. 13, c'; the prezygapophyses are less produced forward than in fig. 12, z.

Glancing along the cervical region, in the articulated skeleton of Dinornis maximus, one sees, as in that of D. elephantopus, that the two (parial) neural spines continue to be developed throughout that series of vertebrae, the uniting basal band subsiding somewhat in the fifth cervical, and each spine being then represented by a ridge continued forward from the hyperapophysis, converging toward its fellow as it rises; but it attains no great height in any vertebra. In the fourteenth cervical, where the parial neural spines are most marked in this respect, the uniting base gains in vertical extent.

The parial hypapophyses ('catapophyses,' Mivart) commence at the fifth cervical as low tubercular ridges. They come nearest to each other at the fourteenth, but do not, in Dinornis, circumscribe a hæmal canal in any vertebra. In the fifteenth cervical the parials combine to form a single medial hypapophysis near the middle of the length of the under surface.

In one skeleton of D. elephantopus this coalescence takes place at a sixteenth cervical, the antecedent series having one more vertebra than in the skeleton of D. maximus here described.

1 Loc. cit. p. 398.
2 Comp. with this modification the cervical vertebra in the Flamingo (Owen, 'Anat. of Vertebrates,' vol. 1. p. 29, fig. 20, h).
The pleurapophysial plate is sculptured outwardly by longitudinal ridges and channels; the riblet loses relative length after the sixth or seventh cervical. The pre- and post-axial articular surfaces retain their essential character throughout, being concavo-convex in opposite directions; the fore surface is always superior in breadth, and this dimension, though less in the hind surface, is greater than the vertical diameter. A larger proportion of the neural surface of the fore end of the centrum is uncovered by the neural arch after the third and fourth cervicals.

From the neck series are selected vertebrae for views corresponding to some of those given by Mivart of the Ostrich, which best illustrate the modifications of such vertebrae in the larger flightless bird.

SIXTH VERTEBRA (½ nat. size).

The hypapophyses in the sixth cervical (fig. 14, hy) are oblong, smoothly obtuse tuberosities. The exterior of the parapophysial part (p) of the pleurapophysial plate (p, ps) is longitudinally channelled and ridged; the riblet is shortened, as in Struthio, but in a greater degree. The interzygapophysial bar, though short, leaves a foramen before it is lost in the base of the postzygapophysis. The metapophysis (fig. 14, m, m) is a mere slight outswelling of the diapophysial mass. The anterior depression at the hæmal surface of the centrum is no longer defined; it is the beginning of the longitudinal channel h, banked by the hypapophyses. Behind these the surface is smooth and flat; then again becomes slightly concave transversely at the expanded hind part of the centrum, pc.

1 Mivart, loc. cit. p. 400, fig. 25.
The neural spine is represented by a pointed ligamentous surface above the fore border of the arch; behind this rises the pair of low obtuse processes subsiding into the hyperapophyses above the postzygapophyses.

As the neural roof subsides behind the part between the bases of the parial, quasi-neural spines, their connecting-bar is so indicated. The hind part of each spine extends, subsiding to the hyperapophyses.

TWELFTH VERTEBRA (½ natural size).

The twelfth cervical is chiefly distinguished by the nearer proximity to one another of the hypapophyses, the extremities of which, in a direct hind view (fig. 16, hy), appear below the divisions of the postaxial surface, pe, not at its sides, as in Struthio. The transverse diameter of the postaxial part of the neural arch, taken outside the pedicles, is one fourth less than the same diameter of the preaxial part. The riblet (fig. 15, pl), though longer than in the six or seven preceding cervicals, is relatively shorter than in the fourth (fig. 12, pl). The neural arch attains its greatest length in the twelfth vertebra. The connecting bar (fig. 16, b) of the parial neural spines is slightly raised, and is better defined before and behind by the rough pits for the elastic ligaments than in some of the antecedent cervicals. The breadth of the neural platform across the postzygapophyses is relatively greater, in a small degree, than in the antecedent cervicals; yet their articular surfaces (fig. 15, pz) remain longer in proportion to their breadth. The perforation of the interzygapophysial bar continues.

1 lb. loc. cit. p. 493, fig. 30, e.
The longitudinal ridges of the pleurapophysial plate (fig. 15, pl) are more prominent; the upper one assumes more the character of a metapophysis (ib. m).

The cervical vertebra of *Dinornis giganteus*, figured of the natural size in plate 40, vol. iii. of the 'Zoological Transactions,' is the answerable one to the twelfth in the huger representative species of the South Island of New Zealand. It is less broad in proportion to its length, and thus conforms to the more slender metatarsals characteristic of *D. giganteus* of the North Island. The transverse connecting bar of the neural spines, marked s in fig. 5 of the plate 40, rises nearer to the summits of the parial divisions; the ridges continued from these, forward, converging to the fore margin of the neural arch, are longer and broader than in *Dinornis maximus*; the hollow behind the neural spines is also broader.

The thirteenth and fourteenth vertebrae in *Dinornis* are most nearly matched by the sixteenth and seventeenth in *Struthio camelus*, in which species the eighteenth vertebra

---

**FOURTEENTH VERTEBRA (½ natural size).**

![Image of Fourteenth Vertebra](attachment:image.png)

Aspect.

Fig. 17, haemal (ventral).

(fig. 41 of Mivart), like the fifteenth in *Dinornis* (fig. 19), first changes its parial or double for a single hypapophysis, hy. My figure 17 may therefore be contrasted with figures 34 and 39 of Mivart, which show the same aspect (haemal or ventral) of the vertebrae compared. And here I may note that the processes seen in profile in Mivart's figures 33 and 34 are indicated by the symbol c in the sixteenth vertebra, and by the symbol hy in the seventeenth; similarly, they are described as 'catapophyses' at p. 405, and 'hypapophyses' at p. 406. I note them, under the latter denomination, in
the thirteenth as in the fourteenth vertebra of *Dinornis maximus*, and the similarity is such between these vertebræ that I proceed to the description of the fourteenth.

In the fourteenth cervical (fig. 17) the more approximated hypapophyses, *hy*, arise from a low common prominence further back from the preaxial surface; and the longitudinal channel in the lower surface, in the twelfth and thirteenth vertebræ, is here somewhat interrupted by such prominence. The transition of these into a single medial hypapophysis is thus indicated. The present vertebra in *Dinornis maximus* approaches the character of the seventeenth vertebra in the Ostrich¹, especially in the above modification of the hæmal surface², to which view of the vertebra of *Dinornis maximus*, corresponding to the seventeenth of *Struthio*, I here restrict my illustrations of such vertebra.

The processes (*c* in Mivart's fig. 34, *hy* in his figure 39) are serial homotypes. The recognition of this fact led me to speak of Mivart's 'catapophyses' as 'parial hypapophyses' in the Memoir on *Cnemiornis* (Trans. Zool. Soc. ix. p. 260), and again, under a sense of the convenience of a substantive term, as 'præhypapophyses' (ib. ib.), in contradistinction with the 'hypapophyses' at the hind part of the centrum in the axis and third cervical. The antero-posterior extent of the pleurapophysial plate is shortened in the fourteenth vertebra of *Dinornis*, as in the seventeenth of *Struthio*; but the pleurapophysis itself is less produced in *Dinornis*. The neural spines have not approximated and coalesced as in *Struthio*. The section of the supporting column of the parial neural spines is transversely quadrate; both fore and hind surfaces are impressed by a definite rough tract for the elastic ligaments. The preaxial surface retains a greater relative breadth to the postaxial than in *Struthio*; the vertebraarterial canals are relatively wider.

The next step in the transmutation of Mivart's 'catapophysis' into the normally situated single hypapophysis in birds is presented by the fifteenth cervical of *Dinornis maximus* (figs. 18–21), which is the last of that series in the present skeleton.

A single obtuse process descends from a low base coextensive nearly with the hæmal surface of the centrum (fig. 19, *hy*); but the base of this process in one example is connected by a ridge continued from each side to the hind border of the pleurapophysis (ib. *pl*), and there is a slight swelling (the final trace of the parial character) at the beginning of each ridge. A pair of low tuberosities, connected by a ridge, mark the hind border of the lower surface of the centrum.

With the vertical extension of bone, *hy*, from this surface for muscular attachments, a corresponding but greater one marks the opposite or neural surface, one process (*hy*, fig. 18) descending, the other (*ns*) ascending. The neural spine gives off a pair of low tuberosities, one on each side, near its summit: from each there is continued the usual ridge curving back to the hyperapophysis (fig. 18, *hp*), which still overtops the postzygapophysis, *pz*.

² Ib. ib. fig. 39.
A mere rudiment of the interzygapophysial band now remains, but behind it is a small foramen leading to the cancelli of the neurapophysis; a corresponding foramen is noticed in *Struthio*¹. The pneumatic foramen is, as usual, beneath the base of the

**FIFTEENTH VERTEBRA** (*½ nat. size*).

Aspects.

Fig. 18, lateral; 19, hæmal (ventral).

...diapophysis, which process shows its tuberous outstanding metaphysis (fig. 18, *m*) well marked above the pleurapophysial band, *pl*. This, as in the seventeenth (last cervical) vertebra in *Struthio*, is short antero-posteriorly, and each margin is concave, with a blunt production of its hinder and lower angle still representing the cervical riblet. Each vertebroarterial canal (figs. 20, 21, *v*), as in *Struthio*, exceeds the neural canal in capacity.

If the transverse expansion of the fore part of the centrum be reckoned as due to the bases of 'parapophyses,' the fore or preaxial articular surface (*ac*, fig. 20) may be said to extend thereupon; but the parapophysis, *pa*, in *Dinornis maximus* may better be held to spring out external to the preaxial surface than in *Struthio*. The outer

¹ Mivart, loc. cit. p. 409.
FIFTEENTH VERTEBRA (½ nat. size).

Fig. 20, preaxial; 21, postaxial.
border of the prezygapophysis (fig. 20, az) now begins to rise, and gives a more inward or medial aspect to the oblique articular surface. The postzygapophyses (fig. 21, pz, pz) show a corresponding change in the contrary sense, but they do not extend postaxially beyond the centrum in so great a degree as in Struthio. A marked difference between the vertebrae here compared is in the greater height and greater breadth of the neural spine in Dinornis; but the chief distinction is shown by the coexistence in Struthio of an independent or movable pleurapophysis with the first appearance of the single and simple hypapophysis. In Dinornis such condition of the hypapophysis is associated with a continued confluence of the riblet, pl. In other words, the single hypapophysis marks the first dorsal vertebra in Struthio and the last cervical in Dinornis (fig. 18, hy).

The character of the fifteenth cervical in the series of the skeleton of D. maximus is that of the sixteenth cervical in the neck-series of Hutton's skeleton of D. elephantopus; and this is followed by a seventeenth cervical, or one with ankylosed pleurapophyses, beyond which there are seven vertebrae for a dorsal series. But in both the sixteenth and seventeenth cervicals the neural spine is bifid; the ridges from the hyperapophyses converge to the base of a single neural spine only in the first of the series of vertebrae in which the pleurapophyses retain their independence and mobility. If my series of cervicals in D. maximus be, as it seems by characters of juxtaposition, the correct number, Hutton's specimen of the skeleton of D. elephantopus has two additional cervicals, in all seventeen, instead of fifteen as in Apteryx. These remarks are based on a photograph of the skeleton in the Otago Museum.

In a cervical vertebra (figures 22, 23, 24) of D. giganteus, which I regard as homologous with the fifteenth or last cervical of D. maximus, the neural spine (fig. 23, ns) retains, as in D. elephantopus, its bifid character; but the parial portions are relatively less developed, and their connecting bar (ib. b) has begun to rise, indicating, as it were, a rudiment of the single and longer neural spine in D. maximus. The hypapophysis (figs. 22, 24, hy) is single, and its base is supported by the ridges from the pleurapophyses representing the 'catapophyses' of Mivart. The posterior hypapophysial tubercles (ib. hy') are better marked than in figure 19 (D. maximus).

The neck-vertebrae in every species of Dinornis in which I have been able to determine them correspond, with unimportant modifications, with those above described and figured, and in like degree differ from their homologues in Struthio.

In the well-marked class of Vertebrates characterized by the many cervical vertebrae, these, as a rule, are small; but in Apteryx, and especially in Dinornis, they are exceptionally large. Some of those in Dinornis maximus almost equal in size the neck-vertebrae of the horse.

The muscular system, as has been shown in Apteryx (p. 44), is correspondingly developed; and when, to the proportionally still more powerful neck-muscles in

1 Comp. fig. 18, pz, with Mivart, loc. cit. p. 406, fig. 35.
2 Mivart, loc. cit. p. 408, fig. 40.
_Dinornis_, were added their thick integument and covering of feathers, the neck must have been a feature of strength very different from the slender character of that lengthy part in an Ostrich and the like living birds.

**Fifteenth Vertebra, _Dinornis giganteus_ (½ nat. size).**

---

Aspects.

Fig. 22, lateral; 23, neural; 24, hæmal.

This consideration adds significance to the record of one of the oldest living Colonists in New Zealand, recently published.
"In 1844, at Wellington," writes Mr. Hamilton, "I was present, as Governor Fitzroy's private secretary, at a conversation held with a very old Maori, who asserted that he had seen Captain Cook. Major Richmond, then Superintendent of Wellington, was, I think, also present. I cannot recollect who was the Governor's interpreter. This Maori (Haumatangi), so far as my memory now serves me, I should guess was 70 years old; at all events he was brought forward as one of the oldest of his people then residing about Port Nicholson. Being asked 'Had he ever seen a Moa?' he replied, 'Yes, he had seen the last one that had been heard of.' When questioned as to what it was like, he described it as a very large tall bird, with a neck like a horse’s neck. At the same time he made a long upward stroke in the air with his right hand, raising it far above his head, and so as to suggest a very fair idea of the shape of a Moa’s neck and head, such as I have since seen them in the skeleton birds of the magnificent collection which Dr. Julius Haast has gathered together in the Canterbury Museum. There is no bird or animal of large size indigenous to New Zealand to which an old Maori could liken the Moa. The horse was probably the only creature imported by us in 1844 in which he could possibly find any kind of likeness calculated to give us a fair general idea of the shape and height of the bird's neck and head. If he had never himself seen a Moa, how—unless he had received its description, handed down from Maoris, who had seen one—could he possibly have hit upon such an idea as to refer us to the tall arched neck of the horse for a likeness? The gesture which he made with his hand remains impressed upon my memory as freshly as if seen only yesterday, as one that was singularly descriptive. It was like a sketch being made, as it were, in the air."¹

Reckoning, by a convenient, though somewhat artificial character, as a first dorsal the vertebra which first retains its pleurapophyses as independent movable elements, such vertebra (the sixteenth), in Dinornis maximus, answers to the eighteenth in Struthio, of which Prof. Mivart gives two instructive views (½ natural size)².

I subjoin a corresponding figure (figs. 25, 26), similarly reduced, of the first dorsal in Dinornis maximus.

If the hypapophysis (fig. 26, hy) be taken as a guide, the present vertebra in Dinornis would answer to the nineteenth in Struthio, which is the second vertebra in that genus showing the single medial hypapophysis at this region of the spine, and associated with the articular facet, p, for the movable pleurapophysis.

In Dinornis the parapophysis, p, is less produced forward or outward; the neural spine, ns, is more elongated and inclines forward; it is also thicker, more quadrate in section. In another vertebra it is less elongate than in the figure and less inclined forward; the costal surface, also on p, is likewise deeper and is subcircular in shape.

² Loc. cit. p. 408, figs. 40, 41.
The preaxial surface has its vertical extent not so inferior to the transverse as in *Struthio*.

The pleurapophysis articulates with a small shallow pit on a very short parapophysis; the 'head' is supported on a neck 1½ inch long, and slender in proportion to the body and tubercular process, which is sent off at an angle of 45' with the neck; it terminates by a smooth round tubercle, fitting a corresponding pit on the lower surface of the diapophysis, which it thus underprops. The body of the rib is flattened, 1 inch 3 lines broad at the divergence of the cervical and tubercular branches; it is slightly curved inward and forward, and gradually terminates in a point. No hæmapophysis (sternal rib) is developed in the sixteenth (1st dorsal) vertebra of *Dinornis maximus*.

In the first dorsal vertebra of *D. elephantopus* the hypapophysis is more central in position, more tuberous, less compressed, with a shorter base; in other words, retaining more of the character of that process in the last cervical.

The seventeenth vertebra, answering to the twentieth or third dorsal in the Ostrich, and repeating the character of the hypapophysis in the first dorsal, exemplifies also the difference of being the first of the vertebral series, traced from the skull, in which the segment, or osteocomma, is completed by a perfect hæmal arch.
The centrum and neural arch show no notable differences from those of the sixteenth vertebra. The pleurapophysis, with a similar double articulation, has increased in size and conspicuously in length; it also supports an 'epipleural appendage,' which is broad and slightly curved upward, where it overlaps the succeeding rib. The hæmapophysis is ossified and synovially articulated with the pleurapophysis above and with the hæmal spine ('sternum') below. Towards its hæmal end it expands and develops a tubercle.

The size of the dorsals in *D. maximus* increases slightly as they recede, and chiefly in breadth, by the outgrowth of the diapophyses, accompanied by a greater size of the rib and greater length and divergence of its capitular and tubercular processes. In the present vertebra (third dorsal) the base of the hypapophysis, though shorter than in the second dorsal, occupies a greater extent of the hæmal surface of the centrum than in the third dorsal of *Struthio*. Not more of the fore part of the neural surface of the centrum is exposed than in the antecedent dorsals and terminal cervical vertebra. The postaxial surface continues to be narrow in proportion to its height; but its transverse convexity increases, and is relatively greater than in *Struthio*. The transverse concavity of the preaxial surface has also increased; it is still convex vertically along its middle third. In a homologous vertebra of the present species of *Dinornis* I have noted a variety in the hypapophysis in the interruption of its basal extent producing a small quasi second hypapophysis near the postaxial surface.

The pleurapophysis, with a slight increase of length, and of that of its appendage, is as in the second dorsal. The hæmapophysis ('sternal rib') articulates by a transversely extended bitubercular end with the sternum.

The nineteenth vertebra (fourth dorsal, figs. 27–29), corresponding with the first of those having their pleurapophyses free and articulating with their hæmapophyses in *Struthio* (figures 47, 48, 'Mivart,' p. 413), has the centrum less cuneiform in transverse section, the sides converging, with a certain convexity, hæmad to a low and short ridge or keel, produced and thickened anteriorly, near the preaxial surface (fig. 27, *hy*).

Prof. Mivart reckons the dorsal series as commencing with the vertebra thus typically complete in regard to its hæmal arch. I prefer to retain the character of a free pleurapophysis as denoting the present class of axial segments.

Thus the nineteenth vertebra in *Dinornis*, or fourth of the dorsal series, answers to the twenty-first in *Struthio*, which is the fourth supporting a free pleurapophysis (vertebral rib), and the first in which this element articulates with its hæmapophysis (sternal rib). The hæmapophysis of the twentieth vertebra in *Struthio* is developed, but is articulated only with its spine (sternum) and does not join by its opposite end the pleurapophysis. Such condition I have not yet seen in any species of *Dinornis*.

With respect to the twenty-first vertebra in *Struthio*, Mivart remarks, that "it is so much like the twentieth that little need be said in its description" (p. 413). My figure 28 may therefore be contrasted with figure 46 in Mivart's monograph (p. 411, *loc. cit.*) for illustrations of the differential characters in question.
NINETEENTH VERTEbra (4th dorsal; 1/2 nat. size).

Fig. 27, lateral; 28, preaxial; 29, neural.
The three views (figs. 27, 28, 29) of the nineteenth, or fourth dorsal, vertebra of *Dinornis maximus* correspond with those views of the twenty-first vertebra of *Struthio* given by Mivart in figs. 47, 48 (loc. cit.). In this comparison, among the distinguishing characteristics of the Dinornithic vertebra, are, first, the greater relative height of the neural arch and spine, whereby the distance of the parapophysial, \( p \), from the prezygapophysial, \( z \), surfaces is relatively greater. The diapophysis, \( d \), is less extended lengthwise, but more produced transversely and vertically; it also terminates with a tuberosity which might be reckoned as a low metapophysis, fig. 28, \( m \), overtopping the small articulation, \( d \), which now looks outwardly for the attachment of the rib's tubercle.

A reticulo-pneumatic fossa (\( rn \), fig. 27) intervenes, as in *Struthio*, between the par- and diapophysis. A larger pneumatic foramen (ib. \( pm \)) opens behind the diapophysis (\( d \)). The neural spine (\( ns \)) retains its characteristically greater height and thickness, with minor relative antero-posterior extent than in *Struthio*. Its fore and hind surfaces are occupied by well-defined rough tracts for the elastic ligaments (fig. 28, \( l \)).

The preaxial surface (ib. \( ac \)), less transversely and more vertically extended than in the antecedent vertebra, retains something of its bilobed character by the emargination of its upper and lower articular borders. The parapophysis (\( p \)) projects with its rib-surface distinct from the articular facet (\( ac \)) of the centrum. The postaxial surface shows an unsymmetrical form in two examples of this vertebra, encroaching further upon the left side of the centrum in one, and upon the right side in the other. Both are individual varieties.

The hypapophysis (\( hy \), fig. 29), reduced vertically, is coextensive with the under surface of the centrum, and slightly produced and expanded at both ends (fig. 27, \( hy, hy' \)). In the direct view from beneath (fig. 29) the more advanced position of the diapophyses (\( m \)) and the less produced hind part of the neural platform and its postzygapophysial surfaces (\( pz \)) are well shown, in contrast with Mivart’s figure 48, in *Struthio* (loc. cit. p. 413).

The hæmapophysis of the fourth dorsal did not, in the specimen under description, articulate directly with the costal border of the sternum, but through the medium of the hæmapophysis of the third dorsal.

In the fifth dorsal (twentieth) vertebra the fore and hind productions of the hæmal keel of the centrum assume the character of distinct hypapophyses, of which the anterior (\( hy \)) is unciform, being produced forward with the end upcurved, so as to receive the tuberous hind part of the hypapophysial ridge of the fourth dorsal into its concavity; the posterior one (\( hy' \)) is low and simple. Figure 30 is a side view of the centrum of this vertebra, showing this singular and, as far as I have observed, unique development of pre- and post-hypapophyses.

The parapophysial rib-cup (\( p \)) is rather larger, and the neural spine has greater fore-and-aft breadth than in the preceding (fourth dorsal) vertebra. This spine greatly exceeds in both height and thickness that in *Struthio*. A pair of depressions, answering
TWENTIETH VERTEBRA (‘5th dorsal,’ 1/2 nat. size).

Fig. 30, lateral aspect.

TWENTY-FIRST VERTEBRA (‘6th dorsal,’ 1/2 nat. size).

Fig. 31, lateral; 32, preaxial aspect.
to those marked f in Mivart's figure 57 of the last dorsal vertebra, are here well marked.

In the sixth dorsal (twenty-first vertebra, figs. 31, 32) the hypapophysis is suppressed, as in the twenty-second (fifth dorsal) vertebra of Struthio (Mivart, figs. 49–51)¹, with which the present will be compared. The articular surface (fig. 32, ac) thus almost "entirely occupies the preaxial end of the centrum"²: only a few lines breadth on each side of the neural half of that surface is non-articular in Dinornis, and may be ascribed to the fore part of the parapophysis (ib. p). The vertical as compared with the transverse diameter of the preaxial surface is greater than in Struthio. The characteristic height of the neural spine in Dinornis (figs. 31, 32, ns) is still more marked in this comparison. The pneumatic orifice (fig. 31, pn) between the par- and di-apophyses is the chief one for admission of air into the vertebral substance; but a small homologue (ib. pn') of the posterior pneumatic orifice remains.

The postaxial surface (fig. 31, pc) is absolutely and much more relatively approximated to the postzygapophysis (ib. pz) than in Struthio. The neural canal (fig. 32, n) is transversely, not vertically, elliptical (comp. Mivart's fig. 51). The sides of the preaxial surface are much produced, and the transverse concavity of that surface is proportionally deepened. The lower border of the postaxial surface is more produced than in Struthio, rendering the lower contour of the centrum in Dinornis more concave (comp. fig. 31 with fig. 49, Mivart, loc. cit.). The zygapophysial surfaces are relatively more extensive in Dinornis, the dorsal vertebrae being more securely interlocked in the larger terrestrial bird.

The characteristically broad and massive proportions of these vertebrae in Dinornis are well brought out in comparing figs. 27–32 with figs. 47–51 of Mivart, loc. cit. The minor length and greater thickness of the diapophyses, d, and the much greater development of the neural spine are exemplified in fig. 32 as contrasted with fig. 51 (Mivart, loc. cit.).

The vertebra in Dinornis which answers, in rib-character, to that in Struthio supporting the eighth pair of movable pleurapophyses is that which supports the seventh pair. In both genera it is the hindmost rib-vertebra not confluent with the sacrum. In the present skeleton of Dinornis it is the twenty-second vertebra, counting from the occiput; in Struthio it is the twenty-fifth. Of this Prof. Mivart gives four figures³. The chief differential characters of its homologue in Dinornis maximus will be exemplified in the two subjoined cuts from the lateral (fig. 33) and postaxial (fig. 34) aspects.

In the comparison of figure 33 with figure 54 (Mivart'), the deep longitudinal concavity of the under surface (c) of the centrum may be first remarked, due in Dinornis to a downward production of the border of the preaxial articular surface (ac) and a still greater production in the same direction of the postaxial surface (pc), augmented by the development of a pair of hypapophyses (fig. 34, hy). These are not developed in

Struthio. Rudiments may be indicated by the letters hy in Mivart's fig. 54; but they are not noticed in the text. In the transverse direction the hæmal surface of the centrum is convex, as in Struthio.

The preaxial surface in Dinornis is subquadrate, through the production of its inferior angles, which, like the upper ones, are rounded off. Its transverse concavity is less than in the sixth dorsal: it is relatively larger in proportion to the centrum than
in that vertebra. The postaxial surface is more definitely subquadrate, with the angles rounded off and the upper and lower borders emarginate (fig. 34, pe). The transverse convexity is not greater than the vertical concavity; both are feeble, so that the entire surface approaches to flatness; and in a duplicate homologue the flattening is greater than in the specimen figured. In both the surface has lost its synovial smoothness, through suppression of motion upon the first sacral vertebra. The transverse dimension does not exceed, as it does in *Struthio*, the vertical one.

The neural canal (fig. 34, n) is more depressed than in the twenty-first vertebra, and still more deviates from the form shown by the hinder outlet in Mivart’s figure 56 of the Ostrich. The paraphysis in *Dinornis* (fig. 33, p) is represented merely by the raised margin of the capitular concavity. The diapophysis is less massive in proportion to the rest of the vertebra, and especially the neural spine, than in the antecedent dorsal. The neural spine is not carinate along either the fore or the hind border; both present a flat rough surface, about two thirds the breadth of each smooth lateral surface. A transverse section of the spine thus gives an oblong quadrate figure. A pair of depressions at the fore part of the base of the spine intervene between it and the prezygapophyses; they answer to the ‘antero-lateral fossæ,’ f¹, in Mivart’s figures 55, 57. A narrower pair of fossæ hold a like relation to the postzygapophyses, answering to those marked f³ in figs. 56 & 67 (‘Mivart’). The fossæ, f², ib. ib., are feebly, if at all, represented in *Dinornis*.

The pleurapophysis retains its twofold articulation, but has lost in length; its hæmapophysis is attached to that of the preceding segment, and this element fails to reach its spine (sternum) in the fifth and subsequent dorsals.

The sternum may be considered, archetypally, as a coalescence of four or more such hæmospines, the foremost retaining its connexions with its hæmapophyses, which are expanded in *Struthio* and in birds of flight as ‘coracoids;’ but in *Dinornis* the ‘coracoids’ retain the slender proportions of the true thoracic hæmapophyses. They are also here confluent with their pleurapophyses, which, detached as a ‘scapula’ from its proper centrum, has the proximal end free without articular head, and in *Dinornis* is reduced to the normal form of a rib with diminished proportions.

Retaining these views of the ‘general homology’ of the sternum, I find its proper place of description at the part of the axial skeleton here attained.

The sternum belonging to the skeleton of *Dinornis maximus* under description has suffered some mutilation; but a detached example of the bone, transmitted from New Zealand to Edinburgh (Plate XCVIII.), shows a unique condition of integrity.

Still regarding, after long practice in the interpretation of avian fossils, the sternum as one of the most characteristic and taxonomically instructive parts of the skeleton of the bird, I append figures of the natural size of this most perfectly preserved specimen of the bone, which is referable to the largest of the known species of *Dinornis*¹.

¹ This statement is made on the faith of the sternum transmitted with the rest of the skeleton of *Dinornis*
This specimen of sternum is now in the Museum of Science and Art at Edinburgh, and has been kindly confided to me for the purpose of the present Work. It agrees in general characters with that of *Dinornis elephantopus* (Plate LXXII.), but with specific differences. It shows the articular cavities (Plate XCVIII. fig. 5, b, b) for the coracoids, the two costal borders (figs. 3 & 4), and the hind border entire. The latter, besides the two lateral deep and wide emarginations, f, f, has a small and shallow medial one (g, g). A similar, but smaller, yet relatively deeper, medial notch characterizes the corresponding part of the hind border of the sternum of *Dinornis rheïdes* (Plate LXXIII.).

This three-notched type of hind border is, so far as I know, unique, or peculiar to the sternum of *Dinornis*.

The specimen under description (Plate XCVIII.) is more convex externally, more concave internally, than in *Dinornis elephantopus*, as represented by the subject of Plate LXXII. The anterior border is bent inward¹, and mainly defines the deeper part of the concavity on that surface (fig. 2, a). The integrity of that border with its terminal costal processes (d, d) shows it to describe a feeble curve concave backward (fig. 5). It is smoothly rounded, and about half an inch in thickness; its extent in a straight line is 8¼ inches.

An accidental or individual loss of symmetry distinguishes the present specimen. The right cavity (fig. 5, b) for the coracoid is deeper and better defined than the left (ib. b'). It would seem that the chief work of depressing the sternum in inspiration had fallen to the right scapulo-coracoid bone, and that in this act the inspired air had been driven with more force into the left sternal air-cell or reservoir, an act which had been so long or so often repeated as to have pressed the corresponding part of the sternum more outward than on the right side, resulting in a deeper inner concavity (ib. fig. 2, pm) and more prominent outer convexity (ib. fig. 1, s) on the left half of the fore part of the bony plate. On its opposite surface the number of small pneumatic foramina is greater, and they are somewhat larger in the deeper left depression than in the shallower right one.

The lateral borders of the inner concavity are formed by the extension inward of that margin of the costal tract (e, e), especially at the second and third articular surfaces. The outer border near the first or anterior costal surface projects externally. About one inch and a half of the end of the left lateral process seems to have been, in the bird's lifetime, broken from that process, and subsequently reunited to it (at h', figs. 1 & 2).

It is interesting to remark, in connexion with the abrogation of the wing-bones and

---

¹ See 'Note,' p. 255.
power of flight, that the sternum does not increase in size in the ratio of the increase of the legs and general stature of the species of Dinornis.

The length of the present sternum at its mid line, and the breadth from tip to tip of the lateral processes, are less than that of the subject of Plate LXXII. But the length of the body of the sternum anterior to the lateral hind notches is greater in the present bone, whilst that of the part prolonged between those notches is less; the costal border (Plate XCVIII. figs. 3 & 4) is nevertheless absolutely longer in the present sternum; and although in the angle of divergence of the lateral processes \( h, h \) it conforms to the type of the sternum of Dinornis elephantopus, and with it departs in a marked degree from that of Dinornis rheïdes, yet the differences noted are sufficient to indicate that the present perfect sternum accords more closely with that of the skeleton of Dinornis robustus, and has, at least, belonged to a distinct species of the group of Moas, which, on sternal characters, might be denoted by the generic term Palapteryx.

There is, however, a gradational approach to the less divergent type of sternum exemplified in Dinornis rheïdes. In (Palapteryx) elephantopus, e. g., the breadth of the fore border of the sternum being 8 inches, that of the bone at the ends of the divergent processes is 15 inches.

In Dinornis robustus the breadth of the fore border being 8 inches 3 lines, that of the bone at the ends of the divergent process is 13 inches.

In Dinornis maximus the breadth of the fore border of the sternum being 9 inches, that of the bone at the end of the divergent processes is but 12 inches; moreover, the length of the sternum anterior to the notches is relatively rather more than in D. robustus, and makes a corresponding approach to the more elongate type of sternum represented by D. rheïdes.

With these approaches, in sternal gradations, to that type the limb-bones coincide, showing longer and more slender proportions as compared with Dinornis elephantopus and D. crassus; so that, even accepting, or resuming for convenience' sake, my old subdivision of Moas into two subgenera, I cannot shut out the conviction of its essential artificiality.

It is hardly probable that a nominal generic distinction will be ultimately accepted on the differences here pointed out between the sternums of the species of Dinornis outlined in cut, fig. 35, especially as they are associated with corresponding gradational differences of proportion in the bones of the hind limbs.

Admitting such generic or subgeneric group for the species crassus and elephantopus, showing the extreme divergence of sternal processes with robustness of hind limbs, and if the term Palapteryx had not had priority, I must have adopted Reichenbach's *Emeus*¹, of which my Dinornis (Palapteryx) crassus is the type.

¹ Das natürliche System der Vögel, 4to, 1849-50, p. xxx.
Dr. von Haast has followed his ornithological countryman's procedure in a further
generic subdivision of the *Dinornithidae*.

*Dinornis didiformis*—the type of Reichenbach's genus *Anomalopteryx* (1850)—is the
type of Von Haast's genus *Meiornis* (1874). The *Euapteryx* of Von Haast (1874)
is the *Syornis* of Reichenbach (1850), both represented by *Dinornis casuarinus*.

My *Dinornis curtus* is the type of Reichenbach's genus *Cela*: his genus *Monia* has
*Dinornis ingens* for the type. The old generic term *Dinornis* is restricted by Reichen-
bach to the species *D. struthioides*; and *D. giganteus* is referred to a genus *Moa* (1850).

These generifications of the accomplished author of the 'Handbuch der speziellen
Ornithologie' have not met with acceptance or favour at the hands of subsequent
systematists. Whether the parallel labours of Dr. von Haast will be more fortunate
remains to be seen.

Returning to my more congenial task of Comparative Anatomy, if Plate XCVIII,
or the reduced outlines of the sternum in species of *Dinornis* (cut, fig. 35) be compared
with the figures of the sternum of *Struthio* in Mivart's figs. 77–79, the straightness of
the anterior border and the smallness of the contiguous coracoid grooves (b, b' in Plate
XCVIII.) contrast with the undulate contour of the same border and the length of those
grooves (c, c) in *Struthio*, which almost meet at the mid line. The body of the breast-
bone is more convex and bulging in the Ostrich; the lateral processes (called 'xiphoid,'
and marked lx by Mivart) are absolutely and relatively much shorter; the medial
posterior processes, which seem to me more analogous to the mammalian 'xiphoid'
(Plate XCVIII. g, g), are wanting in *Struthio*; and instead of the mid notch (ib. n)
there is, in *Struthio*, an obtuse production.

The costal border shows differences, as in longitudinal extent, in accordance with the
greater number of sternal ribs to which it gives attachment in *Struthio*; this border
differs also in breadth and in the complexity of the articular surfaces, corresponding, in
*Struthio*, to the more expanded and subbifid sternal ends of five of the six pairs of
sternal ribs which articulate therewith in that existing form.

The sternum of *Apteryx* conforms much more closely to the type of that bone in
*Dinornis* than does the sternum in any other known species of bird. Modification has
reigned in the peripheral prehensile portion of the cephalic extremity of the vertebral
column to the degree of generic distinction manifested by the kinds of *Kivi*.

To the side view 2 of "the sacral and caudal vertebrae of a young Ostrich" 3 Prof.
Mivart 4 has added a hemal ('ventral' or lower) view (fig. 60, loc. cit.) and a neural

---

1 "Address to the Philosophical Institute of Canterbury," in the 'Lyttelton Times' of Friday, March 6th,
1874; reprinted in the 'Transactions of the New-Zealand Institute,' vol. vi. June 1874, p. 419.
2 Archetype and Homologies of the Vertebrato Skeleton," 8vo, 1848, p. 159, fig. 27.
3 Descriptive Catalogue of the Osteological Series contained in the Museum of the Royal College of Surgeons
of England,' 4to, 1853, p. 266, no. 1885.
4 "The Museum of the College of Surgeons fortunately possesses a preparation of the sacral vertebrae (figs.
58, 59, 60, and 61) of a young Ostrich in an unanchylosed condition, which enables the serial description of
The modifications of sacral structure here exhibited, which have proved most instructive in their application to the vertebrae of extinct animals, are the alternate disposition of certain centrums and neural arches and of a few other centrums and pleurapophyses. In *Mammalia* such disposition of the heads of ribs across the articular intervals of the centrums is the rule in dorsal vertebrae, and a like disposition of the neural arches occurs in the dorsal vertebrae of *Chelonia*; but the concurrence of the alternating positions of centrums with both elements appears not to have been observed in the sacral region of any vertebrate until the task of determining the singular detached centrums in the *Iguanodon* and other large extinct *Reptilia* led me to a series of researches into the sacral structures and their development in existing *Vertebrates*. These researches led, among other results, to the detection, in the long sacrum of birds, of "a shifting of the neural arch from the middle of the body to the interspace of two adjoining centrums, each neural arch being there supported by two contiguous vertebrae, the interspace of which is opposite the middle of the base of the arch above, and the nervous foramen is opposite the middle of each centrum."  

1. By this modification, "that part of the spine subject to greatest pressure is more securely locked together;" and I further remarked that, "this structure is beautifully exemplified in the sacrum of the young Ostrich."  

The detached centrums of such vertebrae yielded the key to the characters of the individual vertebrae to be completed" (Zool. Trans. viii. p. 420). Probably my preparation, No. 1885, may be here alluded to.


2. Ib. ib.
Dinosaurian vertebrae figured in plates xii. et seq. of my 'History of British Fossil Reptiles' 1. Every subsequent discovery of a true Dinosaur has confirmed the applicability and value of this character of the extinct order.

The 'sacrum' in Dinornis I continue to characterize, as in other birds, by the ankylosis of the vertebrae, through which that single mass of the 'spinal column' results. The concomitant ankylosis of the iliac, ischial, and pubic bones constitutes the 'pelvis.' In birds 'ankylosis converts a large proportion of the vertebral column into a sacrum' 2. When it is said, and legitimately in its taxonomic application, that 'the Cetacea have no sacrum,' it is to be understood that vertebrae homologous with the sacras of the bird have not coalesced: when a mammal is said to have but two 'sacral vertebrae,' the homologues of two of the sacral vertebrae of the bird have coalesced. In Dinornis maximus seventeen vertebrae have so coalesced, and include the homologues of vertebrae which in mammals retain their primitive freedom, and may be characterized as 'dorsal,' 'lumbar,' and 'caudal.' When it is said that birds have no lumbar vertebrae, a similar remark applies to that which has been offered respecting the absence of sacral vertebrae in the Cetacea.

The first or foremost sacral vertebra in Dinornis maximus (twenty-third of the entire series) offers to its pleurapophysis, which retains its mobility, a parapophysial cup near the upper and fore part of the centrum, and a small rough facet on its diapophysis. The pleurapophyses of the second and third sacra are ankylosed each to its parapophysis, and thence, by a bony plate, continued from the upper part of the 'cervix' to the lower part of the diapophysis. These two last ribs are progressively shortened, but still project beyond the iliac roof. Their more reduced serial homologues form the transverse osseous bars abutting against the outswelling antacetabular part of the ilium, with which the pubis has coalesced (Plate XX, fig. 2).

After the second sacral centrum that element, in succeeding vertebrae, quickly loses length. In the section of the sacrum of Dinornis maximus (Pl. CXIV, fig. 2, 1/3 nat. size) the interval between the first (1) and second nerve-outlets, which is 2 inches 7 lines, is reduced to 6 lines between the sixth (6) and seventh outlets, and to a less extent in the four succeeding outlets. Between the twelfth (12) and thirteenth outlets the interval is 9 lines, and it increases to 1 inch 6 lines between the fifteenth and sixteenth (16) outlets. Of these nerve-outlets, the separation of the motory from the sensory division is well marked at their commencement from the neural canal in the fourth sacral, and so continues to the twelfth. In the thirteenth the size of the outlet is much reduced: from this part the myelon is restricted to the supply of the terminal contracted part of the spinal column called 'tail;' and here we have the sign of the beginning of the

1 Quarto, part vi. (1855).
2 'Anat. of Vertebrates,' Svo, 1866, ii. p. 29. The homologies of certain of these with the vertebrae called 'dorsal,' 'lumbar,' and 'caudal,' in other vertebrate classes, are given in my 'Archetypa,' &c., Svo, 1848, p. 90 et seq.
caudal series of vertebrae, of which five have been enlisted or conscripted into the service of the sacrum.

The sacro-neural canal (Plate CXIV, fig. 2) retains a vertical diameter of 8 lines along the first three vertebrae; it then expands gradually to the sixth and rapidly to the ninth sacral, where the vertical diameter reaches to 1 inch 6 lines. The anterior or 'hæmal' myelonial columns would seem to have made a bulge between the eighth and tenth vertebrae; and the neural canal, again contracting, shows its diameter of 8 lines between the thirteenth and fourteenth outlets, and is reduced to 4 lines in the last or seventeenth sacral vertebra.

The motory and sensory divisions of the nerve-outlets continue distinct to the outer surface of the vertebra as far as the twelfth sacral, the neural (dorsal, upper) or sensory division being the smallest, and diminishing more rapidly than the hæmal (lower, motory) outlet after the ninth of these. The canal gains in transverse as in vertical expanse, but in a rather less degree.

Parapophysial abutments cease after the eighth sacral, and are resumed at the twelfth. The diapophysial ones increase in length from the fifth sacral, but with much diminished breadth, to the ninth sacral, when they increase in breadth as well as length, and curve upward, backward, and slightly outward to buttress up the expanded postacetabular part of the ilium.

Between the smooth compact inner layer of bone forming the neural canal and the somewhat thicker outer layer, the osseous substance of the sacrum is coarsely reticulate and pneumatic. Larger subserial vacuities mark, in vertical section (Plate CXIV, fig. 2), some of the anterior obliterated vertebral interspaces; and the longest or chief laminae, rising from the roof of the neural canal, indicate the neural spines at distances corresponding to the nerve-outlets, answering to the fourth sacral vertebra. The spine-plate curves gently forward; while those of the sixth, seventh, and eighth sacrals rise vertically, and the succeeding ones curve gently backward.

In the comparison of the sacrum of Dinornis, as exemplified by the present species, with that of Struthio, as illustrated in Prof. Mivart's paper 1, I may premise that the first three (anchylosed) vertebrae are reckoned, by its author, as 'dorso-lumbar' (26th and 27th) and lumbar (28th) vertebrae. It will be understood, therefore, that in my description of the specimen "in the Museum of the College of Surgeons" 2, figured in Mivart's cut 59, "the neural arch of the fifth sacral vertebra has advanced, and rests over the interspace between its own and the preceding centrum; at the eleventh vertebra it has resumed its normal position and connexion" 2. My 'fifth sacral' is Mivart's 'second' (s 2), and my 'eleventh' sacral is Mivart's eighth; the last five sacrals in the twenty anchylosed vertebrae of the mature Ostrich (Plate XIX, fig. 4) are reckoned by him as the first five caudals in that bird.

In Dinornis the twenty-fourth vertebra (3rd sacral), answering to the twenty-eighth

---

2 'Catalogue ut suprâ', 4to, 1853, p. 266.
vertebra of Struthio (Mivart’s ‘lumbar vertebra’), differs in presenting an unmistakably rib-like pleurapophysis, although unanichylosed. The fourth sacral in Dinornis is the first which may be said to “present no indication of a rib,” and which would be entitled to the term “lumbar,” according to such character. I view, however, the parapophysial element of this transverse process as more probably the serial homologue of the cervical part of the preceding pleurapophysis.

With this explanation the neural arch of the fifth sacral vertebra in Dinornis, as in Struthio, advances and crosses the interspace between its own and the preceding centrum; and the thirteenth vertebra is that in which the arch resumes its normal connexions. Thus the interlocked part of the sacrum in Dinornis is more extensive than in Struthio, and relates to the heavier mass which the pelvis had to transmit upon the femora.

The antacetabular part of the sacrum (1st to 6th vertebra in Dinornis) is relatively shorter and broader than in Struthio; the postacetabular part is still broader in proportion to its length; and this part is shorter than the antacetabular part, instead of being, as in Struthio, longer.

More striking differences are presented by the pelvis as a whole (Plates XIX., XX., XX.a, XCVI, fig. 4). The antacetabular plate of the ischium is relatively longer; the postacetabular part is shorter, but much broader in Dinornis than in Struthio (Plate XIX, fig. 4): the greater relative breadth of the entire pelvis would seem to relate to the larger proportional size of the egg in Dinornis.

The ischium is shorter and deeper than in Struthio: it unites with the ilium anteriorly to bound there the ischiadic notch, which remains open posteriorly, as in Struthio, and is not circumscribed by a second terminal union of the ischium with the ilium, as in Dromaius. The obturator interspace, closed behind, as in Struthio, by ischial confluence with the pubis, and having its fore part defined by the descending process of the ischium, is much narrower in Dinornis, as in Apteryx. The pubis does not send off so long and well-defined a ‘pectineal process’¹, as in Struthio; its body extends backward parallel with the ischium, slightly concave downward, and terminates in the vertical expansion joining the ischium without being continued downward and forward to meet its fellow at the symphysis, a structure which is peculiar, among birds, to the genus Struthio.

The type of the pelvis in Dinornis is that of the Apteryx, not of the Emu or Casowary; it differs therefrom in less marked modifications than from the pelvis in Struthio and Rhea.

The number of terminal sacral vertebrae in Dinornis maximus, answering to those defined as ‘sacro-caudals’², is four. The last of these in Dinornis is the thirty-ninth of the vertebral series; in Struthio it is the forty-sixth.

¹ For this process in Apteryx australis, see p. 35, Pls. VIII. & IX. In the two skeletons of the smaller Kivi (Apteryx Oenuai, Gd.) I have found ossification extending along the ligament attaching the pectineal process to the last sacral rib.

² Mivart, ut supra, p. 420, fig. 62.
In *Apteryx australis* there are nine caudal vertebrae, the anterior ones of greater relative vertical extent than in *Struthionidae*; but as they recede they gain in transverse and lose in vertical diameter. The last two coalesce to form the 'ploughshare' bone.

**FOURTY-FIRST, or SECOND CAUDAL, VERTEBRA (½ nat. size).**

Aspects.

Fig. 36, preaxial; 37, lateral.

I am not certain that I possess the fortieth vertebra or 'first free caudal' in *Dinornis*. The second, if it be not the first (figs. 36 & 37), has the centrum broader in proportion to its length and height than in *Struthio*. The contour of the preaxial surface (*ac*) is subhexagonal, with the upper line short and emarginate, forming the lower boundary of the neural canal (*n*).

The surface of *ac* is irregular, indicative of syndesmotic union with the sacrum (or first caudal), deviating on the whole from flatness by a slight convexity: the opposite-articular surface is undulate, slightly concave at the middle third, convex to the periphery: the angles of the hexagon are rounded off. The under surface is longitudinally concave, a mid channel being bounded by a pair of longitudinal ridges. A thick, short, obtuse, subbifid parapophysial ridge (fig. 37, *p*) extends from the middle of the antero-lateral part of the centrum obliquely backward to near the upper and outer angle of the hinder articular surface. The neural canal (fig. 36, *n*) is small and subcircular; in *Struthio* its section gives a vertical ellipse. The diapophysis is represented by the upper division (fig. 36, *d*) of the tuberous diparapophysis. In *Struthio* the diapophysis is a distinct process from the parapophysis, and is the longer and larger of the two. The neural canal in *Struthio* is surmounted by a thick subquadrate mass with its enlarged tuberous extremity subbifid posteriorly.

In *Dinornis* the character of the double neural spine, which distinguishes, in the present comparison, several of the neck-vertebrae, is resumed in those of the tail. A pair of low, thick, short, tuberous processes (fig. 36, *ns*) diverge from the roof of the neural canal and simulate a 'spina bifida.'

This character is continued through the caudal series to the foremost of the three.

---

1 *Ante*, p. 32, Plate VIII.
vertebræ (figs. 38, 39) which coalesce to form the homologue of the terminal 'os en charrue,' or 'ploughshare bone,' in most other birds, and in all those that fly and possess the 'rectrices' or 'rudder-feathers,' as the tail-quills are termed.

In the description of the skeleton of Dinornis elephantopus, p. 223, nine caudal vertebrae are noted, as in the Aptyryx, reckoning the terminal bone as one of the series, and its leading distinction of shape from that in birds of flight is pointed out. The character of the bifid neural spine is indicated as “a pair of tubercles supported by a low transversely extended neural arch” (p. 233).

In a species of Dinornis, which Capt. Hutton thinks may be D. crassus 1, the last three caudal vertebrae coalesce into the 'ploughshare bone' (figs. 38 & 39); but this, as in D. elephantopus, D. maximus, and doubtless in the rest of the genus, has no claim to the shape, common in birds, which suggested the vernacular name 2.

The neural spine is suppressed in the last two of these caudals (fig. 38, 8, 9), which are reduced to the central element with, perhaps, a neural ridge imperforate; and this ridge forms the uppermost of the three ridges which characterize the three-sided cone constituted by these two terminal vertebrae. Of the three sides the lower is the broadest (fig. 39, 9).

In the penultimate (8th caudal) vertebra the lower surface (ib. 8) presents a triangular excavation, the base being turned forward and the sides formed by the last rudiments of paraphyses (ib. 8, 9, p, p); the apex of the cavity extends to the anchylosis with the last vertebra. The sides of both vertebrae are subconcave, the centrum expanding at both ends. The quasi-paraphyseal expansions of the fore end

---

1 "The box also contains a complete set of caudal vertebrae of D. crassus (?) from Shag Point: these are from one bird."—Letter dated "Dunedin, N.Z., 13th Dec. 1875." These vertebrae were six in number, reckoning the soldered three as one. I doubt their including the entire series.

2 'Os en charrue,' Fr.
of the last centrum (ib. 9, p) extend beyond the hinder expansions of the penultimate vertebra. The centrum of the last vertebra contracts to an obtuse point, grooved below.

The antepenultimate vertebra retains its neural arch, canal, and bifid spine (fig. 38, 7, n), differing only in size and the stunted character of the processes from the antecedent free caudals.

The lower and fore part of the sides of the centrum extend as short, broad, obtuse parapophyses. These render the under surface of the centrum transversely concave. A similar low obtuse diapophysis projects from the base of the neural arch and contiguous part of the centrum with which it has coalesced. The gradual diminution of the terminal vertebrae of the tail to an obtuse point indicates that such an appendage was as little indicated by the plumage in Dinornis as in Apteryx.

In Struthio the transverse processes of the caudal vertebrae have assumed, in the third of the series (fig. 65, p. 429 of 'Mivart'), much of the coalesced characters of the first in Dinornis (fig. 36). The antero-posteriorly compressed and transversely extended mass representing the neural spine begins to shoot out its upper angles in the third caudal of Struthio, and in the sixth (fig. 66, p. 430 of 'Mivart') they more nearly repeat the parial divergent spines in Dinornis (fig. 36, ns). In the eighth caudal of Struthio (fig. 67, p. 430 of 'Mivart') a third low spine rises between them. The ninth caudal in Struthio (fig. 68, ib.), which is commonly found anchylosed at the neural and haemal borders of its postaxial surface with the terminal 'ploughshare,' is the homologue of the foremost of the three terminal coalesced caudals in Dinornis (fig. 38, 7); but it has lost its transverse processes, and a terminally trifid lofty neural arch and spine represent the low arch and pair of tuberous neural spines in Dinornis.

Prof. Mivart 1 rightly notices the indications of the two terminal vertebrae which have coalesced to form the vertically extended laterally compressed plate of bone, with its irregular more or less rounded margin, so markedly distinguishing the termination of the vertebral column in Struthio from that in Dinornis.

The retention of the ploughshare character in the Ostrich relates to the large size of the feathers which it supports, and which represent the 'rudder-quills' ('rectrices') of normal birds of flight. Such caudal plumes, with the similar alar plumes, the better developed bones of the unavailable pair of wings and concomitantly developed sternum and scapular arch, concur in showing that the great existing flightless bird of Africa has receded in a less degree from the volant type than have the extinct wingless birds of New Zealand.

The terminal segments of the 'axial skeleton' in Dinornis differ from those in Apteryx mainly in the minor modifications of the elements and apophyses constituting the palate and beak. As these segments are omitted in Prof. Mivart's analysis of the axial skeleton of the Ostrich, the comparison of the individual vertebrae in advance of the atlas will not be here entered upon.

1 Loc. cit. p. 431, fig. 69.
The skull of *Dinornis maximus* differs chiefly in size from that of *D. robustus* and *D. ingens*. It presents the same type of beak and mouth-bones, the same low broad form of cranium. In the smaller species of *Dinornis*, through the minor difference in the size of brain, its case is in them relatively more convex and raised, a character which is most marked in the comparatively diminutive *Apteryx*. As the parts furthest from the centre are most subject to modifying influences, the bony framework of the beak, of which the palate forms part, departs in *Apteryx* still further than the cranium from the character of the skull in *Dinornis*.

The palatal generic characters of *Apteryx* are detailed at p. 29, and illustrated in Plate VII, fig. 2. The repeated pressure to which the beak is subject in perforating the soil for food being transferred to the hind buttress-bones formed by the tympanics, all the beak-bones articulated therewith have coalesced—the maxillaries laterally with the malo-squamosal styles, and mesially with the palatines, these carrying on the coalescence with the vomer and pterygoids; so that the upper beak, as a single bone, articulates with the tympanics by the diverging columns of its quadrifid base, the two outer and more slender ones with the outer cups, the two inner and thicker ones with the inner cups, the latter being strongly wedged, moreover, before reaching those latter cups, between the orbital plates of the tympanic and the pterapophyses or 'transverse processes of the sphenoid.'

The advantage of a certain yielding movement of the tympanics under extreme pressure cannot fail to be noticed.

As the dinornithic modifications of the palate are more perfectly demonstrated in the skull of a *Dinornis crassus*, recently transmitted to me, than in that of *D. maximus*, they will be described in the section on the Restoration of that Species.

The height of the skeleton of *Dinornis maximus*, as articulated in an easy standing position, in the British Museum, is 11 feet; the length of the trunk (dorsal and sacral series of vertebrae) is 4 feet 4 inches; the length of the hind limb, in the same position, following the angle of the segments, is 9 feet; the total length of the skeleton, from the point of the beak to the end of the tail, following the curves of the spine, is 11 feet 4 inches.

**DESCRIPTION OF THE PLATE.**

**PLATE XCVII.**

Front view of the above skeleton: the individual Professor figured stands 5 feet 11 inches in height: he holds in one hand the original fragment of bone, and points with the other to the corresponding part in the *Dinornis maximus*. From a photograph.