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"CUNNINGHAM MEMOIRS."

No. VI.

ON THE MORPHOLOGY
OF
THE DUCK AND THE AUK TRIBES.

BY

W. KITCHEN PARKER, F.R.S.

With Nine Plates.

Professor William Kitchen Parker died suddenly of syncope of the heart on the 3rd of July, 1890, at Cardiff, while this Memoir was passing through the press.

Should any inaccuracies appear in the text, or in the lettering of the Plates, they are to be accounted for by the fact that my Father only received first proofs up to p. 41 before his death. At Dr. E. Perceval Wright's (Secretary of the Royal Irish Academy) request, I undertook the correcting of the remaining proofs; but, as I had not the opportunity of going through the Paper with my Father first, and as the proofs, both of the letterpress and of Plates V.–IX., had to be corrected as they came, it was not easy for me to revise the whole Paper as satisfactorily as I could have wished.

W. N. PARKER.

Cardiff, *November* 14*th*, 1890.

"CUNNINGHAM MEMOIRS."

No. VI.

*On the Morphology of the Duck Tribe (**Anatidæ**) and the Auk Tribe (**Alcidæ**).*

By W. KITCHEN PARKER, F.R.S. (PLATES I.–IX.)

[READ, FEBRUARY 10, 1890.]

INTRODUCTORY REMARKS.

THE materials for the present Paper have partly been in hand for many years, whilst the rest have been obtained during the last year or two. The *Shoulder-girdle* and *Sternum* of the Guillemot (*Uria troile*) were described in two stages in my work on those parts of the skeleton (pp. 146–148, Plate XVII.); and now the rest of its skeletal structure is given in this Paper. For the young of the Least Auk (*Ciceronia pusilla*) from Behring's Sea, I am indebted to Frederic A. Lucas, Esq., Washington; for the embryos and adult of the Razor Bill, and the adult Puffin, I am indebted to my son, Professor W. N. Parker; for the embryo of the Black-necked Swan, to Dr. Murie; and for the cygnets of the White Swan, to the late T. W. Pocock, Esq. The early stages of the Common Duck were obtained by me during the spring of 1887; and in these the dates of incubation were obtained.

For many years after the publication of my first two Papers on the Osteology of Birds,* my attention was directed solely to the skull, that part of

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* "On *Balænïceps rex*": Transactions, Zoological Society, vol. iv., Plates LXIV.–LXVII., pp. 269–351: and "On the Gallinaceous Birds and Tinamous": *ibid.*, vol. v., Plates XXXIV.–XLII., pp. 149–241.

the structure of the Vertebrata, the elucidation of which seemed to be my proper task. Of late, however, I have strayed into a "by-path meadow;" for the other parts of the organs of support promised me as much pleasure and profit as the skull itself.* That promise has been fulfilled; not one word of it has failed; and now I can only wonder at my own self-denial in not drinking from these other springs for so many years. That distinguished friend who first laid the yoke of the skull upon my shoulders, also tempted me into this wider field of research. In Professor Huxley's Paper "On Dinosauria and Birds,"† we have the following remarks:—"If the whole hind-quarters, from the ilium to the toes, of a half-hatched chicken could be suddenly enlarged, ossified, and fossilized as they are, they would furnish us with the last step of the transition between birds and reptiles; for there would be nothing in their characters to prevent us from referring them to the Dinosauria."‡

The value of these remarks is not in the least diminished by any after-thought of the reader; yet it is true that they refer to the "hind-quarters" merely. But in its *neck* the bird resembles a Plesiosaurus; and in its *head* an Ichthyosaurus: moreover, there are various "remnants" in the *fore-quarters* of a bird that, as it seems to me, can only be interpreted by the light of the "paddle" of those aquatic reptiles. Hence I do not in the least believe that an Iguanodon begat the fore-fathers of the humming-bird.

The two families of birds whose morphology is treated of in the present Paper are very distantly related. The Alcidæ lie in the centre, so to speak, of a considerable number of families of water birds, and are manifestly related to the Grebes and Loons, Podicipedidæ, and Colymbidæ, birds that seem to be, both sorts of them, the modified descendants of Marsh's Hesperornis. However this may be, the Alcidæ are quite as nearly akin on one side to the Penguins as they are on the other to the Loons and Grebes; and there is this initial difficulty with regard to their relationship

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* See "On the Wings of the Common Fowl": Philosophical Transactions, 1888, Plates LXII.–LXV., pp. 385–398.

† Quarterly Journal Geological Society, 1869, pp. 12–31.

‡ *Loc. cit.*, pp. 30–31.

to *any actual descendants* of Hesperornis, that in that huge toothed bird the pre-sacral vertebræ are all "cylindroidal" in their articulation; whereas the Alcidæ, like the Penguins and the Gulls, have their dorsals "opisthocœlous." In this they are just a step above Marsh's Ichthyornis, which has its pre-sacral in a very low stage, namely, "amphicœlous," a condition that is not quite lost in the existing Laridæ. To complicate the subject still more, as if to keep the way of the *tree of descent*, Professor Huxley has already classified the Alcidæ and the Laridæ together. They are put with the Petrels (Procellariidæ), birds whose dorsals are cylindroidal, like those of Hesperornis, the Grebes, and the Loons.* But the true position and genealogy of the duck tribe (Anatidæ) presents as tough a problem as the auk tribe (Alcidæ); we have, here, a faggot of tough problems, that will task the ingenuity and strength of two or three generations of biologists.

The structure of the skull in the duck-tribe is so similar to that of the fowls, in all things at first, and in many things permanently, that I have only taken up that part of the skeleton after it has acquired all the true anatine characteristics, namely, in the nearly ripe embryo of *Cygnus nigricollis*. For I had long ago worked out the skull of the common fowl, the early stages of which illustrate so accurately those of a duck, goose, or swan.† The skull of the guillemot (*Uria troile*), my example of an alcine skull, is worked out as early as the third stage in the chicken (*op. cit.*, Plate LXXXII.) The swan's early stage corresponds with one between the fourth and fifth stages in the chick (*op. cit.*, Plates LXXXIII., LXXXIV.). In the rest of the skeleton the more primitive condition of the parts has been worked out in the embryo duck. In these parts I have gone down far below the morphology of the adult Iguanodon, and have, as I believe, unconsciously thrown some light upon its development, for that huge beast was highly specialized. It had got a long way from its amphibian ancestors: its size, as well as its peculiar "hind-quarters," attest this.

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* See his Classification of Birds, Proceedings, Zoological Society, 1867, pp. 457, 458.

† See Fowl's Skull, Philosophical Transactions, 1869, Plates LXXXI.–LXXXVII., pp. 755–807.

THE MORPHOLOGY OF THE ANATIDÆ.*

The Cranium in Cygnus.

The intense ossification seen in birds makes this part of the skeleton a "closed book" in the adult; embryos, near the time of hatching, are the most profitable for interpretation of the various parts, and for comparison with what is found in the skull of other types.

The two extremes of cranial structure in those hot-blooded Sauropsida are to be found, on one hand, in the Tinamou, which retains many of its sutures, and has one, or even two, rows of supra-orbital scale bones; and, on the other, in a Passerine bird, where the metamorphosis of a skull, essentially reptilian, has reached its utmost perfection.

The *ectocranium* of the nearly ripe embryo of *Cygnus nigricollis* (Plate III., figs. 1–6, and Plate IV.) has most of its sutures open, and remains of those that are closing. These bones are very massive for a bird, and have a struthious coarseness about them: in the adult bird this is greatly altered by the absorption of much of the diplöe, for the sake of pneumaticity. The facial splints, as compared with those of the chick, are very broad; for we have in these "lamellirostres" (or sifters) a spoon-shaped bill, not ending insensibly in a more or less hooked point, but in a neat "unguis" like a finger-nail, and adapted to the flatter part in the mandible, like a thumb to a finger-nail in us. The premaxillaries (*px.*), as in osseous fishes, dominate the upper face: they form three-fourths of the spoon-shaped "rostrum," and are already ankylosed in the foremost third. Unlike mammals, the bird has long "nasal processes" to its premaxillarium—long, narrow splints, that run backwards between the nasals, and overlap the forehead. Laterally (Plate IV., *p. n.*) the dentary margin, covered with a false dentition of horny laminæ, overlaps the maxillary (*mx.*), and reaches to the jugal bar (*j.*, *q. j.*). The notch between these processes is rounded, and a similar notch in the nasal (*n.*) finishes behind a large

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* See, on this subject, Dr. R. O. Cunningham's Paper "On the Steamer Duck (*Micropterus cinereus*)": Transactions, Zoological Society, vol. vii., Plates LVIII.–LXII., pp. 493–501.

oval space, in which is seen the alinasal folds (*al. n.*) and external nostril (*e. n.*). Already we have come across two agreements between the anatine and the gallinaceous skull, the hidden position of the maxillary like its counterpart, the "os mystaceum" of the perch, and the large oval space in which the nasal vestibule is exposed; these birds are both "holorhinal." The Alcidæ, as we shall see, are "schizorhinal," the nasals not being notched behind, but split.

In the Anatidæ the fore-part of the skull is very peculiar; the lachrymal or pre-orbital region is unusually long (see Plate III.). The nasals (*n.*) have a very large frontal plate, and the "hinge" is in front of that plate, not at the posterior edge of the nasal bones. They become thinned down and elastic where the motion is required. The lachrymals (*l.*) here attain their greatest size, and have the longest suture above; they then become narrow and are hooked backwards below, and help, by their hind margin, to enclose the very open orbit.

In the fore palate the premaxillaries (see Plate III., fig. 1, *px.*) have a short palatine process that binds upon the inner edge of the maxillaries (*mx.*); the median region is taken up by the huge temporary prenasal part of the intertrabecula (*pn.*); half the dentary edge is formed by the maxillary, overlapped by the premaxillary; each palatine process (or maxillo-palatine, *mx. p.*) runs inwards and backwards, approximating, behind, to its fellow; and then, ending in a rough point, they diverge to embrace the vomer at its thickest part. This latter bone is a flat vertical spatulate plate, with its broad end behind; pointed somewhat there, it is again fixed between the sharp styloid "ascending processes" of the palatine (Plate III., figs. 1 and 5, *v.*, *pa.*). At present the vomer is only composed of one centre; another appears on the antero-superior corner afterwards (Plate II., fig. 15, *v.*). The vomer, palatines, and pterygoids belong to the mid-palate; a pre-palatine bar, however, runs far forwards, wedged into a deep notch in the maxillaries. These large, long bones (*pa.*) form the lateral boundaries of the nasal passages, which open at their hinder part in one common median "posterior nostril." Their widest part is near the angle of the upper jaw; they narrow in, sinuously, to their end; they approximate then, and send forwards and upwards their sharp ascending process. The "middle nasal openings" are between the vomer and the palatines.

The next bones are the pterygoids (*pg.*). They are only one-third the length of the palatines, which are wedged into their fore-part below; whilst the pterygoids form a peg in front, which is fitted into the upper face of each palatine. This is a curious doubly-pegged joint, which is imperfectly developed in the fowl tribe; *their* palatines and vomer are very slender, and the pterygoid peg is not so small and neat; it is styloid. Nevertheless these two families agree in having a truly azygous vomer, and in not having this pterygoid peg segmented off and fused with the palatine, as in most birds. Also in the small epipterygoid process of the pterygoid, in the breadth of its fore end, and in the fact that it articulates with the basi-pterygoid processes of the basis cranii at its front third, the geese and fowls agree. For, in most birds, when these parts are developed, the articulation is at the middle of the pterygoid: in the struthious birds, Tinamous, and in the embryo of Opisthocomus, it is at the end.

Although the palatines and pterygoids, because of their histological development, are here classed with the parts of the "ectocranium," they are in reality degenerated *endo*-cranial tracts that have lost their cartilaginous pith.

Behind the palate, under the broad hind-part of the endocranium, there are three tracts of parosteal bone that at an early stage became fused together as one tract this bony growth is the "parasphenoid"; the three parts are the "basi-temporals" behind, and the "rostrum" in front (Plate III., figures 1 and 5, *pa.s.*, *s.*, *r.b.s.*, *b.t.*).* Of all birds the fowls and the duck tribe have the basi-temporals most massive; this is well seen in the goose, and in *Tetrao urogallus.* The parasphenoid is generally, not always, in one piece in the Ichthyopsida; it sometimes has a separate centre in front in certain frogs.† It grafts itself on the basis cranii, aborting the cartilage, in some of the Urodela.‡ In birds which have a certain amphibian stigma § in many parts of their organization,

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* Fowl's Skull, Plate LXXXII., fig. 2.

† Philosophical Transactions (1881), Plates V. and VIII.

‡ Transactions, Linnean Society, series ii. (Zoology), vol. ii., Plates XVII. and XX.

§ In the existing reptiles the parasphenoid is but little developed.

this grafting of a "parostosis" on the basal cartilage, thus taking the place of a normal endoskeletal bony centre, takes place very early; and the three primary centres, fused into one, support, in front, the interorbital wall, then develop large "anterior tympanic recesses," and, behind, form most of the thick but excavated basicranial floor (see Plate III., figs. 1 and 5, *r.b.s.*, *b.t.*, *a.t.r.*, and Plate IV.). The basi-temporal mass, a transverse tract bulging forwards at the middle, lies on a lower plane than the fore-part; in a deep chink between the two masses, the eustachian tubes (*eu.*) converge towards each other.

I have already spoken of the articulation of the basi-pterygoids with the pterygoids; this takes place in a remarkable manner,* for a new plate of cartilage is developed on both bones; in the Struthionidæ† the pterygoids acquire an articular plate of cartilage, but the basi-pterygoids are direct outgrowths of the basis cranii, and their articular facet is formed by an arrest in the process of ossification of the outgrowth, as in Lizards.

This shows how far the fowls and the goose tribe have travelled from those archaic birds—the Struthionidæ and their immediate allies.

The cheek, in this and most birds, is very feeble, and is formed of three overlapping splints, the foremost of which is a mere outgrowth of the maxillary, its jugal process. This is overlapped by a separate style of the same size, the jugal (*j.*); and under and within these the quadrato-jugal (*q.j.*) binds the whole together to the quadratum (*q.*); it is one-third longer than the jugal, and is hooked inwards behind, where it is articulated to the quadrate. These parts are true parostoses, and are extremely unlike their broad counterparts in the Crocodiles and Tortoises, and in Hatteria.

The roof-bones and temporal plates add three pairs more to the category of parostoses; the foremost of these are the frontals (*f.*), which are the largest bones in the skull, and are yet extremely deficient above and over the orbits. A large "fontanelle" still exists at the part where the small hole is seen in Lizards—the *orbit* of their median eye; in old geese this fontanelle remains, sometimes bringing the bird near the Lizard, but

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* See Fowl's Skull, *loc. cit.*, Plate LXXXIII.

† Philosophical Transactions, 1866, Plates VII.–XV.

the organ itself is very little developed in birds. The parietals (*p.*) are of small axial extent in the Anatidæ, as in the Ruminant and Cetacean Mammalia; they meet the frontals, are overlapped laterally by the squamosals (*sq.*), and overlap the supraoccipital (*s. o.*).

The squamosals (*sq.*) are roughly pentagonal bones that overlap the frontals and parietals at their junction, binding the supraoccipital (*s. o.*) behind, and forming an eave over the auditory recess.

The rest of the osseous centres belong to the *endocranium*. These are transforming the massive "chondrocranium," a remarkable beaked structure, with a short, wide, cranial basin. This has to be described before the bony tracts.

Much of this can be seen from below (Plate III., fig. 1), and has also to be surveyed on its side (Plate IV.); its end (Plate III., fig. 3) from above (Plate III., fig. 2), and in a section taken longitudinally and vertically, a little to the left of the mid-line (Plate III., fig. 5); thus the crested and rostrate fore-part is seen from its side, and not in section. The occipital base, sides, and plane show that this part is a bulging and oblique hindwall; it also forms the hindmost part of the floor. The auditory capsules (*au.*) are very large, and are jammed in obliquely between the occipital arch and the sub-transverse posterior sphenoids.

At present the notochord (*nc*) forms the axis of the basi-occipital bone (*b.o.*); it has shrunk from its extension into the posterior clinoid wall (Plate III., fig. 5, *py.*), and now forms only the axis of the hindmost cranial segment. Right and left, it was enclosed in the "parachordal" cartilages, which becoming alate laterally, and their wings meeting over the myelon, formed also the hinder skull basin and its end wall, *i.e.* alisphenoids (*a.l.s.*), exoccipitals (*e. o.*) and supraoccipital (*s. o.*).

The proper axial skeleton, namely that related to and formed upon and around the notochord, ended from the first behind the pituitary involution of the oral membrane. The chondrocranium therefore is sharply divided into a *post-pituitary* and a *pre-pituitary* region. Looking at these parts from the standpoint of adaptation the pre-pituitary part seems to be a morphological aftergrowth—almost like an afterthought. For in these *high* skulls, as in the high skulls of many osseous fishes the fore-part of the skull serves mainly as an orbito-nasal wall, a partition run up between the eyeballs behind and the nasal capsules in front; in the bird, as in Cartilaginous Fishes, that which forms the middle part of the foundation of the wall is carried forward as a long "pre-nasal rostrum." This part forms most of the skeleton of the skate's large beak; in the bird it is *the temporary model on which the secondary facial skeleton is formed.* But the skate has a *low* and the bird a *high* skull; in the one the brain lies down on a flat floor; in the other it is tilted up behind and a little over the interorbital wall (Plate III., fig. 5).

In this, as in other things, the bird is not the direct offspring of any form that we know of: it has chosen this and rejected that, "wittingly," so to speak; its feathers are a "new thing upon the earth." The space between a lizard's scale and a peacock's train-feather is very considerable, and I know of no hot-house and no manure that would "force" the one to form the other. As far as to the hinder part of the *septum nasi* (*s. n.*) the pre-pituitary part of the chondrocranium is formed of three rods: the trabeculæ and intertrabecula (*tr.*, *i. tr.*).* These parts are, as far as my researches show, the oldest by far; the cartilages that form right and left of the notochord appear to me to be comparatively recent developments of the cartilaginous supporting tracts.† Over the optic nerve (II.), morphologically between it and the olfactory nerve (I.), the trabecular or pre-pituitary wall shows a slight development of the orbito-sphenoids (*o.s.*). Between the olfactory regions the nasal roofs are continuous with the common orbito-nasal partition-wall; and the median part sends backwards a small *crista galli* (*cr.g.*). The roof is in three regions, namely, the "aliethmoid" (*al.e.*) behind, the "ali-septal" (*al.sp.*) in the middle, and the "ali-nasal" (*al.n.*) in front; the latter folds not covered with bone (Plate IV., and Plate III., fig. 2, *al.n.*). The true olfactory region is short and simple, and is walled in behind by a fold which corresponds to the "pars plana" of human anatomy; but there are no special "upper" and "middle turbinals" in this and other Carinate birds. The inferior turbinals

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* See Challenger Reports, "Skull of Green Turtle": Zoology, vol. i., Plate II., figs. 6, 7.

† See my Paper "On the Marsipobranch Fishes": Phil. Trans., 1883, Plates VIII.–XXVI., pp. 373–453.

are scrolls of cartilage with from one and a-half to two coils;[*] they remain unossified as a rule.[†] In the generalized, archaic, and retrograded Struthionidæ the turbinals anticipate those of Mammals, and are extremely complex.[‡] Also in these birds[§] the solid orbito-nasal partition is never taken away in any part; in the Carinatæ it is removed, under the naso-frontal transverse line, to form the *cranio-facial hinge*, a remarkable structure peculiar to Carinate birds, and necessitated by the abortive development and new function of the fore-limbs. This departure from what is typical is well shown in the swan's embryo (Plate III., fig. 5, *c.f.c.*); for the "cranio-facial cleft" is now a large round notch and is quite similar to what is seen in some species of those of undecided types—those Struthious Carinatæ, the Tinamous.[||] The trabeculæ in their fore-part, and the inter-trabecula at its hinder third have been roughly sawn across, so to speak, and the wall, above, removed for three-fourths of its height. Here we have a secondary segmentation of parts that in us are only marked off by the different condition of the tissues, the "perpendicular ethmoid" being ossified, and the "septum nasi" only partially calcified. Here the perpendicular ethmoid (*p.e.*) is already larger than the membranous space that separates it from the septum nasi (*s.n.*).

The morphology of the "pre-nasal rostrum" (*pn.*) is evident: it is a mere fore-growth of the intertrabecula, and in skates, saw-fish, and even in some Ganoids it is often of great length.[¶] If we look at the under view (Plate III., fig. 1) and at a much earlier stage in the chick (*op. cit.* Plate LXXXII., figs. 2 and 2A, *p.n.*) we shall see what use is made of it in the bird, where it is first used, and then absorbed. It is more spatulate in the swan's than in the fowl's embryo, being the model in the former case of the large premaxillary spoon.

The brain is tilted up over the orbito-sphenoidal region, and lies low down

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[*] Fowl's Skull, Plates LXXXIII. and LXXXVI.

[†] In Land and Water birds.

[‡] Ostrich's Skull, Plates X. and XII.

[§] *Ibid.*, Plates VII. and VIII.

[||] Ostrich's Skull, Plate XV., fig. 8 (*c.f.c.*).

[¶] See "On *Lepidosteus osseus*": Phil. Trans., 1882, Plate XXXVIII., fig. 1 (*p.n.*).

in the broad hollow of the cupped hind cranium, the post-pituitary or notochordal region. Here the *chondrocranium* is rapidly ossifying even in this water bird with *precocious* young. But in those birds that have tender young, the "Altrices," in which the Carinatæ have many culminations, the process is much more rapid, as are all these *pre-nasal transformations.* In the wren (*Troglodytes europæus*) at the twelfth day, when it is ripe for hatching, it has had only half the time for development as this almost ripe embryo of the swan, and yet it is as far advanced. Here in the case of the wren we see the result of a veritable "forcing" process in a real, and not imaginary, "hotbed." The parachordal cartilages have formed a transversely kidney-shaped occipital condyle (Plate III., fig. 1, *oc.c.*), and the basioccipital bone (*b.o.*) is oblong; it has not proceeded far right and left of the notochord (*nc.*). The ex-occipitals (*e.o.*) are multiangular plates, that are margining the foramen magnum, and enclosing the outgoing hypoglossal, vagus, and glosso-pharyngeal nerves (xii.). There is still a large cartilaginous bed in which these bones lie; at a distance above them, equal to their breadth, we see the large double supraoccipital (*s.o.*). This bone has the remains of its primary suture above; it is shield-shaped, with the sides deeply notched; this round notch half encloses the "lateral occipital fontanelle" (*l.o.f.*), which is finished by the squamosal and auditory capsule. This structure is confined to the Grallæ, plovers and cranes, &c., and to certain water birds—gulls (in which it becomes filled in afterwards), and Alcidæ, besides these normal Chenomorphs. Here the goose tribe parts company with the fowls, which have no such structure. The frail skull of the lesser Limicolæ shows a notch above the foramen magnum, where the two supraoccipital centres have not united. This notch tends to fill in in the hemipods, but in pigeons and in owls it does not fill in, except below, so that a "middle occipital fontanelle" remains, a mere pin-hole *like the parietal orbit of Lizards,* but assuredly without any such meaning as that famous "sky-light"; so the mind of the morphologist is greatly exercised as to the purpose of these closed-up windows.

Laterally, the posterior sphenoid has the main part of its wings ossified as the alisphenoids (Plate III., fig. 5, *a.l.s.*); these are almost transverse in this position, and form, indeed, the post-orbital wall. Not only so, they send out a large spur of cartilage (Plate IV., *sp. o.*), the "sphenotic process," which, in some birds (*e.g.* owls), is ossified separately, and thus gives us the remains of the large *post-frontal* bone (sphenotic) of an osseous fish. In the old bird this might be taken for a post-orbital process of the frontal, or for a rudimentary zygomatic process of the squamosal; it is overlapped by those parts, but belongs to the endoskeleton. I find no other Vertebrates except the Urodelous amphibians that anticipate the peculiar development of the basi-sphenoid of the bird. The basal bars that unite to form the main beam in a reptile are ossified intrinsically. The bird, like the Urodela, has no distinct "basisphenoid"; but the cartilage borrows its bony matter from the hind part of the median parasphenoid, after which it runs forwards, free from the cartilage, as the "basisphenoidal rostrum" (Plate III., fig. 5, *pa.*). Once the ossification overtakes the cartilage round the pituitary space (*py*), it runs rapidly into the floor of the skull behind, and right and left. Together, this grafted bone, and the superficial growths—which form the anterior tympanic recesses, and the basi-temporal plate—produce in the bird, whose skull is so thoroughly pneumatic, very complex tympanic outworks, as complex as those of the crocodile,* but of a different type.

As in those osseous fishes that have a high skull, the pituitary floor is open; it is finished by the parasphenoid; the internal carotids (*i. c.*) enter the skull through this space, creeping over the basitemporal plate, whose diplöe forms a bony tube for each artery. At present the pinched-up anterior sphenoid (*o. s.*, *p. s.*) is unossified; but the perpendicular ethmoid (*p. e.*) is a large slab of bone behind the notch for the hinge, larger than the notch. The *auditory* sense-capsules, like the *olfactory*, are built into the cranium, and have to be described as parts of it, although they have no original right to this position. These parts are very large, and each cartilaginous capsule, which is planted like a bulb in the side wall of the hind skull, soon coalesces with the proper cranial walls. These oval capsules are tilted backwards, so as to lie supine, and almost in a horizontal position (Plate III., fig. 5). The upper part of each capsule is occupied with the three *semicircular canals* (*a. s. c.*, *p. s. c.*, *h. s. c.*), and under the arch of the anterior canal there is a recess like that for the "flocculus cerebelli" in

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* Transactions, Zoological Society, vol. ii., Plates LXII.–LXXI.

the Mammal. The *lagena*, or rudimentary cochlea, is buried in the basilateral cartilage (Plate III., fig. 1) over the hind edge of the basitemporal plate. The recess, or "meatus internus" for the seventh and eighth nerves (vii., viii.) is shallow, the meatus externus is membranous and very short, and the tympanic cavity is formed by the utilization of many parts round the primary tympanic (or 1st) *cleft* (see Plate IV.). In front, the large quadrate bone (*q*), mistaken by our ancestors for the *tympanic, and mistaken for it still by those who are not embryologists*, forms the front wall of the porch. Its floor is formed by the basitemporal, its inner wall by the auditory capsule, and its roof and sides by the squamosal. Sometimes there is one, sometimes more than one, *six* even, true *tympanic* bones.* I find no separate tympanic in the Anatidæ; but in the duck the floor and sides approximate, closing in the cavity, all but a narrow chink; this structure is seen still better in the green woodpecker (*Gecinus viridis*).† In that bird this secondary tympanum is like a small Cowrie shell (*Trivia*). Round the meatus internus (Plate III., fig. 5, vii., viii.) a considerable oblong bone, the periotic (*pro.*), is already formed; the opisthotic (*op.*) is seen behind and below; a chink separating it from the exoccipital (*e. o.*); it is a much smaller bone; externally it joins the delicate bar that separates the *fenestra ovalis* from the *f. rotunda.* The epiotic is not seen here, and is rare in birds.

There are three *visceral arches* developed in a bird; the palatine extension forwards—a part of doubtful morphology—I have already described as the *pterygoid* and *palatine* membrane bones: bones that had no true cartilaginous model. The proper pier of the mandibular arch, the quadrate (*q*), is well developed; it is much more like that of an amphibian than the quadrate of a serpent or a lizard. It is indeed developed distinctly from the chondrocranium, and does not coalesce with it at any part; but it has a large "pedicle," or orbital process, and a large "otic process" with two condyles, as in the Peristeropodous Gallinaceous birds, and in most of the Carinatæ. The quadrate has already a large bony shaft; the pedicle and the articular regions are still soft. That bone corresponds to the upper piece of a branchial arch, with only two segments; that is its true nature: it is

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* Transactions, Zoological Society, vol. ix., Plates LV., in *Corvus corone.*

† See Transactions, Linnean Society, second series (Zoology), vol. i., Plate II., fig. 2.

a "pharyngo-epihyal." The core of the mandible is a cerato-hypohyal (Plate IV. and Plate III., fig. 4, *ar. mk.*). Here let it be noticed that the *posterior* and *internal* angular *processes* (*p. a. p.*, *i. a. p.*) are parts of this "articulo-meckelian" bar; these processes are unusually developed in the cultrirostral fowl, and in these lamellirostres, also in that lamellirostral relation of the Ibis, the Flamingo. The cartilaginous rod (*mk.*) runs inside the dentary splint (*d.*) nearly to its end; and the kinship of the trabeculæ to the visceral arches is nowhere more plainly suggested than in this stage of the bird; that, however, is a knotty problem. There are *two layers* of bone covering this rod, a *deep* and a *superficial* layer. The deep deposit is the *ectosteal* "articulare"; its *endosteal* part has not yet appeared; the superficial or parosteal bones are the dentary (*d.*), the splenial (*sp.*); the supra-angulare (*s. ag.*) and the angulare (*ag.*). I find no coronoid in this family, nor in the Gallinaceæ; otherwise it is quite like the mandible of a reptile; the coronoid does turn up in the Passeres, and in some Grallæ.

The *hyoid* arch of this, as of other birds, is essentially reptilian. Its "pharyngo-branchial" element is, at first, quite separate from the rudiments of the rest of the arch. All those Vertebrata that have a *fenestra ovalis* have the pharyngo-branchial element of the second visceral arch modified, as a *stapes* or *columella*. This may be severed from or united with the other segments of that, the hyoid arch. In the Hatteria, and for a time in the Crocodile, these parts become united: in the bird they also unite, and the arrested sub-apical or epi-hyal element remains continuous (confluent) with the stapes. It is generally very small, but sometimes shows a dilated cerato-hyal tract. In the crow,* in the fowl,† and in the Anatidæ, Alcidæ, and many others, it varies very little, and is extremely small and slender.

The distal part of the hyoid arch (Plate III., fig. 6), below the aborted membranous tract, is mainly hypo-hyal; but that is not a separate segment, and the term for this part is still "cerato-hyal" (*c. hy.*); the two, right and left, coalesce in front, and almost separate off a true basi-hyal. This *lingual skeleton* is very large in these Anatidæ. The third

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* Transactions, Linnean Society, series ii. (Zoology), vol. 1., Plate XX., figs. 8, 9.

† Fowl's Skull, Plate LXXXVII., fig. 3.

visceral arch, corresponding with the first branchial arch of an osseous fish, is composed of two segments (*br.*), nearly equal in length. The lower of these is almost ossified. The upper in these birds is thick below; and the thick part is flat above. This is very characteristic of the duck tribe. There is a basal piece of cartilage, thick in front of the articulation of the third visceral arch, and slender behind; the fore-part of this (*bh. br.*) corresponds with the first basi-branchial of an osseous fish; the hind-part with the second, and even third.

In a nestling cygnet of the common swan (*Cygnus olor*), fourteen inches long, and presumably three or four weeks old, the skull as seen in section (Plate V., fig. 1) shows a great advance in development as compared with the almost ripe embryo. The superficial bones are still distinct, but they meet well together now, and are acquiring their permanent form. The frontals (*f.*) are still very thin; but they and the short parietals (*p.*) have obliterated most of the great upper fontanelle of the embryo. A small triangular patch of the squamosal (*sq.*) can be seen inside the skull. In front the premaxillaries (*px.*) are fused together, except in their thin nasal processes; and their *core*, the prenasal cartilage, is now absorbed: they soon after this become fused with the maxillaries. The basi-sphenoidal rostrum (*pa.s.*) is still free from the base of the interorbital septum, except behind; and, further back, the basi-temporal plate (*b.t.*) shows its independence of the basis cranii proper. The perpendicular ethmoid (*p. e.*) forms the hind boundary of the *hinge notch* (*c. f. c.*). It has reached the top of the plate, where the aliethmoidal folds are given off; and behind it reaches the small interorbital fenestra (*i. o. f.*). Below, it only reaches to the trabecular beam, which projects a little in front of it, and is then lost for a space; this beam reappears under the irregular septum nasi (*s. n.*), but all the pre-rostral part in front has disappeared. Where the septum nasi leans forward above, giving off the ali-nasal folds, there an oval space is seen under it, finished below by the bones of the face. This is often seen in water-birds as an open window between the right and left nostrils. The alisphenoids (*al.s.*), the borrowed basi-sphenoid (*b. s.*), the basi-, ex-, and supra-occipitals (*b. o., e. o., s. o.*) are all well developed, and are only divided by a narrow tract of cartilage. The small opisthotic (*op.*) clings, now, close to the large prootic (*pro.*); the epiotic is replaced by a large ingrowth from the supraoccipital (*s. o.*). The passages for the outgoing nerves (i., ii., v., vii., viii., x., xii.) can be seen well in this view.

In a gosling (*Anser palustris, domesticus*) six weeks old I found the well-known antero-superior spine of the vomer in a separate condition (Plate II., fig. 15, v., vi.). In the adult black swan (*Cygnus atratus*, Plate II., fig. 14, *pa.*, *i. pa.*) I found a pair of inter-palatine bones that tend to make this bird doubly desmognathous. The same milioline bones are often found in the Ducks (Anatidæ).*

In the old *Cygnus olor*, as in *Chauna chavaria*, the forehead becomes largely swollen and pneumatic, and the lachrymals, fused with the frontals, are extremely large and swollen; the sphenotic process also being very large, these parts nearly meet below the orbit. In *Dendrocygna acuta* these processes do meet and coalesce; thus a suborbital bar is formed, like that which is seen in most of the Psittacidæ.

In the old white swan (*Cygnus olor*) the lateral occipital fontanelles become filled in with periosteal bone: in an old black swan (*Cygnus atratus*) I find them open but small.

The interorbital fenestra becomes filled in in the swans; and in the common species this part is very thick and spongy.

There are several kinds of birds that have a dentated horny mandible: none outside the Anatidæ have the "quaffering organ" perfect, except the Flamingo, a "Pelargomorph." But the archaic Chenomorphæ—the Palamedidæ—are cultrirostral, and have a beak similar to that of a fowl: they look downwards in the direction of the *Gallinaceous Root;* and the Peristeropodes of the same region, like them, become desmognathous. We should have to travel far back, however, before we came to the meeting-place of these two types. Within the bounds of the Anatidæ, proper, the bill varies extremely in width: the two extremes are the Merganser (*Mergus*), and the Shoveller (*Spatula clypeata*).†

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* See Wiedersheim's Comp. Anat. of Vertebrates: Translation by W. N. Parker. Macmillan & Co., 1886: p. 79, fig. 65, *B. pl.*

† See Shufeldt "On the North American Anseres": Proceedings, U. S. Nat. Mus., vol. 11, pp. 215–251, fig. 2, p. 218, and fig. 16, p. 232.

On the supposition that the cold- and hot-blooded Sauropsida—reptiles and birds—have arisen, during time, from a similar (or the same) amphibian platform, this one family (the Anatidæ) is sufficient to show what the morphological force can effect when working on teleological lines.

On the Development of the Vertebral Chain in the Anatidæ.[*]

In the present Paper I shall deal with that in which these birds differ from the Fowl tribe. The earlier stages have been worked out in the chick, and the results will be published, at an early date, elsewhere.

On the Vertebral Chain in Cygnus nigricollis *and* C. olor.

In the advanced embryo of *Cygnus nigricollis* (Plates III. and IV.) the vertebræ are in what may be called a Reptilian stage; the osseous centres are still distinct. The swans, however, although they are the true nobility of the tribes of the water-birds, are yet remarkable for the retention of some Reptilian characteristics. This is true as to the great length of the chain, and also because of the presence of ribs up to the occiput. This is also seen in the large Ratitæ; but even the largest existing form—Struthio—has not so many vertebræ, by ten, as the common swan. On the other side of the Class, the specialization of this chain by the suppression of possible links or segments is seen in the multitudinous lesser Passerines, and in swifts, humming-birds, and other Coccygomorphæ. More than half of the *twelve thousand* species known have, on an average, only *forty* vertebræ, even in the embryo. The African ostrich has *fifty-six*,[†] and the common swan *sixty-three*. Numerical law is not very strict in birds; yet those six thousand species just mentioned have in a great majority just *fourteen* cervicals, or twice as many as in Mammals. *Twelve* also is a common number for the *avian sacrum* in the small high-type birds; and from *ten* to *twelve* vertebræ in the caudal region is as a rule the number in the embryo. In this embryo there

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[*] For an account of this part of the skeleton in birds generally, see Proceedings, Royal Society, 1888, pp. 465–482.

[†] See Mivart, Transactions, Zoological Society, vol. viii., p. 430.

are *twenty-two* sacrals and *twelve* caudals: there are *five* dorsals in swans—a common number. But in the same bird, on the two sides, the number of lower cervicals that have free ribs, the number of dorsals, and the number in the secondary divisions of the sacrum—all these things are variable to a remarkable extent.

As to the adaptive modifications of the several links of this beautiful chain, there is nothing like it in the class to which *we* belong. Birds "seal up the sum" of adaptive modification of these intercalary segments of the vertebrated organism.

In the cervical region *C. nigricollis* has one less than the common swan—only *twenty-four*. The first two of these (the "atlas" and "axis") are less perfectly ossified than most of those that follow; but in these the two moieties of the neural arch are ossifying, and in the axis, its *own centrum*, in the hinder part of the body. I shall explain this in the next stage. The third to the eighteenth inclusive have a bony tract in their rudimentary ribs. The last two, the twenty-third and twenty-fourth, have segmented styloid ribs that are fast becoming bony. Much, however, of each vertebra is cartilaginous; and the notochord (on which these rings are strung—through their *base*, not through their *canal*) is still of considerable size.

But the type of these vertebræ is already established. They are "cylindroidal" or "heterocœlous"; so are all the pre-sacrals. The cartilage, but not the bone, has met over the neural canal. The *riblets* that protect the vertebral arteries, half-filling in their long burrowing passage, were, for an extremely short period, distinct as cartilaginous points, as I shall show in another Paper. They now connect the "diapophyses" with the "parapophyses"—the upper and lower "transverse processes"; and all distinction of parts is lost up to the twenty-second vertebra. The styloid part of these costal "remnants" is lost in the nineteenth and the three next vertebræ; and in this stage the osseous centre has not yet appeared. These birds are remarkable in that the *axis* only has an upper and lower spine. In the third both are obsolete: the upper, even, is a mere ridge. This is remarkable; for of all birds the swan has the longest neck, and moves it with most variety and grace; moreover, in grazing and quaffering it uses considerable force. Nor is there any closed inferior arch for the carotids in these types, such as is seen in the heron and its congeners, long-necked birds, but in which the length is gained rather in the individual vertebra than in a great number. In the lower part of the neck the neural arch gradually becomes crested, thus approximating to the dorsal region: a feeble keel also appears below. The rather long cervicals increase in their width, gradually, until they reach the large wide dorsals: near them they shorten. The facet for the "tuberculum" of the free ribs gradually creeps upwards so as to fit under the end of the large transverse process: that for the "capitulum" is a raised oval basin near the fore margin of the projecting articular part of the *centrum.* In these things the dorsal vertebræ agree with the two last cervicals. The spine is now a large obliquely oblong up-growth, and the upper transverse processes are very wide: they all have a slight lower spine, which becomes feeble in the last, and is nearly obsolete in the first sacral (dorso-sacral).

Amongst the other Carinatæ there is no such *sacrum* as this of the swan; it is nearly twice as long as in the multitudes of small and high-class birds. Here, in this embryo, there are *twenty-two* vertebræ (Plate IV. and Plate III., figs. 9, 10) enclosed between the ilia, and indeed the next, or first caudal is partly between those plates.

Here ossification is confined to the basal region; the sheath of the notochord has acquired twenty-two bony rings; and the osseous matter has crept into the investing cartilage, right and left; in the true sacral region, where the vertebræ are very short and wide, the deposit is bilobate; there are not, however, two separate centres, for each centre begins round the azygous notochordal axis. The great *Avian sacrum* has four regions, namely, the dorso-sacral with four vertebræ, the lumbo-sacral with three; the sacral, proper, with four, and the uro-sacral with eleven.

The spines are never quite obsolete, but are highest at the two ends of the series; the fourth dorso-sacral has half-developed ribs, to which belong half-grown sternal pieces below (Plate IV.). The three lumbo-sacrals have only thick, short diapophyses, buttressing the *pre-ilia;* the next four, or sacrals, proper, have these abortively developed in their lower part. Prickles are seen in the last two, however, and these are remnants of ribs. This is seen in the two next or first two uro-sacrals, where they are separate bars, and become separately ossified like their several homologues in the neck. The rest of the uro-sacrals have only diapophyses; all these in the true sacrals and uro-sacrals, are pedate or dilated where they articulate with the *ilia*, and being broad, proximally, they thus leave a round space, which is filled with the corresponding ganglion of the "posterior root" of the sacral nerve (*g.*). Both in the lumbo-sacral, sacral, and uro-sacral regions there is, in an earlier stage than this, an abortive attempt at forming more ribs than remain, even as remnants, for in the embryo of the common duck I find the first five uro-sacrals with rib-bars; the last three of these, however, are soon lost.* In these vertebrates the *metamorphosis* of the organism is not confined to a certain strict term, as in insects, but goes on for a long and, indeed, indefinite time; the "Anura" show this to a lesser extent. The diminishing series of vertebræ that form the skeleton of the tail (*cd. v.*) has its transverse processes longest in the middle; its spines are low and broad, and the third has, beneath, a small intercentrum which passes under the second: there are seven of these milioline cartilages. In this specimen there are *six* free simple vertebræ, and in the uropygial part six more; the last of these segments, however, is merely the naked end of the notochord (*nc.*) sticking out; it does, however, become clothed with cartilage, and then converted into bone. At first the uropygial piece (*region*) is formed, as a rule, of *six* segments; long ago, however, in the winter of 1842–3 I found in a recently-hatched common duckling ten osseous centres in a row in this part (Plate II., fig. 12). This was, most likely, due to domestication. Like the overgrowth of digits in the foot of the Dorking fowl, it is a proof of the exquisite sensitiveness to surroundings that exists in these types.

Of the distinct and functional ribs in this embryo seven had perfect sternal pieces; the eighth pair were nearly perfect; their lower bars were not ossified; the rudimentary ninth piece was far from its arrested upper bar; the ribs were rapidly ossifying; the long last cervical, and four at least (generally in swans the fifth also) have appendages (*c.a.*), cartilaginous tracts growing from the middle of the rib, at its hind-edge, and overlapping

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* See Proceedings, Royal Society, 1888, p. 479.

the next following rib. The sacral and caudal regions of embryo ducks in earlier stages than this (Plate II., figs. 1–3) will be described with the hip girdle.

In the *second stage* cygnets of *C. olor*, fourteen and fifteen inches long, and about a month old, there are many important changes to be noticed in the vertebral chain.

In the *atlas* (Plate V., figs. 2, 2A, 3, *at.*) the two centres of the neural arch are united above, and a considerable deposit of bone has taken place in the base; that basal piece, however, is not the true centrum, but an occipito-atlantal "inter-centrum" (*i.c.*). The centrum, proper, of the atlas has become fused with that of the axis (*ax.*) to form its odontoid process, as in us; it is now a considerable bony mass inside the thick odontoid pivot of this peculiar cranio-vertebral articulation. The *atlas* is procœlous, but in most land and water birds the cup is deeply notched for the pivot; in many of the nobler arboreal birds the cup is complete, save for a small hole through which the odontoid ligament passes to tie the process to the basis cranii.

The back of the atlas fits to the front of the axis by an almost flat-faced joint, but this is not an articulation of centrum with centrum, but of the first and second inter-centra dislocated in some degree through the arrest and tilting of the borrowed atlantal centrum or odontoid process. *Under* and *behind* that process, in that part of the base of the axis which binds on to the atlas below, another inter-centrum is seen; whilst the proper centrum (*c.*) of the axis is behind both the bony tracts seen in this second vertebra. Only post-zygapophyses are seen in the atlas, both pre- and post-zygapophyses in the axis and all the rest of the pre-sacrals. Also the hinder face of its centrum fits on to the next in the same manner as all the remainder of the pre-sacrals; the joint is "cylindroidal," the centra seeming to be *convex* behind, whilst in reality they are *concave*. A vertical section (fig. 2A) corrects what the horizontal section (fig. 4) seems to show; of course we have the exact opposite of this in the fore-face of each centrum. Thus the fore-face of a normal ornithic centrum, as is well seen in wide, flat vertebræ, is a convex condyle that rolls in the rounded groove of the one in front of it. This joint, assisted by the *yoking processes* or zygapophyses, allows, with perfect safety to the myelon, a very considerable amount of mutual movement between vertebra and vertebra. But this is only part of this delightful piece of animal mechanics. There is an annular meniscus interposed between the contiguous cartilaginous surfaces in this synovial joint (fig. 4); and this part being annular allows the suspensory ligament (*s.l.*) to pass from one to the other; this ligament is nothing more than the old notochord.

But even this is not a full account of the care with which nature has provided for the bird, in the structure of its neck—which is indeed *its one arm.* As I have already mentioned, the vertebral arteries burrow their way along the sides of the centra in the neck; and behind the *axis*, in all birds, the riblet finishes a tunnel right and left at the fore end of each vertebra. Here, as in the great Ratitæ, the topmost cervicals, the *atlas* and *axis* have, like so many reptiles, ribs up to the occiput. There was no bony riblet in the first stage (Plate IV.); here, in these cygnets, there is a small ossification right and left on both these bones.

That on the atlas (figs. 2, 3, $c.r.^1$) is a short needle of bone formed in a costal part of cartilage that had become imperfect. That on the *axis* (fig. 2, $c.r.^2$) is quite normal, like those that follow: it is a bony wedge pointing backwards, and is part of the *costal band* that ties together the upper and lower transverse processes.

I have mentioned that in the herons and some other birds there is an *antero-inferior bridge* to several of the cervicals (6 or 7) for the protection of the carotids. The ribs do not fasten their "capitulum" between two centra, as in us; and they have a synovial joint for both capitulum and "tuberculum." The latter is a gliding, the former a cup-and-ball, joint (Plate V., fig. 4, *r.*, *c.*).

Thus everything in the skeleton of birds is carried to its uttermost perfection. *They*, not *we*, are, in respect of bodily movements, the crowning forms of creation.

The dorsal vertebræ differ little from the last cervical (Plate IV., *c.v.*, *d.v.*): the *primary dorsal region*, however, has been largely taken in, to form the fore-part of the long sacrum (Plate V., fig. 11): the avian sacrum is *four regions in one.*

Finding how close the Anatidæ come to the Ratitæ in many things, notwithstanding their aquatic habits, and feeling sure that the very term "Ratitæ," as *ordinal*, is a mistake—a misleading term—I shall now show how near these forms, the duck-tribe and the ostrich-tribe, come together in the structure of their vertebral chain. Both have cylindroidal pre-sacrals, and both have ribs on the *atlas* and *axis*. Finding (from my son, Professor T. J. Parker*) that the intercentra of the atlas and axis were the same as in the Carinatæ, I looked for them in a ripe embryo of the mooruk (*Casuarius Bennetti*).† That embryo is as large as the cygnets a month old, and as much developed: its three foremost vertebræ (Plate IX., figs. 13–15) and its pelvis‡ show this.

The sectional view (Plate IX., fig. 15) shows that the odontoid process (*od. p.*) leans over the atlantal intercentrum (*i.c.*), and is scooped below where that intercalary element fits in. Then, again, by a remarkable adaptation the second intercentrum (*i.c.*) comes close behind the first; and the proper centrum of the axis only forms two-thirds of that *compound* vertebra. The two opposed intercentra are narrow transverse plates of bone, half as wide across as the contiguous centra. The cartilage is imperfect over the vertebral artery in the *atlas* (*at.*), and the riblet is not yet ossified: that on the *axis* (*ax.*) is also small, at present, but is embedded in cartilage: that on the third (*c.v.* 3.) is much larger. The common Cassowary§ has no ossified atlantal rib, nor has the Rhea;‖ but the Emu ¶ has it well marked on both sides. In *Struthio*** it is seen on one side only. So that in these forms the atlantal ribs are less constant than in the Anatidæ; and it is worth noticing that in the swans the sacrum has one or two vertebræ more than in the giant African ostrich, which has only *twenty*.†† The sacral vertebræ of the cygnet (Plate V., fig. 11) do not correspond with

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* An exhaustive memoir on the morphology of the Apteryx has been prepared by him, and will see the light, in the Philosophical Transactions, as soon as the present Paper.

† See Zoological Transactions, vol. iv., Plate LXXII.

‡ Philosophical Transactions, 1888, B., Plate LXV., figs. 8–10.

§ Mivart, Transactions, Zoological Society, vol. x., p. 28, fig. 23.

‖ *Ibid.*, p. 3, fig. 3.

¶ *Ibid.*, p. 17, fig. 14.

** *Ibid.*, vol. viii., p. 388, fig. 2.

†† *Ibid.*, Transactions, Zoological Society, vol. viii., p. 420.

what I find in very old specimens. I will therefore give the *vertebral formula* of each of my stages:—

——	C.	D.	D. S.	L. S.	S.	U. S.	Cd.
Cygnus nigricollis, embryo .	24	5	4	3	4	11	6 + 5
,, *olor*, one month old .	25	5	3	4	4	10	6 + 5
,, *olor*, aged	25	5	4	3	4	10	7 + 5

Thus, whilst the two first have *sixty-two* vertebræ in all, the third has *sixty-three;* and there is a difference in each case as to the number in the different regions. A little overgrowth of bony deposit, in the case of the black-necked swan, would give it *twenty-three* sacrals, as its first caudal is partly between the ilia. This great number of vertebræ in the *Cygninæ* may be adaptive: it is manifestly Reptilian.

The great length of the thorax in these heavy wide-bodied birds has necessitated the development of three or, mostly, four pairs of ribs in the dorso-lumbar region: in a large number of birds there is only one pair. The gentle manner in which the individual vertebræ are modified as they pass from one region to another is well seen in this stage (Plate V., fig. 11). The lines of fusion of the vertebral elements in the embryo are still cartilaginous: where the uro-sacral region begins there two pairs of separately-ossified riblets (*s.r.*) are seen below the corresponding diapophyses. I find three pairs in *Casuarius Bennetti* * in which only two pairs of ribs are developed in front (*loc. cit. s.r.*); but these two *sacra* are very similar, and the same number of vertebræ are enclosed by the ilia in both cases. In the mooruk (*Casuarius Bennetti*), however, the first of these retains its distinctness as a dorsal vertebra.

The arrested and somewhat retrograded Ratitæ show their loss of parts and want of specialization in the caudal region. Mivart (*op. cit.*, p. 430) gives *ten* as the number of caudal vertebræ in the ostrich. I find only *eight* in the mooruk. The same abortive condition of this part is seen

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* Philosophical Transactions, 1888, B., Plate LXV., fig. 8, *s. r.*

in the Tinamous; but in the Anatidæ, as in most Carinatæ, and especially in certain arboreal birds, it is a highly developed or greatly specialized* part; for the two first moveable joints in the caudal series become procœlous, and also acquire a joint-cavity. This is partly perfected in the swan, but is best seen in such birds as the horn-bills: the rest of this series is gently amphicœlous; the two contiguous facets are joined together by fibro-cartilage. The nobler Carinatæ with strong "rectrices," or tail-quills, have intercentra in this region to give greater purchase to the "depressor coccygis."† In the cygnet (Plate V., figs. 5, 6, 11, *i. c.*) I find *eight* of these milioline cartilages: the last three of these belong to the uropygial series: the three in the middle are the largest. These figures show how strongly these unfused caudals are like those of the Ratitæ: in the swans and their congeners their number is greater; and the uropygial piece is a highly specialized *region.*

In the adult the cervical vertebræ have a notable structure. From the third to the eighteenth inclusive, the re-entering angle between the neural arch and the retral styloid rib is largely filled in by a secondary bony lamina: thus the canal for the vertebral artery is walled in altogether in from half to two-thirds of its extent: behind, in each vertebra, the outer wall remains membranous. At the lower end of this series this plate is separated by a fenestra from that part of the wall which is formed by the open part of the riblet: thus, there is a delicate "flying buttress" running obliquely upwards and backwards from the riblet to the neural arch—a very elegant structure; and, in this manner, the canal is often protected, notably in the Cuculine types. In the swan and its congeners the wall is completest; and any cervical vertebra of a bird of this kind is easily recognized.

All the vertebræ of the swan are pneumatic, except the caudals: the cervicals, except at the two ends, are elegantly oblong, depressed more than usual, and narrowest at the beginning of the post-zygapophyses. The huge dorsals have ossified tendons on their spines and diapophyses.

Altogether, this is one of the neatest groups of the Class; but as the

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* See Proceedings, Royal Society, 1888, p. 472.

† See Macgillivray, British Birds, vol. 1, p. 46, fig. 6.

old sorts of the Chenomorphæ are not all extinct, the Palamedidæ still lingering in the neotropical region, the classification of these birds is upset, and the hedge set about the group is greatly injured.

The *Sternum* and *Shoulder-girdle* of the early stage in the swan (Plate I., fig. 5), along with the wings, are remarkable for their small size at present. There must be some ontological reason for this; and putting together such facts as are patent, an approximation to the truth of the matter may be made. At present the sternum is entirely cartilaginous; it remains so, and is very small, relatively, in the large cygnets a month old. When it does ossify it is by *endostosis* at first, and the three main tracts are imperfectly distinct from each other. In fowls and struthious birds the sternum ossifies earlier and by *ectostosis*, in very definite tracts; though large-winged, the unwebbed Palamedidæ have a smaller sternum than the Anatidæ; but both groups have sternum and wings large. The most generalized of the Anatidæ are the geese, and the true land geese most of all. The largest of all, by far, the extinct Cnemiornis (Owen) of New Zealand,* and several existing forms, are terrestrial birds: the most generalized forms I have met with, judging from the structure of embryos at a similar stage as those of *Cygnus nigricollis*, are *Chloëphaga poliocephala* of the Falklands, and *Cereopsis novæ-hollandiæ* of Australia.

I therefore imagine the fore-parents of the Chenomorphæ to have been near akin to those of the Ratitæ and those of the Gallinaceous tribes—all land birds. In that case, after the dying out of the true teeth, those primordial forms, neither geese, swans, nor ducks, at that time, *acquired* the webs on their feet, and those horny *succedanea* to teeth that were needful for them in their peculiar method of gaining a livelihood, namely by straining out the mud of watery places for the sake of living food. Not the less did they *browse* and *graze*, as many of them do to this day; the most aquatic—the Fuligulinæ and the Merganserinæ—being the most completely carnivorous.

The extension backwards of the sternum in birds—the "xiphoid" or

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* This gigantic goose was fast becoming one of the Ratitæ (Transactions, Zoological Society, vol. ix., Plates XXXV.–XXXIX.; and *Cygnus falconeri* was an Anserine swan (Transactions, Zoological Society, vol. vi., Plate XXX.).

"metasternal" region*—is, in this embryo, only one-fourth as long as the whole tract: the notch between each cartilaginous tract is further forward than the insertion of the last sternal rib. The rostral process, in front, between the coracoid grooves, is small. The keel is rather acute-angular in front, and dies out behind, not reaching to the end of the median metasternal process. Only three-fourths of the costal edge has sternal pieces; these died out during development in the fore part: their vertebral counterparts are seen above as the styloid ribs of the two last cervical vertebræ. Seven cinctures are complete; the eighth nearly so; the ninth is less than half developed; and in two distinct tracts there was an attempt to develop *eleven* cinctures. This makes one figure the ancestral bird with a very long thorax. Yet in true land birds, and in the most archaic in existence, more so truly than the Ratitæ, the Tinamou only finishes *three* cinctures (*T. robustus; T. variegatus* has *four*), and it has the longest sternum of any bird; it is almost all metasternum, and yet has a large keel.† The coracoid grooves are separated by the small rounded "rostral process" in the Anatidæ: the coracoids (*cr.*), therefore, do not overlap as in many birds. The falcate scapula (*sc.*) and the strong broad-based coracoid are quite normal, and are ossifying fast: the "clavicular process," or *precoracoid root*, is small in these types. The furcula (Plate IV., *fr.*), however, is the most instructive part of the shoulder-girdle, and makes most for a kinship between these birds and the Ratitæ. In the Tinamou the furcula is simple: it has no cartilaginous nuclei ossified and fused, as in most birds, notably in the Passeres, the Rapaces, and the Pelecaninæ. In most of the Ratitæ it has died out; but styloid remnants—simple clavicles—are seen in Cassowarys and Emus ("Shoulder-girdle and Sternum," Plate XVII., figs. 3, 4). In the Palamedidæ the furcula is composed of two massive and simple clavicles fused together as in Tinamou, and forming a U-shaped bone—*quite like that which has been made out in Archaeopteryx.* The furcula of the swan is quite similar, but not so massive nor so pneumatic as in *Chauna chavaria.* The simple parosteal clavicles of Reptiles, because of their superficial, sub-

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* See Lindsay: Proceedings, Zoological Society, 1885, pp. 684–716, Plates XLII.–XLV.

† Transactions, Zoological Society, vol. v., Plates XXXIX. and XLI.

cutaneous nature, are more variable than the endo-skeletal part of the shoulder-girdle: in Chameleons they are suppressed; and in Crocodiles only the *third* piece, the "interclavicle," is present (*op. cit.*, Plate XI., figs. 4 and 8).

Going back to an earlier stage, we see in the embryo duck (*Anas boschas*) after nine days' incubation (Plate I., fig. 5) that the scapula and coracoid are fused into one bar, which is bent upon itself *at more than a right angle:* it is *much less* so in the adult. The early position is Reptilian, and so is the continuity of the two parts (see in the "Urodeles," *op. cit.*, Plate III.). The antero-inferior bar, or "pre-coracoid," has the same arrested development as in the Rhea, Cassowary, and Emu (*op. cit.*, Plate XVII.); and the membrane that so strongly walls-in the interfurcular space has in it, above, a small patch of nascent bone, the future "furcular ramus" (*fr.*). The moieties of the cartilaginous sternum are uniting, and are sending down a small keel; the costal edge has seven sternal pieces (*s.r.*), and there is only room for *one* more on the pre-costal process—not *two*, as in the swan. The hinder half of the metasternum is membranous at present.

The Wings of the Anatidæ.[*]

In the nearly ripe embryo of *Cygnus nigricollis* the *humerus* and *ulna* are of the same length; the *manus* is one-eighth longer (Plate IV.). The ends of the main rods are still unossified, as are the carpal segments; the general form of each element is now the same as in the adult.

The proximal row of carpals has only the two normal avian pieces—the radiale[†] (Plate III., fig. 7), and the ulnare (*uc.*); the latter is evidently morphologically compound, for it has two unequal lobes, one on the extensor and the other on the flexor face of the limb.

The distal-carpals (*d.c.*^{1}, *d.c.*^{2}, *d.c.*^{3}) are still distinguishable above the metacarpals. The 1st (fig. 7, *d.c.*, *d.c.*^{1}) is small and ventrally displaced; it lies below the larger lunate 2nd segment; that piece is now fairly confluent

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[*] For bibliographical notices, see "Fowl's Wings": Philosophical Transactions (1888), pp. 385–398.

[†] The "radiale" carries a spur in Plectropterus (Sclater: "Ibis," vol. iv., 1886, fifth series; p. 300, fig. 3

with the 1st metacarpal (*m.c.*^{1}) in front; and the 3rd distalcarpal (*d.c.*^{3}) behind. This latter is mainly on the ulnar side of the manus, for the "index" and its carpal are inordinately large, and have dwarfed the parts on each side; the large round head of the metacarpal of the index (*m.c.*^{2}) is clearly seen wedged in between the 1st metacarpal (*m.c.*^{1}) and the 3rd distalcarpal (*d.c.*^{3}), and capped by its own large curved carpal (*d.c.*^{2}). The small patelliform 1st distalcarpal looks forwards and downwards towards its own metacarpal (*m.c.*^{1}), which is only one-third the length of the next, and is not yet ossified. This segment has a large proximal "trochanter," partly formed of a band of fibro-cartilage; this part, in some birds (e. g. Parra and Pluvianus), and notably in the Palamedidæ, carries a defensive spur. The 1st metacarpal has hinged upon it a "pollex" (*dg.*^{1}), nearly as large as the two last phalanges of the index (*dg.*^{2}); of course this latter has another—its proximal phalanx, and both are normal digits as to the number of their segments. In each of these digits the distal phalanx is the core of a claw. They are *ungual* phalanges; they are already ossifying at their tip, and the others have a shaft-bone.

But the proximal phalanx of the index has a flat dilatation on its hinder or ulnar edge (*dg.*^{2}); and the metacarpal of the index has, in the duck, near the top of its bony shaft on the ulnar side, a small accessory cartilage (Plate I., fig. 6, *m.c.*^{2}); the dilatation on the proximal phalanx arises as a distinct cartilage later than the main segment. The 3rd digit has a metacarpal (*m.c.*^{3}) only one-third the diameter of the 2nd; it reaches only to the bony shaft of that rod above; but at its lower end it reaches a little further down; its ends are still soft, and the upper is modelled on the extensor face into a distinct head; on the flexor face it is confluent with its own distalcarpal (*d.c.*^{2}) This narrow bar is bowed out in the middle so as to leave an interosseous space for the muscle of that part; below, it dilates a little, and then has articulated to it a *single* phalanx (*dg.*^{3}), where in a Reptile there would be *four* phalanges; this is only one-third the size of the second phalanx of the index; it is not yet ossified. Altogether, the index has overshadowed and starved the 3rd or hind-finger. As a rule, in old birds, this is the hindmost digit. There is, however, a very small remnant of a 4th metacarpal on the flexor side of the 3rd near its top (Plate III., fig. 7^a, *m.c.*^{4}); the accessory cartilage attached to the 2nd metacarpal is on the extensor side. I shall refer to these parts again in describing the Alcidæ.

The wings, like the sternum of the cygnet (Plate V., fig. 7), grow slowly; all there is to remark upon, as yet, is the extension of the bony shaft and the ossification of the 1st metacarpal (*m.c.*^{1})

In old swans the relative, as well as the really great size of the wings, is greatly altered from that of the nearly ripe embryo; this is well seen by comparing the fore and hind limbs.

In that early stage the ulna was 17 millims long, and the tarso-tibia 27 millims. In the old white swan the ulna is 270 millims long, and the tarso-tibia 203 millims, or only four-fifths. The humerus is now 287–5 millims long, or 17·5 millims longer than the ulna. The manus is now 240 millims, or 30 millims shorter than the ulna. But in the embryo the manus, as I have shown, was one-eighth longer than the humerus and ulna, which were both of the same length.

I found, in the old white swan, the distalphalanx of the pollex 10 millims long, and that of the index 14 millims; they were, in both, straight and sharp-pointed—they had lost their *claw-form.* Thus the specialization in those birds is seen in the humerus becoming larger than the ulna, instead of being the same size, while the manus, which was one-eighth longer than both those segments, is now 30 millims shorter than the ulna, and 47·5 shorter than the humerus. The teleological bearing of this is, that the wings have largely changed their size as compared to the legs; they were only half the size—they are now much larger. The overgrowth of the humerus, as compared with the ulna, has reference to the quiet, buoyant, continued power of flight in these birds; the ulna has gained more room for the secondaries, whilst the space for the primaries, although larger, is relatively less. The humerus is the only pneumatic bone in the limbs of the Anatidæ; in *Chauna chavaria* only the ungual phalanges retain the marrow. All these things suggest that the Anatidæ were, in their remote parents, stout strong-legged land birds, with short wings, a small sternum, and with no special fitness for an aquatic life, beyond that of wading in shallow waters.*

* Wolf's excellent figure of *Chauna nigricollis* (Proc. Zool. Soc., 1864, Plate XLI., p. 74) shows that archaic *hen-faced* "Chenomorph" in the very attitude and act of wading; its resemblance

If I were to go no further down, and no further afield, than this examination of the large embryo of the nestling and the old swan, half the interest of the matter would be still untouched. I have still to describe the early stages of the wing in the common duck, and the rare conditions of this part seen on the embryo of Chloëphaga, and in the adult of one of the Palamedidæ.

Stage 1.—*Wing of Embryo Duck* (Anas boschas), 9*th Day* (*less advanced*).

The paddle-shaped fore-limb at this stage differs but little from the hind-limb (Plate I., figs. 1, 2). There is a tendency to lobulation of the spatulate end of the limb; and this is manifestly due to the growth, along certain lines, of radiating thickenings of the tissue which are fast growing into pointed hyaline cartilages. There are, already visible, three such rays in the fore-limb, and four in the hind-limb. There is, indeed, an arrest, almost suppression, of two of the normal rays in the wing, and of one in the leg.

If these limbs be considered to be the modifications of what we see everywhere in Reptiles, it is evident that some of the rays have been smothered in their growth—probably, in some degree, by the great start that the developed parts have got.

Potentially, the seeds, so to speak, of the missing rays were duly sown; for in the case of the wing, one of the two lost rays makes a little attempt at growth, and the one missing ray in the leg does the same; but the developed parts have "sucked their verdure out."

Already, the main regions of the limb are differentiated; and the chief segments have become hyaline cartilage; the more inconspicuous elements and distal parts of the skeleton of the wing are still composed of embryonic cartilage or "indifferent tissue"; as to the larger rods, I have not overdrawn their distinctness. Whilst the muscles are still in formation, the harder tracts of tissue for their origin and insertion are already prepared. This is well seen in the humerus (Plate I., fig. 1, outside view of

to the coots (Rallidæ), in respect of its huge toes, which are really those of a swan without the web, made the old Ornithologists (Vigors, Cuvier, &c.) put it with the Rallidæ and also along with Parra and Megapodius.

right wing) and in the cubitus (*r.*, *u.*). Distinct from these parts, but only semi-distinct from each other, are the parts that form the carpus; on the ulnar side, a large wedge of soft cartilage (*ue.*) is seen, with its sharp edge above; and on the radial side there is a thick mass (*re.*) notched both by the ulna (*u.*) and the radius (*r.*) Beyond these, at the mid line, another large mass is seen (*d.c.*^{2}), and on its ulnar side a much smaller half-distinct nucleus (*d.c.*^{3}); these both become the second and third distalcarpals. Growing forward from them, quite cartilaginous rods are seen; these, which are more and more soft towards the end, are distinctly segmented a little beyond their middle. Thus we have the large second and the small third metacarpals (*m.c.*^{2}, *m.c.*^{3}), with their sprouting phalanges (*dg.*^{2}, *dg.*^{3}) forming the second and third digits. The first distal carpal is not evident in this stage (I shall show it in the next); but the first metacarpal with its sprouting digit, the pollex, is already clearly seen.

The small rough model of a bird's-wing skeleton is to be clearly seen in this weak rudiment up to the wrist (carpus); but the three rays are the diverging, sprawling fingers of a Reptile.

STAGE 2.—*Embryo of Duck after Nine Days' Incubation* (*more advanced*).

In a further growth of the wing (Plate I., fig. 3, inside view of right wing) the sprawling of the fingers is not so great, and the softer parts are more clearly outlined; they are now almost hyaline cartilage. The preparation here figured was a stronger and larger embryo than Stage 1, but the period of incubation was the same. The elbow is now definitely bent; and, the whole structure becoming *avian*, the bird is becoming more and more, the *reptile* less and less.

What may be called the *necessary* and *normal* parts of the skeleton of the wing are all now present. These are the parts chosen beforehand by the elective affinities of the morphological force to form this—the strangest type of limb. The human arm and hand are simple and primitive, and nearly normal in comparison with this "freak," which is specialized for flying. We have only to look at the large masses of hardening cartilage that form the avian radiale and ulnare (*re.*, *ue.*) to see that they are only semidifferentiated lumps of tissue. They, as can be proved by their behaviour in certain birds, represent two or sometimes three carpals of more normal fore-limbs; the ulnare is in two lobes even now.

The three distalcarpals (fig. 3, *d.c.*^{1}, *d.c.*^{2}, *d.c.*^{3}) can all now be seen on the inner or flexor side of the wing; the first (*d.c.*^{1}) is a small hemispherical nucleus inside the junction of the second metacarpal with it distal carpal (*m.c.*^{2}, *d.c.*^{2}). The latter is a large lunate mass, curving round the head of its own metacarpal; it thrusts the third distalcarpal (*d.c.*^{3}) forward. This is an oval piece, larger than the ventrally displaced first, but only one-fourth the size of the second.

The pollex (*dg.*^{1}) shows its distal phalanx as a conical mass of soft tissue on the end of the proximal phalanx. The index (*dg.*^{2}) and the third digit (*dg.*^{3}) have only their proximal phalanges in the state of hyaline cartilage. The third digit is drawing nearer to the second, which all along has been twice its bulk, but not much longer.

Stage 3.—*Embryo of Duck, after Twelve Days' Incubation.*

During the next three days the transformation of the tridigitate paw (or paddle) into the wing has been very rapid, and almost complete as to form.

The main bones (Plate I., fig. 6, *r.*, *u.*) have acquired an ectosteal sheath, and all the elements are well solidified as hyaline cartilage: moreover, fusion of some of them has already taken place, and new parts have become differentiated. The various joints, or condyloid faces of the segments, are now fairly modelled by the process of mutual adaptive growth of contiguous parts: these are very perfect, notwithstanding the limited mobility of this metamorphosed member. The proximal carpals, the radiale and ulnare (Plate I., figs. 6, 7, *re.*, *ue.*), are now very perfectly preformed in cartilage: the radiale is a massive lunate wedge; the ulnare is a bilobate segment, with its "elbow" behind, and its longer oval lobe on the inside: it overlaps both the ulna and the third distalcarpal (*u.*, *d.c.*^{3}).

The large projecting second distalcarpal (*d.c.*^{2}) is now confluent with the first metacarpal (*m.c.*^{1}) in front, and the third distalcarpal (*d.c.*^{3})

behind: thus, its own huge metacarpal (*m.c.*[2]) has its head inclosed in a thick cap of cartilage. Its outline, however, is quite clear; so also is that of the third metacarpal (*m.c.*[3]); but its distalcarpal (*d.c.*[3]) is fused above. The first distalcarpal (fig. 7, *d.c.*[1]) is now a clear bud of cartilage, flattened on its adherent face, and placed inside the head of the second metacarpal. The first metacarpal (*m.c.*[1]) runs parallel with the unossified head of the second; it is half the size of that head, and has a large flat "trochanter" on its proximal end; it then narrows and forms a condyle for the pollex (*dg.*[1]). That digit, with its metacarpal, is half the length of the whole index, metacarpal, and phalanges, together; but its proximal phalanx is as long, but not as stout, as that of the second; its distal phalanx (so-called *ungual*) is almost the size of that of the index, which is nearly as large as the second or middle joint of the digit. In the pollex, especially, it is seen that the distal phalanges are not *ungual* as yet, but are lobate and flat at their free end, and represent not the claw-joint of a Reptile, but the last piece in the soft-ended finger of an amphibian.

At present, the terminal pieces of all the three digits are alike; but that on the third (*dg.*[3]) represents merely the proximal stump of a Lizard's third fore-toe, which has four phalanges in it. The first and second digits in this wing are normal; the third is aborted.

But a much more abortively-developed digit is seen behind the third: this (*m.c.*[4]) is a rudiment (or *remnant*) of the fourth metacarpal of a Lizard's fore-foot: it is on the flexor side of the hind margin of the third, close to its rounded and distinct top. This remnant is common in the Carinatæ: in Opisthocomus this digit re-appears as a proximal phalanx; it is, in that bird, a distal, not a proximal, remnant.

An *accessory cartilage* is now seen as a thin flap on the ulnar side of the proximal phalanx of the second digit (*dg.*[2]): the second and third metacarpals have acquired a considerable bony (ectosteal) tract. The distal phalanx of the second digit is not so well developed on the right (fig. 6*a*) as on the left side: bilateral asymmetry is not uncommon in the wings of birds.

Stage 4.—*Embryo of Duck, after Fourteen Days' Incubation.*

After two days more there are two new ectosteal tracts—those of the proximal joint of the pollex and of the index (Plate I., fig. 8, *dg.*[1], *dg.*[2]); the other parts are similar, but larger: the first distalcarpal (*d.c.*[1]) is growing towards its own metacarpal (*m.c.*[1]). The difference in the size of the two lobes of the ulnare is now well seen (figs. 8, 9, *ue.*). The distal phalanges of the pollex and index (*dg.*[1], *dg.*[2]) are becoming curved as ungual joints.

Stage 5.—*Embryo of Duck, after Eighteen Days' Incubation.*

In this stage (Plate II., figs. 4–6) there are several points to be noticed. The second phalanx of the index (*dg.*[2]) is ossifying; and the large curved distal joints of both that and the first digit (*dg.*[1], *dg.*[2]) have a terminal horny sheath. In the more enlarged figures (figs. 5, 6) there are some important parts displayed more plainly: the accessory tract of the second metacarpal (*m.c.*[2]), which is very small in the Anatidæ, and very large in the fowl tribe, can be seen as a narrow tract of cartilage growing forwards from the ulnar side of the great distalcarpal (*d.c.*[2]). The first distalcarpal (fig. 5, *d.c.*[1]) is now a thick band of cartilage which has grown across the head of the second metacarpal, and has applied itself to its own metacarpal (*m.c.*[1]). In the same view the fourth metacarpal (*m.c.*[4]) is plainly seen as a small pyriform nucleus of hyaline cartilage. On the outer or extensor face (fig. 6) the peculiar free end of the outside of the third metacarpal is also well seen.

Stage 6.—*Embryo of Duck, just Ripe.*

In this stage I have shown the proximal end of the manus (Plate II., figs. 8, 9): it differs but little from the last; but the fourth metacarpal (*m.c.*[4]) is becoming confluent with the top of the third (*m.c.*[3])

Stage 7.—*Duckling Three Days Old.*

The same parts are shown in this stage (Plate II., figs. 10, 11): the fourth metacarpal (*m.c.*[4]) is now confluent with the third (*m.c.*[3]): the accessory part to the second metacarpal (*m.c.*^{2}) is now a thin point of cartilage embracing the large bar on its ulnar edge above.

STAGE 8.—*Old Duck* (Anas boschas).

As compared with that of the swan, the wing of the mallard—and also that of the tame duck and of the sub-family Anatidæ generally—is relatively, as well as really, short: they are heavy birds to be carried with such wings as they possess.

In these smaller forms the cubitus is considerably the smallest of the three divisions of the wing-skeleton, and the manus the longest; they beat their wings rapidly in flight, unlike the "longipennes," birds with very long humeri. During the growth of the duckling, the carpals all acquire an endosteal centre; the two proximal segments remain free; the three distal become fused with the metacarpals, and these with each other; the second and third at both ends. The ungual phalanges of the pollex and index remain in the adult as sharp and straight pieces: the latter is the longer; and thus, besides the free synovial articulations of the two proximal carpals with the cubital bones above, and the compound manus below, the pollex has two, the index three, and the third digit one, moveable articulation permanent—just as much as is necessary in this transformed arm and hand, with its marvellous investment and its new function.

The Hip-girdle of Anas boschas.

In this species I am able to give three stages earlier than that of the nearly ripe embryo of the swan (Plates IV. and V.); and these show what transformation an average reptilian pelvis undergoes in the bird, correlatively with that of the shoulder-girdle and wing. The changes are very great in these parts, but not so great as in those.

Morphologically, the steps or stages of this metamorphic process may be said to be *four* in number: we have—1, the general Reptilian; 2, the Ornithoscelidan; 3, the Struthious; and 4, the normal Carinate stage. These stages are not so clearly defined in the hind-limbs: they are very marked in the moieties of the hip-girdle.

STAGE 1.—*Pelvis of Embryo Duck, Nine Days' Incubation* (*less advanced*).

This first, or Reptilian, stage of the hip-plate (Plate II., fig. 1) is shown in relation to the hinder-part of the vertebral chain, which is rapidly forming round the notochord (*nc.*), and over the myelon.

This stage is well illustrated in Miss A. Johnson's valuable Paper on the development of these parts in the Chick.* The vertebral formula of the adult duck is as follows :—

C. 16; D. 5; D. S. 3; L. S. 3; S. 3; U. S. 7;
Cd. 8 + 5 = 13: Total, 50.

Of these the last two cervicals have free ribs: and also the first three sacrals, or dorso-sacrals; and there are rib-bars on two or three—originally on five—of the urosacrals.

Now, the three true sacrals are exactly over and between the acetabula. In this first stage, therefore (Plate II., fig. 1), there are four in front of these covered by the anterior lobe of the ilium (*pre-ilium*), and three urosacrals by the posterior lobe or *post-ilium*—ten altogether, instead of sixteen as in the adult. At a still earlier stage there would be fewer,† in which stage the crest of the ilium is scarcely more dilated than the "supra-scapula," as in some Lizards (see, in Stellio, Shoulder-girdle and Sternum, Plate XI., fig. 1, *s.sc.*). It has, moreover, to be kept in mind that hosts of small and nobler birds have only *ten* vertebræ embraced by the ilia, although *eleven* is the most common number: the duck is a medium, the swan an extreme, case.

In *Iguanodon bernissartensis* there are *ten* vertebræ fairly between the ilia, as in my first stage in the embryo duck.‡ This first stage, however, has the hip-plate, as a whole, not in an Ornithoscelidan, but in a general Reptilian condition. It is instructive to see how the pre-ilium at present preponderates over the post-ilium; for it is the great development of the latter region that makes the bird's pelvis so remarkable; a still more remarkable fact being the adumbration, by the unwieldy Iguanodon, of the

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* Studies, Morph. Lab., Camb., vol. ii., Plate IV., figs. 3–6.

† See A. Johnson, *op. cit.*, Plate IV., figs. 3, 4.

‡ Dollo, Bull. Mus. Roy. Hist. Nat. Belg., t. ii., Plate V.

hip and legs of such small, light, airy forms as the nobler types of birds. Of the vertebræ that are built in between the hip-plates the last seven are, properly speaking, caudal; then follow, as a rule in this bird, thirteen more, the last *five* forming the uropygial piece. But I have seen as many as *ten* segments in that terminal region (Plate II., fig. 12); that would give *twenty-five* for the post-sacral or caudal series.* These, were they elongated as in the tail of Archæopteryx, would have formed another "Saururous" type. It is easy to imagine such a *hind-spine* as the one depicted (Plate II., fig. 1) as rapidly developing into the tail of a Saururous bird, instead of contracting itself into the stunted and largely fused uro-sacral and caudal series of a duck, or of any normal Carinate bird.

Palæontology is extremely tantalizing at this point. Geologically not so much older than Marsh's toothed birds, the Archæopteryx has no claim of fatherhood upon *them:* the gulf is not so great as between the Iguanodon and the Humming Bird; it is, however, *unbridgeable*, notwithstanding.

One more remark. In cartilaginous fishes—above all, in the Ray family—the neck becomes a *quasi*-sacrum; for the shoulder-girdle is fixed like the hips of higher forms: the fore limbs dominate the hind limbs, as they are the chief paired organs of progression.

The flying bird would seem to be relapsing in this respect, the fore limbs being its main organs of progression: but the bird is merely a land animal modified; hence its hind limbs are well developed also.

In the formation of these noble feathered forms it is instructive to see the part played by the notochord, and the rapid manner in which it becomes contracted and obscured, and then transformed into a mere ligament; in my first stage (Plate II., fig. 1), had it gone on growing and developing the vertebral segments on and around it, this bird must have soon become one of Professor Huxley's "Saururæ"; it was, however, *ordained to become* one of his Carinatæ.

By careful dissection of early embryos, Miss B. Lindsay† was able to

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* See Proceedings, Zoological Society, 1863, p. 1–8.

† Proceedings, Zoological Society, 1885, p. 704.

show that the shoulder-girdle of the bird arises as three (*apparently*) separate tracts of embryonic cartilage; that is, however, prior to the formation of true or hyaline cartilage, for this tissue runs freely from the scapular to the coracoid region, thus forming one curved bar. The pre-coracoid tract only partially ossifies, and that in two ways, namely, by a rudiment growing directly from the coracoid, and often by *one* or *two* distinct cartilaginous tracts; the rest of the antero-inferior bar grows into a mere "parostosis"—the simple clavicle. But there is no parostosis in the hip-girdle: the whole structure answers to such a shoulder-girdle as that of the Amphibia, Chelonia, and of *Struthio camelus*. (See "Shoulder-girdle and Sternum, Plates III.–VIII.; Plate XII.; and Plate XVII., figs. 5, 6.) This subject is rendered difficult through the peculiar development of the hip-plate in the Dinosaurs. (See Dollo, *op. cit.*, Plates III. and V. See especially Plate III., fig. 2. In *Iguanodon bernissartensis* the pubis sends forwards a large broad prepubic bar, called by Dollo "pubis"; whilst the *already rotated* pubis—the long, narrow hind-part—he calls "post-pubis"; the term *pre-pubis* is the better for the fore-part. The ischium also, where it binds upon the post-pubis, sends down upon that bar a shorter anterior and a longer posterior process, to enclose the proper obturator foramen. Now, if these parts and processes be compared with those seen in the shoulder-girdle of certain Lizards, *e.g. Iguana tuberculata* (*op. cit.*, Plate IX., figs. 1, 2), and if the unossified free edge is supposed to be absent, then we are shown how that these plates may send out secondary bars: in the Iguana there is one large bar from the scapula, and two in front of the coracoid proper. So I interpret the processes on the pubis and ischium of the Dinosaurs. In birds the pre-pubis is often suppressed, but it has a considerable development in the Ratitæ, Tinamidæ, Gallinaceæ, and the Ground Cuckoos (*e.g.* Geococcygx, &c.). In Dollo's Plate III. the pelvis of a young fowl is figured: in it the small pre-pubis is shown to be ossified by the *ilium*, and not by the pubis. In other Carinatæ, as far as I have seen, the same thing takes place; a good instance at hand being the pelvis of a newly-hatched quail (*Coturnix dactylisonans*). In it the pubic ossification reaches the base of the finger-shaped pre-pubic lobe; afterwards the suture between that bone and the ilium runs directly inwards, as in Dollo's figure; and thus the spur receives its bony deposit from the ilium. In an earlier stage of *Phasianus versicolor* the spur is endosteally ossified, and is in front of the suture between the ilium and pubis.*

I feel certain that Professor H. G. Seeley, F.R.S.,† has unnecessarily raised a difficulty and a doubt about the pubis of the Crocodile; and that the view taken by Rathke, Hoffman (in his later writings), Huxley, Hulke, and myself, is quite right; our interpretation of this part will be found to be true. In perfect harmony with these received views are the figures given in Miss A. Johnson's Paper (*op. cit.*, Plate IV., figs. 3–6); and my own first stage in the duckling, fig. 1 (Plate II.), as compared with figs. 2 and 3, suggest the same identification, exactly.‡

In my figure of the first and second stages in the embryo duck I have shown a considerable amount of distinction between the three main parts. This is seen still better in a chick than in these embryos. In it, especially when the pubis and ischium have just rotated, the three parts are semi-segmented from one another; a deepish chink is formed, as although a piece of cardboard were nearly cut through with a knife; the chinks are filled with connective tissue cells: at the first adjustment with a high power these seem to pass through. A deeper adjustment shows an extremely thin tract of cartilage on the inner face of the object: anyhow, this is very noteworthy, showing that the root and foundation of the limb is formed of *three rays*—parts that are homologous with those that form the fore-limb.

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* In a letter from one of the best of living palæontologists, J. W. Hulke, Esq., F.R.S., received December 15th, 1887, in answer to one from me, he says:—"In your fig. 3 of a bird's pelvis you represent the pre-pubic spur as wholly iliac. The corresponding spur in Apteryx, and in *Rhea americana* certainly contains a pubic element; for its suture, in immature specimens, runs through the spur, which has thus an iliac and a pubic component."

Bearing thereon, Mivart's figure of the pelvis of a young Ostrich (Trans., Zoological Society, vol. viii., p. 437, fig. 74) shows this; but unfortunately the *cartilaginous* spur was not preserved nor figured. Yet, if that figure be compared with one of the adult (p. 433, fig. 71), it will be evident that the ilium and pubis meet in the root of the process.

† Proceedings, Royal Society, 1887, *pp.* 235–242.

‡ The embryos of the Crocodile referred to by Professor Seeley as coming from me (*op. cit., p.* 24) were unfortunately too old for such researches. Two years afterwards I recovered the early stages which I had wished to put into Professor Seeley's hands.

The flabelliform ilium (*il.*) is parallel with the spine in its dilated part; but its axis is at a right angle with it: such an ideal line would pass directly between the two lesser bars, the pubis and the ischium. The former of these has now very nearly the position which is permanent in the crocodile.*

In this early stage the pubis and ischium diverge at less than a right angle: they are broad and flattish tracts composed of hyaline cartilage in their upper three-fourths, but are still in a state of "indifferent tissue" below: the angles of the ilium are in the same stage, as yet. The deep setting of the femur has stopped the growth of the cartilage, so as to show, already, a large hole in the fundus of the acetabulum.

STAGE 2.—*Pelvis of Embryo Duck of Nine Days' Incubation* (*more advanced*).

In this stage the hip-girdle embraces fifteen of the general sacral series of vertebræ; only the last appears like a pre-caudal. In a general way this condition is very Dinosaurian, for the pubis (*pb.*) and ischium (*isc.*) are rotated backwards, but are still at a great distance from the caudal spine, and are relatively very large. Afterwards (fig. 3) the pubis becomes much longer than the ischium; now it is but a little longer: in Dinosauria, as a rule, the ischium is much longer than the pubis. There is no pre-pubic spur; and, at present, besides the absence of any bony deposit, the distal parts of all the three bars are still composed of indifferent tissue. They are all free from each other behind, so that there are no "fenestræ," but a series of long notches, a sacro-iliac, an ilio-ischiatic, and an obturator notch. A comparison of this, of the next stage, and of that of the almost ripe embryo of the swan, with those of the adult Ratitæ and of the Gallo-struthious Tinamous, is very instructive as helping to throw light upon the forms that birds assumed in the olden times.

We have, however, to be very careful to sift out the specialization of

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* Huxley, Proceedings, Geological Society, 1869, p. 27, fig. 3; Dollo, *op. cit.*, Plate III., fig. 1 *c*.

arrested types; for, as a rule, existing archaic forms are in some respects more modified than the culminating types; and we must recollect that they have as long a list of ancestors, and have been as long in existence in the loins of those ancestors, as the newest and noblest forms.

That the Ratitæ represent several distinct families of birds there can be no doubt; nor can it be doubted that the Tinamous are less degraded archaic forms closely allied to them. I have already shown how near the embryo swan's pelvis comes to that of the African ostrich. In this second stage of the duck the hip-plate wants but little further growth and modification to make it into one like that of the cassowary.* In a few birds (*e.g.* the Buceridæ and Picidæ) the pubis, in the adult, becomes fused with the ischium, below, as the post-ilium does normally, above. In the cassowary all these bars are fused together in the cartilaginous condition: a little further chondrification would have done this in this second stage of the duckling. Further, in the chick, at this stage, the pelvic plate is precisely like that which is seen in the adult Tinamou. All these things are to be noticed and kept in mind.†

Behind the sixteen vertebræ that are, all but one, enclosed between the hip-plates there are thirteen segments, forming the caudal series: these are terminated by the blunt end of the notochord (*nc.*).

The rapidity of this pre-natal transformation is extremely great—as great as anything to be seen in the flowering of plants. The first and second stages had both been incubated nine days; but the second had got, in some way or other, a fair day's start, as to growth, of the first; and, in this short time, the whole difference between a general Reptilian and a Dinosaurian pelvis had been effected.

STAGE 3.—*Embryo of Duck after Twelve Days' Incubation.*

Here (Plate II., fig. 3), we see how rapidly the Carinate bird's pelvis passes into its typical condition: the general size has greatly increased;

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* Philosophical Transactions, 1888, B., Plate LXV., figs. 8–10.

† See Mivart, Transactions, Zoological Society, vol. viii., pp. 385–451; and vol. x., pp. 1–52; and "Gallinaceous Birds and Tinamous": Transactions, Zoological Society, vol. v., pp. 149–241, Plates XXXIV–XLII.

the cartilage is completed, and in parts is being transformed into bone. The pre-ilium (*pr.i.*) is now broader and relatively shorter; and the post-ilium (*pt.i.*) is well ossified, and is very broad behind the sacro-ischiatic fenestra (*s.i.f.*). That space is not yet enclosed by fusion of the post-ilium with the ischium (*isc.*), but lies upon its hinder half, or nearly half; its broad, lobate hind-part lies upon the long, curved, and spatulate hind-part of the pubis (*pb.*). As in the African ostrich and the swan, the pubis of the duck and its congeners becomes greatly unlike that of a Dinosaur: instead of being shorter it is one-third longer than the ischium. Bony deposit is seen both in the pre-ilium and the post-ilium, fore and aft of the acetabulum (*ac.*), and at the lower border: the bony shafts of the pubis and ischium are rapidly elongating; that of the former remains unossified at its dilated end in the adult, and then the pubis is twice as long as the ischium: it is somewhat shorter in Stage 1, a little longer in Stage 2, and one-third longer in Stage 3. These pubic bars differ little in the ostrich and the duck tribe, except that in the latter they do not coalesce, but remain as distinct elastic supports to the oviduct in oviposition.

The Hind-limbs of Anas boschas.*

Stages 1 and 2.—*Embryo of Duck, Nine Days' Incubation* (*less, and more matured*).

My earliest stage (Plate I., fig. 2) is very nearly the equivalent of that given by Miss A. Johnson in the chick (*op. cit.* Plate V. fig. 9). It is remarkably like the fore limb (fig. 1) of the same stage, already described; but it has four developed digits, and the rudiment of a fifth.

The main rods are composed of hyaline cartilage, sharply differentiated from the surrounding tissue: the distal parts are still "indifferent" and soft. The rapidity of growth of these embryos is well illustrated by a comparison of the humerus with the femur (fig. 1, *h*; fig. 2, *f.*); for they have already acquired their peculiar form. In the next segment, the leg,

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* The reader is referred to the following Papers out of many on the subject. They will be sufficient to show that it has taken a quarter of a century to find out what are the real elements

the two limbs are now sharply in contrast; for the fibula (fig. 2, *fb.*) is only half as thick as the radius (fig. 1, *r.*); moreover, the inner (or pre-axial) rod in the wing is the shorter and slenderer piece: in the leg it is the outer (or post-axial), namely, the fibula (fig. 2, *fb.*). This difference and the opposite direction in which the limb is bent—the *elbow* backwards, and the *knee* forwards—show what great changes the ancestral amphibian limb has undergone.*

The palæontologist will see at once how carefully the bird walks in the steps of the Dinosaurs. My figure of the skeleton of the leg (fig. 2) can be simply superimposed upon his. There is part for part, digit for digit: the nearly useless fibula, dominated by the one necessary segment of the leg proper, the tibia, is already slender and short; it is only one-third the thickness of the tibia, and its terminal part runs short of the ankle-joint: it is only five-sixths of its proper length; whilst the distal part of the tibia is dilated so as almost to reach the fibular, or outer, edge of the limb. What seems like an "elbow" at the top of the tibia is, in reality, the rudiment of the large, folded cnemial crest: this part is developed like a "trochanter," and always has its own epiphysis in a young bird. In many birds there is no other epiphysis whatever.

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of this remarkably modified limb—a limb curiously transformed from what is typical, and, what was still more unexpected, its almost perfect conformity with that of the Dinosaurs.

W. K. P.: "Osteology of *Balæniceps rex*": Transactions, Zoological Society, vol. iv., 1851–61, p. 343.

Gegenbaur, C.: "Vergleichend-anatomische Bemerkungen über das Fussskelet der Vögel": Archiv. für Anat. und Phys. Jahrgang, 1863: pp. 450–472.

Huxley, T. H.: "Dinosauria and Birds."—Proceedings, Geological Society, 1869, pp. 12–31.

Morse, E. S.: "On the Identity of the Process of the Astragalus with the Intermedium."—Anniversary Memoirs, Bost. Soc. Nat. Hist., 1880, Plate I., pp. 1–10.

Baur, G.: "Der Tarsus der Vögel und Dinosaurier."—Morph. Jahrbuch, Bd. VIII. (Taf. 19, 20, pp. 417–456.

Johnson, A.: "On the Development of the Pelvic Girdle and Skeleton of the Hind-limb in the Chick."—Stud. Morphl. Lab. Camb., vol. ii., 1886, Plates IV., V., pp. 13–27.

W. K. P.: Proc. Roy. Soc. 1887, pp. 57–58: N.B.—On p. 58, line 11 from the bottom, for "always," read "never."

* This is not well shown in the somewhat diagrammatic figures here given, in which the *inner* or *anterior* side is figured *behind* and *below*.

But in all birds, whilst growing, there is what seems to be a large distal epiphysis to the tibia.*

The absence of any apparent tarsal bone in existing birds has been so long taken as a fact about which there is no question, that, even now, some of my fellow-labourers are still sternly opposed to such a great primary complexity in this part, as for some years past I have been able to demonstrate.

Both in Dr. G. Baur's figures of sections† and in the figure, just referred to, of Miss A. Johnson there is no sign of a cartilaginous intermedium, such as I have figured in my first and second stages (Plate I., figs. 2 and 4, *i.*). Happily, however, they both show the distinctness of the *tibiale* and *fibulare*, and also the proximal rudiment of the fifth metatarsal. My preparations of these parts in the duck's embryo were made in the early part of 1887: those of the chick in a stage equal to that of Miss Johnson's fig. 9 were made a year before. After lying in oil of cloves for some months all these preparations were mounted in Canada balsam: they show still more clearly now what I discovered then. In Dr. Baur's method—by *sections*—nothing would be easier than to miss the thin intermedium; for it lies *above* and considerably in *front of* the tibiale and fibulare. Both under a lower and a higher power it can be clearly seen as a thin pyriform cartilage, with its broad end below, and lying in front of the fibrous lower end of the fibula (*fb.*). The *tibia* (fig. 4, *t.*) soon gets behind it, as it becomes very much dilated below.

When the microscope is adjusted so as to show the tibia, fibula, tibiale, and fibulare (Miss A. Johnson's fig. 9 shows this well), then there is no intermedium to be seen. The gentlest elevation of the object glass, however, makes all these parts cloudy. And now the intermedium comes clearly into view: it may easily be mistaken, even then, for a part of the dilated base of the tibia. Now, as this distinct tract of cartilage becomes ossified by *ectostosis* at about the middle of incubation; and, as the tibiale and

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* My figures of this *pseudo-epiphysis* in an emu chick, six weeks old, were made in the year 1842. After much meditation upon this anomalous structure, I, at length, timidly suggested that this part was, in reality, the *astragalus*, and not an *epiphysis*.

† "Der Tarsus der Vögel und Dinosaurier," Plate XX.

fibulare are still *mere endosteal nuclei* in the centres of the cartilage in cygnets one month old, how can the ascending process be a mere outgrowth, or periosteal addition, to either the tibiale or fibulare, or both parts, which have no such periosteal structure possible until the bird is fairly adult? Also, to which of these tarsals does it belong? and why do they develop this *tibial clamp*, seeing that they must so soon be fused with the main bone?

Another question arises, namely, *is it a tarsal* bone?—was it not a *third shaft-bone* in the leg of the old ancestors of the reptiles and birds? As cartilage, it arises earlier than the tibiale and fibulare—as bone, much earlier; and its mode of ossification is not that of any tarsal (or carpal) that I know of.*

At present the fibulare (*fbe.*) is a round nucleus of soft cartilage, only one-third as large as the transversely-expanded tibiale (*te.*). This is well shown in the chick in Baur's sections, and in Miss A. Johnson's dissection.

The distal part of the tarsus is in a very undifferentiated condition. Only one nucleus can be traced (*d.t.*): this appears over the middle of the perfect metatarsals ($m.t.^3$); it then grows right and left as a horizontal wedge. The most evident subdivision of this piece is to be seen in nestling sparrows (*Passer domesticus*) when the bony deposit is in these lobes. Belonging to the 2nd, 3rd, and 4th metacarpal, this piece corresponds with the inner part of the "cuboid," and the outer and middle "cuneiform" bones of one foot. But in our foot there is an element called the "scaphoid": it is wedged in between the astragalus (*tibiale*) and the three cuneiform bones. This element is more or less developed, generally, in embryo birds: in fowls, struthious birds, and Tinamous, and in arboreal birds generally, it becomes ossified, and serves as a *sesamoid* to the plantar tendons. Morse (*op. cit.*, Plate I., fig. 8) figures it in the embryo of the Eider duck, and puts a ? to it.

It is not quite distinct even in my second stage; but I shall describe it in

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* I greatly rejoice over the work of my young friends, whose views are criticized above; but I have spent *years* over this kind of work, where they have spent *weeks*. There is such a thing as "personal equation" to be made account of in scientific research; and there is such a state of mind in some workers, that they believe in no eyes but their own.

the 4th. This nucleus is found in the large interarticular plate, which is seen between the proximal and distaltarsal masses in the inner (*tibial*) side of the joint, and becomes thrust backwards when the ankle is complete: the scaphoid is a *centrale.* This part was first seen by me to have this interpretation early in 1886; and soon afterwards (independently) by my son, T. J. Parker, in the embryo of the *Apteryx.* It is very large in the adult *Buceros ruficollis*, and is permanently anchored to the large interarticular fibro-cartilage. Even in the adult, where it serves a sesamoidal function, it is permanently fixed between the astragalus and the part which answers to the middle cuneiform bone.*

These two stages (Plate I., figs. 3, 4) show how the fore-paw of a reptilian form begins to take on the ornithic characters. In its utmost specialization (the whole limb becoming single down to the toes, and then supported on four, three, or even two of these), the leg and the shank being, as in the flamingo and stilt plover, extremely elongated; and yet, so exquisitely hinged and upheld, that one limb alone is sufficient for the firm support of the whole body. This last result of the avian transformation cannot be too much admired. Nor are the varieties of the avian leg and foot less excellent in this class, each member of which is a cunning gymnast. Here in the duck we have the beginning of that modification of the hind limb which has attained its utmost perfection in the loon (Colymbus). Already, in stage 1, the hallux, or 1st digit, is being carried away from the tarsus; in stage 2, its arrested metatarsal ($m.t.^1$) is attached to the middle of the next ($m.t.^2$); still, even in this stage, the toes are sprawling, and their metatarsals are free and diverging. In stage 1 the digits (fig. 2, $dg.^{1-4}$) are soft, and their phalangeal segments very undefined; in stage 2 (fig. 4) these are hardening and sub-dividing: the remnant of the 5th ($m.t.^5$) can now be seen as a globular mass of softish cartilage. Had it been developed with three or four phalanges at its end, the reptilian foot would have been complete.

Even in the second stage the toes are amphibian as yet; and the general

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* See T. J. Parker, Proceedings, Royal Society, 1888, p. 487; and W. K. Parker, *ibid.*, 1887, p. 58.

web, which is retained for all but the 1st digit, is simply the common expansion of the paddle, or hind oar, of a low, swimming creature.

STAGE 3.—*Embryo of Duck, after Twelve Days' Incubation.*

In three days' growth the sprawling reptilian foot becomes almost typically *ornithic:* it is typically *ornithoscelidan.* What concerns us most now is the further and further marking of the elements of the ankle-joint and instep, tarsus and metatarsus. The bony shaft of the tibia (fig. 10, *t.*) is creeping along the cartilaginous rod; the fibula, also, and the femur are ossifying. In the figure, the parts that form the ankle-joint are shown in a dislocated state for illustrative purposes. As yet the tibia, proximal tarsal, and distal-tarsal masses, and the metatarsals (fig. 10) are all distinct; but the three elements of the proximal tarsal row are all fused together: the distal was always undivided. The tibia, having starved the fibula, is dilated below and deeply grooved, with extensor tendons in front: it is gently concave behind. The curious knuckle which is strapped to it below has a double condylar face below, and is like two heavy wheels joined by a broad axle. This part is hollowed out, right and left above, for the lobes of the tibia to fit into; while towards the outer (or *fibular*) side, there runs upwards a long tongue of cartilage, which is bound to the front of the outer tibial ridge; actually, this band reaches to the tibial ectostosis. On its tibial side it has a square but convex bridge of newer and softer cartilage attached to it, which passes over the deep *tendon valley* of the tibia.*

In the Papers, above referred to, neither Gegenbaur nor Huxley seem to have dreamed of there being more than the *astragalus* in the large proximal tarsal mass. The latter says (*l. c.*, p. 29) of this part in the fowl :—" The astragalus is a much depressed bone, with a concave proximal and a convex pulley-like distal surface. A process ascends from its front margin in the groove in the front face of the tibia. This process is comparatively short, and perforated by two canals for the *tibialis anticus* and *extensor communis* in

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* In my Memoir on *Balæniceps*, p. 343, I erroneously ascribed the formation of the tendon bridge to the " ascending process " of the astragalus.

the fowl; while in the ostrich and emu it is extremely long and not so perforated." Note here that the later band of cartilage had already become ossified and fused with the short ascending process in the pullet's leg described by Professor Huxley; and here again the anatine type is seen to correspond with the struthious, and to differ from the gallinaceous. I trust that these figures and descriptions of mine will at least suggest to the palæontologist that he is not observing the *primitive condition* of the limbs of Dinosaurs, nor, indeed, of the remains of any *adult* extinct reptile whatever.

If, in the development of a duck's leg, such a complete fusion of the three primary proximal tarsals takes place in three days (Plate I., figs. 4 and 10), surely some allowance may be made for the pre-natal transformation of an ornithoscelidan reptile. It is seen here (fig. 10, *tb.*, *fbe.*, *i.*) that the lesser fibulare has become completely fused with the larger tibiale, and the intermedium with both: these three were all equally independent of each other. The long tongue-shaped intermedium (*i.*) is united with the fibular part of the common mass by a shorter, and to the tibial parts by a longer tract of cartilage. The scaphoid, or centrale (*c.*) is a lunate wedge of cartilage behind the tibial side of the joint, and is not, in the duck, formed into solid cartilage as it is in the fowl. The great distaltarsal (*d.t.*) has become completely formed, so as to show two concavities above for the condyles of the proximal piece, and also a rounded intercondylar process to fit into the hollow in the front of the upper piece; behind, it has sent down four ridges, the larger on the tibial side; these form the tendon-bridges and pulleys (fig. 11). The three main metatarsals ($m.t.^{2-4}$) are seen now to be closely applied to each other, and to be ossifying; their round tops fit into three concavities in the base of the distaltarsal. The fifth metatarsal ($m.t.^{5}$) is still to be seen as a small nucleus of cartilage: the first has not been figured; it has got down nearly to the end of the shank. Even the condyle of the second, however, is higher up than either that of the third or the fourth. This is an adaptive condition having relation to the aquatic habits of the bird.

STAGE 4.—*Embryo of Duck, Fourteen Days' Incubation.*

In this stage the intermedium (Plate I., fig. 12, *i.*) is still unossified; but this process begins directly after this time, that is on the fifteenth day, or at the middle of the period of incubation. The tibia (*t.*) is still distinct from the mass below; the centrale can be seen as a definite nucleus; the fifth metatarsal ($m.t.^5$) is now confluent with the fourth.

STAGE 5.—*Embryo of Duck, Eighteen Days' Incubation.*

The ossification of the intermedium, which began on the fifteenth day, is now nearly perfect, only the connective tract at the base being soft. The ectosteal tract (fig. 13, *i.*) begins as a thin bony ring round the bar, below the middle, and rapidly runs to the apex below it: the tibiale and fibulare (*tb.*, *fbe.*) are still unossified, and are still free from the tibia, above: the toe of the pedate base of the intermedium bounds the round intercondylar concavity in which the knob of the distal tarsal fits: the tendon bridge over these is now well developed.

STAGE 6.—*Duckling, Three Days old.*

In the middle of the first week after hatching, the sections through the ankle-joint show a bone in each of the pulley-like elevations of the proximal tarsal mass; and also one in the centre of the great distaltarsal. The tibia is still distinct from the former, and the metatarsals from the latter (Plate I., figs. 14, 15, *t.*, *tb.*, *fbe.*, *d.t.*, *m.t.*).

In one figure (14) the tibiale is cut through, but the lower bony centre is not reached; in the other (15), both the fibulare and the metatarsal centres are exposed; these are all three of the normal kind of bony deposits for these short segments of the limb. They are "central endostoses," and are a long while coming to the surface; so that, if the ascending process were in reality a mere periosteal growth of the double proximal tarsal, two things would have to be proved concerning it: firstly, that it did not appear until the bird was fully adult; and, secondly, that it had not its own osseous centre. The merest tyro in anatomy knows that this is true. In the duckling of the first week the "centrale" has degenerated into a mass of fibro-cartilage, forming part of the tendon sheaths at the back of the joint. Water-birds do not conserve this element as an ossified and distinct piece.

The Hind-limb of the Swans (Cygninæ).

In the almost ripe embryo of *Cygnus nigricollis* (Plate III., fig. 8, and Plate IV.) the ankle-joint is quite like that of the fifth stage of the embryo duck, except that the intermedium (*i.*) is shorter. After hatching, the growth of the swan's young is evidently slower than that of the duckling—cygnets of a month old being not much more advanced in this respect than ducklings of the first week. Happy in the possession of two of these, which were about equal in size to a teal (*Querquedula crecca*), I can show that, whilst the intermedium begins to ossify by the middle of the incubating period, the central endostosis, forming the rudiment of the tibiale, fibulare, and distal tarsal, has only reached the perichondrium at the end of a month after that period (Plate V., figs. 8–10); no periosteal deposit is possible as yet; and, even afterwards, the double mass (when the tibiale and fibulare are completely fused) is covered with articular cartilage, except where it has become fused with the tibial shaft-bone. Thus, the formation of the ascending process, as a *periosteal outgrowth*, is impossible.

The rest of the hind-limb in the swan, and in the Anatidæ generally, is constructed for swimming, and even for diving, in the ducks, and especially the mergansers. The two inner and larger post-tarsal ridges form a bridge over a flexor tendon, as in the fowl: the tarso-metatarsus is compressed laterally: the fourth digit is elongated, the second and first elevated, and the latter is small and free.

Wing of Embryo ($\frac{3}{5}$ ripe) of Falkland Island Goose (Chloëphaga poliocephala).

When Dr. R. W. Shufeldt called the displaced first distal tarsal "pentosteon," five carpals were known in the young bird; although, in almost every case, only the two proximal pieces remain distinct.

Dr. Morse* satisfied himself that the so-called "ulnare" was a double nucleus. And he was right: it is so, morphologically; and is, not unfrequently, actually subdivided into two, or even three nuclei. In a Paper, soon to be printed,† I have shown that the "radiale," also, may be in two pieces: for a time it is so in Opiosthocomus, the subject of that Paper; and I find it so, also, in *Falco tinnunculus.*

The subdivision of the ulnare is seen in two of the most terrestrial forms of the Chenomorphæ, namely, in this goose and in the screamer (*Chauna chavaria*). This is the more interesting, because the long-legged terrestrial geese are very apt to have spurs on their wings (*e.g.* Chenalopex, Plectropterus); and these spurs have their highest development in the unwebbed Palamedidæ—birds with cultrate bills. Thus, whilst on one hand the Chenomorphæ are walking, or, at most, wading birds; on the other, the mergansers have certainly a smack of both the cormorant and the diver in their nature. This makes it extremely difficult to conceive of the whole bundle of Chenomorphæ as branches of one stem.

In the embryo of *Chloëphaga poliocephala* the claws are well developed in the wing (Plate V., figs. 12 and 13), that on the index ($dg.^2$) being especially long. The parts at the lower hinge of the wing are as remarkable for their great number as these parts in an adult bird generally are for their fewness. The radiale (*re.*) is single; but the thick U-shaped ulnare ($ue.$, $c.^1$, $c.^2$) has both its crura segmented across, almost perfectly, to form an outer and an inner "centrale" (fig. 14, $c.^1$, $c.^2$). At this stage the three distalcarpals ($d.c.^{1\text{-}3}$) are clearly marked out; and on the edge of the third metacarpal, on

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* *Loc. cit.*

† In the Transactions, Zoological Society of London.

its flexor side (figs. 14, 14[a]), there is a distinct rudiment of a fifth metacarpal (*m.c.*^{5}). On the proximal part of the second metacarpal, at the outer face of its ulnar edge, there is a distinct semi-lanceolate accessory cartilage (*m.c.* 2^1): the accessory part to the proximal phalanx of the digit (*dg.* 2^1) has coalesced with the main piece on its ulnar side, and is ossified by it, not independently. The sub-division of the ulnare is not so evident on the *right* side as on the *left.* When the spur is formed on the "trochanter" of the first metacarpal (*m.c.*^{1}) in some of the geese, there is in this case a considerable tract of fibro-cartilage ready for any such adaptive growth.

Whilst the peculiarities of this embryo, and of that of the kestrel, were the only types in which I had seen this remarkable sub-division of the radiale in one, and of the ulnare in the other, they caused me much anxiety: now I find that this is not so rare a condition as I had supposed.

But for a quarter of a century I had been aware of a divided "ulnare" in *Chauna chavaria.* In that bird, on the left side, there are two proximal carpal bones attached to the ulna (Plate II., fig. 13, *ue., c.*): the outer is the *outer centrale*, and the inner is the "ulnare" proper: this is one-third larger than the other. Here, again, this peculiarity is seen on the *left* side, and not on the right.

In the other Palmipeds we shall see parts of the wing-skeleton that have hitherto been quite unnoticed. We are only just waking up to the fact that the things that now are have not been so always since the foundation of the world.

In the cultrate Palamedidæ, and in some of the lamellirostral forms, the wing has *spurs* similar to those on the shank of the Phasianidæ. Dr. Sclater* quotes, with approbation, the views of Mr. J. Amory Jeffries.† His words are:—" Mr. Jeffries shows definitely, for the first time so far as I can make out, that the spurs which are in some cases found on the wings of birds are of an entirely different nature from the claws also met with on

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* Ibis, 1886, p. 147.

† "On the Claws and Spurs on Birds' Wings": Proceedings, Boston Soc. Nat. Hist., vol. xxi., p. 301.

the same organs, and have in fact nothing whatever to do with them." In a note on this same page, Dr. Sclater says:—"Even so recent an authority as Dr. Selenka* has confounded together the spur and claw of birds. His account of the subject contains several serious misstatements, and is obviously not based on his own examination. Owen's 'Anatomy of Vertebrates' (*cf.*, *op. cit.* II., p. 74) likewise confounds claws and spurs. It must be even admitted that Nitzsch (usually a model of accuracy, and the first scientific describer of the claws of birds) did not quite understand the differences between claws and spurs."†

I must also, myself, confess to having confounded claws with spurs in my Paper "On Balæniceps,"‡ and also in that "On Gallinaceous Birds and Tinamous," § I have put the hallux as the *second toe*, considering the spur of the cock to be the abortively developed *first toe*.

That error was corrected by Gegenbaur,‖ and his views were adopted by Huxley.¶ The hind-toe or hallux does certainly correspond with the innermost, or first toe, in a lizard's hind-foot, just as the pollex of the bird corresponds with the innermost digit of the fore-foot of a lizard. The normal number of phalanges determines this, namely from *two* in the first to *five* in the fourth, and then a diminution in number in the fifth.

But this matter cannot be settled and made sure for ever to science by the study of adult birds. If Dr. Sclater had compared the wing of *Chauna derbiana* (*op. cit.*, p. 150, fig. 2) with Dollo's figures of *Iguanodon bernissartensis*,** or even with some of my figures of the early state of the digits of the wing,†† his sense of certainty would have yielded to the confusion of

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* Bronn's "Thier-Reich": Aves, p. 75.

† See his "Osteographische Beiträge, No. 5": Ueber das Nagelglied der Flügelfinger, besonders des Daumens: Leipzig, 1811.

‡ Transactions, Zoological Society, vol. iv., Plate LXVI.

§ *Ibid.*, vol. v., Plate XXXV.

‖ "Vergleichend-anatomische Bemerkungen über das Fussskelet der Vögel": Archiv. für Anat. und Phys., 1863.

¶ Proceedings, Zoological Society, 1867, p. 417.

** Bull. Mus. Roy. Hist. Nat. Belg., t. i., Plate IX., figs. 2, 3.

†† Philosophical Transactions, 1888, B., Plate LXII., figs. 1, 2.

mind attributed by him to Owen and Nitzsch. In that huge extinct reptile, with its extremely avian hind-quarters, both the pollex and the fifth finger diverge at a right angle from the rest. If the horn-core and the small bone at its base had been anchylosed to the other parts, nothing would have appeared more certain than the precise homology of that pollex with the upper spur in Palamedea and Chauna. The difficulty does not, however, cease here. In a continuation of his valuable Paper,* Dr. Sclater shows that the large spur on the wing of the spur-winged goose (*Plectropterus gambensis*) is on a projection of the radiale, or inner proximal carpal. Nothing, to those who are satisfied with *adult anatomy*, could be clearer than this proof that the spurs are of an entirely different nature from the claws also met with on the same organs, and have, in fact, nothing whatever to do with them.

But we must, as the saying is, "go slowly that we may make the more speed." I would remind Mr. Jeffries and Dr. Sclater that, in the evolution of the cheiropterygium from the ichthyopterygium, *claws are a late specialization.* Only Dactylethra, amongst existing Amphibia, possesses them. In the Reptilia, as in Dactylethra, the *straight nailless terminal phalanges* grew out into the skin-fold, and there received a horny covering, both the dermal layer and the terminal phalanx becoming covered, and so forming a hooked claw.

But the normal digits of the highly specialized pentadactyle cheiropterygium are not the only parts we have to deal with in the limbs of birds and mammals. Neither birds nor mammals are the descendants of *true* reptiles, but of much more ancient and generalized types.

I find, taking the birds as a whole—in this bird and in that—a row of cartilaginous nuclei inside, or in front of, the normal first digit, or pollex. These I shall describe in a Paper succeeding the present. Not only these segments of a "pre-pollex," but intercalary segments are also common in the developing wing of a bird—feeble forkings of the digits; a reappearing, or rather a *lingering*, of vestiges or remnants of some archaic polydactyle limb. In the common fowl the core of the cock's spur is at first a solid

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* Ibis, 1886, pp. 300–301, fig. 3.

fibro-cartilage—a "pre-hallux": it fuses with the second metacarpal after it has become ossified.

Now, the presence of two spurs on the same limb in the shank of Polyplectron, and in the wing of Chauna,[*] seems at first blush to decide the merely *adaptive* and, as it were, *accidental* nature of these spurs. My answer to this is that there are two phalanges which appear between the pollex and index in birds; and that the distal of these two segments is present in by far the greater number of Passerine birds. That segment is a triangular plate of true hyaline cartilage, autogenously ossified by *endostosis*, and becomes fused with the *ectosteal sheath* of the second metacarpal, near its lower end; and is manifestly the true homologue of the horn-core of the distal spur in the Palamedidæ.

THE ALCIDÆ.

This palæarctic family, which has only lately lost its chief—*Alca impennis*—is still rich in forms ranging in size, if we take in the great lost species, from a large goose to a small gosling; for *Ciceronia pusilla* scarcely exceeds the size of the latter.

These birds are the *isomorphs* of the nearctic penguins (Spheniscidæ); and, in the case of the great auk, the approach of the northern to the southern type was very close.

As to the penguins, they are a much more isolated type than the auks and guillemots, and are also much more uniform. Specialized to the uttermost in one direction, they are nevertheless evidently *archaic*. The tendency of the Alcidæ is in the same direction: they appear, however, to have begun to modify in this direction later than the penguins, and the transformation is only partial. This, however, is pure conjecture. Professor Huxley's "Classification"[†] breaks down most among these water-birds. His "Cecomorphæ" are a promiscuous flock of Palmipeds driven together by the "whiff and wind" of his taxonomic force. If it pleases

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[*] Sclater, *op. cit.*, p. 150, fig. 2.

[†] Proceedings, Zoological Society, 1867, pp. 415–472.

him to call the group the gull-form, he must not be surprised if the next classifier should scare them all apart again.

Dr. Marsh did this unconsciously; for his toothed birds show, if they show anything (and they are the most lucid revelation we have had on this subject as yet) that the divers and the gulls were as far apart in the secondary epoch as they are now. The Ichthyornis is evidently an archaic toothed gull; and the Hesperornis, which anticipates the modern terrestrial Ratitæ, has, like its nearest living relatives, the grebes and loons (Podicipitidæ, and Colymbidæ), cylindroidal vertebræ down to its sacrum. Ichthyornis, a Carinate, has its pre-sacrals amphicœlous—a condition scarcely improved upon by the existing gulls in their hinder dorsals: their cervicals are cylindroidal. This modern group of the Alcidæ, like the existing gulls, have opisthocœlous dorsals; and so have the penguins and the plovers, the cormorants and the darters; but grebes and loons, like Hesperornis, have the whole pre-sacral series cylindroidal; in which they agree with the modern Ratitæ on one hand, and with the petrels and all the "Steganopods" or Tolipalmatæ, except the cormorants and darters (Phalacrocoracidæ) and Plotidæ.

In respect of the dorsal vertebræ the Alcidæ and Laridæ agree, and their skull* is very similar fundamentally; but so, also, is that of the aberrant Limicolæ, *e.g.* Chionis, Attagis, and Thinocorus; and the Rallidæ, also, come very close in this respect. The fact of the case is that, in great numbers of those schizognathous birds that abort their basi-pterygoids, there is a wonderful conformity in this respect.

But the skull of the penguins is also one of the same type; it is somewhat more archaic certainly; but there is nothing in that part, nor in the rest of the bird, it seems to me, sufficient to warrant the separation of that one family into a sort of order—the "Spheniscomorphæ"—whilst gulls, skuas, petrels, auks, guillemots, loons, and grebes are put together by force into a sort of "happy family": their harmony will end the moment the personality of the "keeper" ceases to dominate them.

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* See Huxley, *op. cit.*, p. 430, figs. 10, 11.

In some respects the gulls and auks agree; they are as unlike, on the whole, as it is possible for two groups of water-birds to be.

THE MORPHOLOGY OF THE ALCIDÆ.*

The Cranium in Uria troile.

STAGE 1.—*Skull of Embryo of* Uria troile, *One-third ripe.*

The chondrocranium, at this stage, is fully formed (Plate VI., fig. 1). The basal part is the most instructive; the other regions will come under notice in the more advanced stages.†

The transitory, as well as the permanent, parts of the endocranium are well developed; much of the latter will undergo osseous transformation. The chondrocranium, at present, has some little likeness to that of a skate, the skull proper being so short, and the pre-nasal rostrum so long; but this is a high skull, like that of a perch, and that of the skate is a low one. Here the brain is tilted upwards in front, and lies on the coping of a large wall: in the skate, as in the Amphibia, the brain lies down on the flat basi-cranial floor. The chondrocranium has not yet begun to ossify; the notochord (*nc.*) is still large; but the parachordal tracts have united across it, have coalesced with the cartilaginous ear-capsules, and have sent upwards lateral growths that have met, right and left, and become confluent, over the hind brain. Behind, the double tract of cartilage has formed the almost hemispherical occipital condyle (*oc.c.*); and, in front of

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* For the osteology of the same parts of the embryo of Alcidæ, see my "Shoulder-girdle and Sternum" (Plate XVII., figs. 10–14, pp. 146–148); and of the adult bird, see Owen, "On *Alca impennis*," Transactions, Zoological Society, vol. v., Plates LI.–LII., pp. 317–335; and R. W. Shufeldt, "Osteology of Arctic and Antarctic Water Birds."—Journal of Anatomy and Physiology, vol. xxiii., Plates I.–V., pp. 1–39; *ibid.*, Plates VII.–XI., pp. 165–186; *ibid.*, pp. 400–558.

† For figures and descriptions of the very similar skull of *Gavia ridibunda*, see Transactions, Linnean Society, series 2, vol i., Plates XXVI.–XXVII., pp. 140–151.

this, and further outwards, we see the passages for the hypoglossal (xii.), and vagus and glossopharyngeal nerves (ix., x.).

The auditory capsules occupy a very large space in the sides and base of this delicate semi-transparent chondrocranium. The lagenæ (*au.*), and the canals (*a.s.c.*, *h.s.c.*, *p.s.c.*) shine through the thin, clear walls. In front of these capsules the base of the skull suddenly closes in; the notochord is lost to view, for it ascends into the post-clinoid wall (see in stage 3, fig. 8, *p.cl.*). In front of that wall there is a round opening—the pituitary space, which receives a secondary floor, but is not, as in our cranium, floored with cartilage—the seat of the "sella turcica." That open hole was formed by the growth of the trabeculæ round the pituitary involution; there they met, and coalesced with, the parachordals or investing mass enclosing the notochord behind. Meeting in front of this open space, the trabeculæ run forwards, and, *apparently*, at this stage, form the long, thick, rounded balk of cartilage which runs forwards to the end of the beak. But a little in front of the pituitary space there was formed a median cartilage, which wedged itself in between the other two, and can therefore be fitly called the *intertrabecula.* The paired trabeculæ only run half way to the end; flattening out, they grow upwards and help to form the orbito-nasal partition wall (see, in 3rd stage, fig. 8, *tr.*, *p.e.*, *s.n.*). The trabeculæ, in some cases, send out flat cornua where they end.* I do not see these parts in Uria. The foremost third of the long wall is free; it has no wall growing upwards from it: it is a large *Raiine pre-nasal rostrum.* Just when it is becoming free, it is somewhat twisted, as also is the primary mandible below (fig. 2, *mk.*). I shall refer to this in the next stage. The large alisphenoidal, and the aborted orbito-sphenoidal wings will be described in the 3rd stage (fig. 8, *al.s.*, *o.s.*).

Instead of the direct basi-cranial outgrowths for articulation with the pterygoids, as in lizards and the Ratitæ,† these birds, like the fowl and most other Carinatæ, develope separate *remnants* of those basi-pterygoid outgrowths (fig. 1, *b.pg.*). In these, and many other birds, these parts,

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* See in Chick, Philosophical Transactions, 1869, Plate LXXXIII., fig. 4, *s.v.l.*

† See Philosophical Transactions, 1866, Plate VII., figs. 2 and 4, *ap.*

and the joint formed by them and the pterygoids, is only a temporary structure; and in many of the passerines the remnants themselves are suppressed.*

The pier of the first visceral arch—the quadratum (*q.*)—is a large segment, and very amphibian in the bird, as in the Chelonia. Here we see that its pedicle or primary swinging point, the orbital process is free and rounded; its secondary head, or "otic process" is large and bilobate, obliquely. Below, the short, thick, main bar ends as a sinuously convex condyle for articulation with the next segment of this inverted arch—the articulo-meckelian rod (fig. 2, *m.k.*). That rod, right and left, is almost as solid as the great cartilaginous skull balk: it is a long, terete, sinuous rod, gently lessened in front, rounded at its end, and lobate and scooped behind for articulation with its own upper segment: it has, like its counterpart in the marsupial Mammals (the future malleus), both an internal and an external angular process (*i.a.p.*, *p.a.p.*). The meckelian rods do not coalesce distally, or in front, as they do in the Mammalia, but remain free as long as they exist, as in lizards and snakes.† In morphological language, the quadrate is the first epi-branchial, and the articulo-meckelian rod the first cerato-branchial. They were gill arches.

The second visceral arch—the hyoid—is half suppressed. Its uppermost segment, as in the Amphibia and Reptilia, has been dominated by the organ of hearing, and is aborted and specialized: this part is the columella (fig. 1, *co.*): it has a dilated proximal, and a trifid distal end. In morphology it is a pharyngo-branchial segment. In some birds a distinct epi-branchial segment is formed, and coalesces with the lower ray of the columella—the "infra-stapedial": distally, the cerato-hyal appear in the hypo-hyal region. The right and left cerato-hyals (fig. 3, *c.hy.*) are terete, lessen forwards, and meet each other in the sagittiform tongue. Between and behind these the old basi-branchial reappears (*b.br.*): it is thickest towards the front, and lessens behind, where it ends

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* Monthly Micr. Jour., March 1st, 1873, Plates VIII.–X.

† Philosophical Transactions, 1878, Plates XXVIII., XXIX.; and *ibid.*, 1879, Plate XLI., fig. 3, *mt.*

free and pointed: it represents several median segments. One branchial arch, which answers to the first gill-bearer in osseous fishes (fig. 3, *br.*[1]), is developed. It is in two segments; the larger is the distal; this is ossifying: the lesser is still soft, and is free above; it curls round behind the occiput. I have not described the nasal capsules in this stage: I shall refer to them in the next.

The ectocranium, at this stage, has all its primary centres of ossification started: they are creeping tracts of osteoblasts forming in the subcutaneous web, and are very similar in character, in form, and in relation to those which are formed in the chondrocranium of an osseous fish. Indeed, it is with the Ichthyopsida generally, and not with the existing Reptiles, that the developing skull of a bird has to be compared, if its interpretation is to be made sure. Yet, no osseous fish or existing amphibian, and no reptile now living, has such an extremely prognathous face as this. As the primary pterygo-palatine arcade (*pg. pa.*) is almost entirely suppressed, the pterygoids and palatines are here reduced to the condition of mere parostoses like the premaxillaries, maxillaries, jugals, and quadrato-jugals (*px. mx.*, *q. j.*). All *ascent* in the Vertebrata skull is attended with the fading of the chondrocranial parts, and the flourishing of the ectocranial elements. The dominating splints of the upper face are the premaxillaries (*px.*), as in typical osseous fishes: these use the Raiine pre-nasal rostrum (*p.n.*) as a model, then destroy it by their own overgrowth. The maxillaries (*mx.*) are mere "ossa mystacea" lying behind and within the premaxillaries: they have already formed an angular process, the part that overlaps the jugal arch, and also their palatine process—maxillo-palatine (*mx.p.*)—a curved retral style, with its curved outline inwards. Between these two processes the palatine (*pa.*) sends its styloid fore-part: it then dilates, bends outwards, and sends inwards an ascending process to bind upon the basis cranii, and with its fellow to hold the vomer as in a vice. Overlapping the inner side of these bones, behind, we see the falchion-shaped pterygoids (*pg.*) that are already cupped at their other ends, and are fitted to the knob on the quadrate: this knob is a small stump of what was, in the ichthyopsidan ancestor, a long pterygo-palatine cartilage. The quadrato-jugal (*q.j.*) hooks itself into the outer face of the quadrate (*q.*) behind, and overlaps the jugal (*j.*), and the third or jugal process of the maxillary (*mx.*) in front.

Perfecting the palato-maxillary framework in front, we see the vomer (*v.*); at present it is in two halves, which are mixing their osteoblasts under the intertrabecular balk; these moieties, in front, reach to the middle of the maxillo-palatine, and, behind, touch the ascending processes of the palatine.

Outside the quadrate, the squamosal (*sq.*), its proper splint, is walling in the temples, right and left: out of sight, in this view, the nasals, frontals, and parietals are rapidly forming: they will be described in the next stage (Plate VII. and Plate VI., figs. 4, 5, *n.*, *f.*, *p.*). On the lower jaw (Plate VI., fig. 2) four splints are forming, the dentary splenial, supra-angulare, and angulare (*d.sp.*, *s.ag.*, *ag.*): there is no distinct coronoid.

The last parostosis to be described is the first to appear in the development of the skull in the Vertebrata: this is the parasphenoid. To support the huge hypertrophied mass of hyaline cartilage in those selachian Ganoids, the sturgeons (Acipenseridæ), with their imperfectly developed vertebral chain—not fairly differentiated from the cranium, a huge bony splint, is formed, a hard balk under a soft balk for support and strength. This is the first appearance, morphologically speaking, of the parasphenoid.*

Passing to the higher Ganoids and Dipnoi, and thence to the Teleostei, on the one hand, and the Amphibia on the other, we see the parasphenoid becoming dominated by the cranium, and having no sub-vertebral development. All at once, in existing Reptiles, it is fading away, and is quite lost in some lizards (*e.g.*, Trachydosaurus), and in the Chelonia.

It is to the extinct Reptiles, and to the Amphibia, that we must look for anything like what is found in the basis cranii of a bird; and in the former class, not to the Ornithoscelida, with their bird-like hind-quarters, but to those *quasi-Cetaceans*, the Ichthyosaurs.

As a rule, the parasphenoid is like a dagger, with its blade, guard, and handle. In some Anura (*e.g.* Pseudis)† there is no handle to this bone:

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* This is Professor Huxley's term (see "Elem. Comp. Anat.," 1864, p. 170)—a term which, in Morphology, is "a nail in a sure place." This is the bone which, in fishes, was to be divided by Owen's saw! That act of violence was not needed.

† See Philosophical Transactions, 1881, Plates II., X., XI., XII., *pa.s.*

this is what is seen in this embryo of Uria (Plate VI., fig. 1, *pa.s.*). Here the blade is very narrow, being developed later than the guard, which has a right and left centre of ossification in birds.* In the Amphibia, when not in one centre, this element has the point of the blade separate.†

STAGE 2.—*Skull of Embryo of* Uria troile, *two-thirds ripe.*

In this stage (Plate VI., figs. 4–7, and Plate VII.) the *general* has rapidly passed into the *special;* this is in a typical schizorhinal skull, with a sharp face, and having the nasal (*n*) bones split almost up to their frontal or hinder margin. It is now a pattern-form, so to speak, for all those skulls that with this form of the nasals are permanently schizognathous, as in this bird and in a large number of the swimming and wading forms—gulls, grebes, loons, rails, plovers, cranes, &c.; and also for many that become desmognathous, as the ibises, spoon-bills, storks, &c.‡

The endocranium (Plate VI., fig. 4) now shows the normal osseous centres; the oblong basi-occipital (*b.o.*) has formed round the notochord; at a distance from it the ex-occipitals (*e.o.*) are seen as large square plates, enclosing the nerves; and, at a greater distance, the double supra-occipitals form a keystone to the occipital arch. The basisphenoid (*b.s.*) is not, as in Reptiles and Mammals, an independent bone, but, as in certain Urodeles, the parasphenoid (*pa.s.*) grafts itself upon the cartilage at that part: the alisphenoids (Plate VII., *al.s.*) are large cartilaginous wings, with a thick sphenotic outgrowth (*sp.o.*). A large pyriform fenestra (*i.o.f.*) is formed in the high, interorbital wall: above the narrow upper end of this oblique span the presphenoidal region (*p.s.*) is somewhat lipped; these lips are the arrested orbitosphenoids (*o.s.*). Running under the wall, and becoming

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* See Philosophical Transactions, 1869, Plate LXXXII., fig. 2, *b.t.*

† Philosophical Transactions, 1881, Plate VIII., fig. 2, *pa.s.*

‡ All such characters as holorhinal and schizorhinal, schizognathous and desmognathous, are valuable and useful in classification, up to a certain point. The exceptions, however, are the most instructive forms, such as the flamingo—an anserine ibis, and psophia—a tinamine crane: these are exceptionally holorhinal among schizorhinal tribes.

free at the fore end, the trabecular balk, in its fore half, where it is simply the azygous intertrabecula (Plate VI., fig. 4, *i.tr.*), becomes twisted: it is like a worm struggling to be free; and, indeed, it is becoming fast bound by the enclosing parostoses, that conquer and then destroy it, after building themselves upon it. This rod is only two-thirds as thick as it was in Stage 1 (fig. 1, *p.n.*). Seen laterally, the nasal labyrinth is large, and is quite cartilaginous at present. In all birds the perpendicular ethmoid (*p.e.*) is greatly overgrown, and, in its ossification, thrusts the presphenoid upwards, by meeting and uniting with the basisphenoid: it surrounds all but the hinder and upper part of the great fenestra (*i.o.f.*), and reaches, in front, to the craniofacial hinge (see Stage 3, Plate VI., fig. 8): beyond that part the mesethmoidal wall is differentiated into the septum nasi. The great appearance of complexity in the outer walls of the nasal labyrinth only partially corresponds to what is found within. In front of the orbits the cartilaginous roof, continuous with the wall, is folded over, and a flat plate—"pars plana" or antorbital—is developed as the back wall of the labyrinth: its pointed antero-inferior corner is free, and is the rudiment of the ethmo-palatine bar of a frog, or other Amphibian—Anuran or Urodele. The simple coiling downwards and inwards of the aliethmoids, and the aliseptal coils which form a scroll of less than two horns, the inferior turbinal (Plate VII., *i.tb.*) are like those of the duck or fowl.* The alinasals or valvular folds (*al.n.*) that grow from the fore part of the septum, and in front of it, answering to our "alæ nasi," are long and simple: the external nostril (*e.n.*) which they form is obliquely sub-terminal and reniform.

The quadrate (*q.*) is now ossifying; a large ectosteal sheath has formed on it; and a flat ectosteal plate (fig. 6, *ar.*) has applied itself to the proximal part of the articulo-meckelian rod (*mk.*) on its inner side; the endosteal centre which completes the articulare is formed afterwards. Answering to the single intertrabecula above, the paired meckelian rods below are longer and slenderer than in the last stage. Like that rod they are strangely twisted, but still more so (as if writhing within the splints); and, had they belonged

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* See Philosophical Transactions, 1869, Plate LXXXVI.

to the embryo of a captive, or even to that of a less domestic bird, I should have set down this structure to the account of teratology. That view is inadmissible; equally so is that of their having any teleological meaning. We are thus shut up to an ontological hypothesis. The moderate beak of the guillemot, with its horny sheath, has manifestly been modified from a much longer and a dentiferous beak—one like that of Marsh's toothed birds, and not unlike that of the long-faced Pterodactyles.

If this be the case, we may claim for these embryonic stages an importance equal, in science, to the various adult forms that are being slowly revealed to us in palæontology. As a morphologist "I magnify mine office," and boldly put my stages side by side with my friend O. C. Marsh's adult extinct forms.

This stage and the next are good for showing the normal form of the splint bones or ectocranium of a carinate bird—so unlike those of a Pterodactyle, or of Archæopteryx, and which are a marvellous refinement of such superficial bones as we see in the skull of the existing Ratitæ. Once attained, this type of growth of the outer skull-case is not in any important degree departed from. The figures here given might serve as a generalized diagram for the ectocranium of any one of the existing Carinatæ, which number more than twelve thousand species. If this fact does not prove that all these forms had one father, it at least suggests that they all arose from very similar ancestors.

The very peculiar form of a sauropsidan cranio-facial apparatus was a necessity that arose when the fore-paws were manacled and made useless for prehension in types that were to rival all others in intelligence and skill. We have on one hand, in the beginning, the dull, cold, aquatic quasi-salamandrian ancestor, and, on the other, in these latter days, the lively, hot-blooded songster—that most cunning winged architect. Thus, as the beak has to become the hand, and the neck the arm, the upper face has to be hinged upon the skull proper, and the lower face adapted, in its free mobility, to its elastic upper counterpart.*

In the fixed face of man, or any other mammal, the face and cranium

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* For a description of this apparatus, see Bell's "Human Hand," pp. 172–174.

make one undivided skull; the ecto-cranial plates are all firmly tied one to another, to form the solid whole. Here in the bird the extremes meet, of free mobility in the face and palate, and of complete fusion, by loss of all the sutures, in the proper cranial part; but the original form and condition of the splint-bones is quite similar in both regions. These parostoses are extremely thin and elastic in this second stage; but they have already almost a reptilian completeness, and fit one to another in perfect adaptation. The once double premaxillary (*px.*), in a manner truly avian, sends its nasal processes up to the forehead, between the split nasal bones (Plate VI., fig. 5, *n.*), the upper fork of which binds, right and left, upon those splinty processes. Below, in the fore-palate (fig. 4), the premaxillary is sharply split into a dentary and a palatine process on each side; and the great maxillary (*mx.*) wedges itself in between these styloid forks. That bone, becoming a triangular plate, then gives off, externally, a short angular and a long and slender jugal process; and, on its inside, is produced into a larger retral hook, the maxillo-palatine process (*mx.p.*). The jugal arch, externally, is finished by the long and slender jugal and quadrato-jugal (*j.*, *q.j.*), the former overlapping the other two splints, the latter hooking itself into the side of the quadrate (*q.*).

The palatines (*pa.*) are rather broad laths, bent a little outwards, broad behind, and styliform in front; the style runs along the inside of the palatine process of the premaxillary. The pterygoids (*pg.*), like two short pieces of "knee-timber," tie the palatines to the quadrate bones; they are only half the width, and one-third the length, of the latter; and, bending inwards at their middle, abut upon the temporary basi-pterygoids (*b.pg.*). In front, the pterygoid is styloid, and lies upon the palatine; that part undergoes osseous segmentation, and is then the temporary mesopterygoid; it then ankyloses with the palatine: behind, the pterygoid has a cupped facet, which forms a joint with a little ball on the quadrate. Returning to the palatine, we find, on its postero-internal edge a small keel, and outside it, a fossa: this structure is for muscular attachment: above, and in front of those keels, right and left, we see the styloid ascending process. The vomer (*v.*) wedges itself in at that part, and is clipped by these processes; it is a large, long, oblong bone, notched in front, and split in more than its hinder half: it was in two pieces (Plate VI., figs. 1, 2, *v.*).

The maxillo-palatine processes (*mx.p.*) ride over the palatines, and then, hooking themselves backwards in a rounded form, bind against the sides of the double vomer in its fore half.

Above, the lachrymals (Plate VI., fig. 5, Plate VII., *l.*) are seen to be small bony hooks, with just a rudiment of a free supra-orbital process, and a descending part that binds in between the descending arm of the nasal and the antorbital cartilage. The frontals and parietals (*f.*, *p.*,) fail at present to fill in this swollen roof, thus leaving a large fontenelle (*fo.*). The squamosals (*sq.*) are very remarkable, and show us that we have here a bird not cognate with the Anatidæ—the aquatic branch of the bifurcated gallo-anserine types—but a relation of the gulls and their allies. This is at present inexplicable; for, in the Cretaceous epoch, as we have seen,* the divers and the gulls were as far apart as they are at this day. In the swan (Plate IV., *sq.*) and in the fowl (*op. cit.*, Plate LXXXIV., fig. 8, *sq.*) the squamosal is a broad shield-shaped plate; but here, in this diver, it is long and falciform (Plate VII., *sq.*)—quite like that of the gull. This, we shall soon show, is not the only thing in which these two kinds of birds agree. Nevertheless, if Professor Huxley's Cecomorphæ is to contain both these types, it must also be strong enough to bind together Marsh's Hesperornis and his Ichthyornis.

The parasphenoid on the base (Plate VI., fig. 4, *pa.s.*) runs over the vomer as a grooved and styloid bar, the trabecular balk lying in the groove (see next stage, fig. 8, *pa.s.*); it has made a floor to the pituitary space, has ossified the basisphenoidal region, has formed the anterior tympanic recesses, and has grown into a pair of basi-temporal wings (*b.t.*) that support the lagenæ (*au.*).

Below, the four mandibular splints (fig. 6, *d.*, *sp.*, *s.ag.*, *ag.*) are elastic "withs" that are binding the struggling meckelian rods, which they will soon overcome (see next stage, fig. 8).

The hyoid arch in this stage is composed of the columella (*co.*) above and the two arches below; the infrastapedeal at about this time, acquires a small addition in the form of an arrested epi-hyal tract; this, in

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* Transactions, Linnean Society, New Series, Zoology, vol. i., Plates XXVI.–XXVII.

the adult, is the small tape of cartilage that lies upon the basi-temporal plate, at the lower edge of the membrana tympani. The rest of the hyoid (fig. 7) has not altered much, except in size, since the last stage (fig. 3); yet the cerato-hyals (*c.hy.*) are becoming fused to form a basal piece in front.

STAGE 3.—*Skull of Embryo of* Uria troile, *nearly Ripe.*

A vertically longitudinal section of the skull, at this stage (Plate VI., fig. 8), shows that the hind brain only lies in that part of the floor which is actually basal, and that this is only one-sixth of the length of the head. But the oblique basi-cranial line (from the occipital foramen to the fore end of the frontal cavity for the hemispheres) is half that length; the brain is a curved bulb, with its narrow part at the top and in front. The sudden lessening of the bulb at the middle of the hemispheres removes the necessity for any special orbito-sphenoids beneath it; but it causes a remarkable thrust, outwards, of the huge alisphenoids (*als.*), which are almost transversely placed, and form the back wall of the large orbits, which closely approximate right and left of the interorbital wall. This tilting of the brain is combined also with that of the auditory capsules, for these lie back so as to form an acute angle with the basis cranii. But the shortness of the hinder cranial floor is nothing new; where that floor is long, as in Selachii and Amphibia, the fore half is not axial; the axis, or notochord, always ends behind the pituitary involution. Here, in the bird, it only runs up into the post-clinoid wall (*p.cl.*), and then retreats,* so as to become the axis of the only part that can be shown to be homologous with a vertebral centrum or with centra. In the chick † the notochord becomes sub-moniliform; and, in the last of the three enlargements, the basi-occipital (*b.o.*) arises. Thus, the specialization of the neural axis is correlated with a specialization of the skeletal part that contains it; ‡ in Selachians this moniliform condition

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* See Fowl's Skull, Plate LXXXI., figs. 2–4, *nc.*

† See Fowl's Skull, Plate LXXXII., fig. 3, *nc.*

‡ Transactions, Zoological Society, vol. x., Plates XXXV. and LX., *nc.*

of the cranial end of the notochord is very remarkable, and shows how indefinite the boundary is between the cranium and the spine in those types.*

Whatever may be the nature of the *pro-chordal* tracts of the primitive cranium, they are responsible for a very large part of the cephalic endoskeleton; in this case for five-sixths of its length. The optic nerves (ii.) pass directly over the low hindpart of the great partition wall, at a short distance in front of the foramen ovale (v.), which is a large round notch, at present, between the auditory capsule and the wide alisphenoid. Between those two nerves the sixth, fourth, and third nerves escape into the orbit, whilst the seventh and eighth (vii., viii.) have their passages in the fundus of a pit in the auditory capsule—the "meatus auditorius internus." Between the capsule and the occipital arch the glossopharyngeal and vagus (x.) escape, and the hypoglossal (xii.) through the ex-occipital. Rising almost vertically, with the alisphenoid right and left of it, the wall at its oblique postero-superior corner is slightly two-lipped; these lips are the feeble orbito-sphenoid (*o.s.*). In front of this part the first nerve (i.) runs right and left of the wall-top, grooving it. The olfactory crus is simple, and supplies a very simple nasal labyrinth. In front of the bony sella turcica (*py.*) the great trabecular balk is seen to form a thick base to the wall. Above in the olfactory region the aliethmoidal laminæ grow out from its top; the partition and these alæ chondrify together, and the nasal capsule has lost its independence in these high types. A little further forwards the alæ are called aliseptal (Plate VII., *al.sp.*), and give rise to the coiled inferior turbinal; still further forwards they are called the alinasals (*al.n.*), being the valvular folds that surround the external nostril (*e.n.*). The great partition, once a continuous tract as in the adult Ratitæ, has now a large, oblique, pyriform fenestra between the eyes, and, in front of the true olfactory region, a large semi-circular notch (Plate VI., fig. 8, *c.f.c.*). Behind that notch the wall is triple; in front of it it is single, for the trabeculæ cranii only reach thus far, and the rest is formed

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* See Dr. Emil Rosenberg's excellent memoir, "Untersuchungen über die Occipitalregion des Cranium und den proximalen Theil der Wirbelsäule einiger Selachier." Dorpat, 1884.

of the azygous intertrabecula. Here we see Nature dissecting her own work! The parts that had become fused together are separating once more. Not only is the intertrabecula separated from the ascending wall under this great cranio-facial notch or cleft, but it is, also, under the septum nasi (*s.n.*). That fore part of the general wall is of slight vertical extent in front, and thus the two nostrils communicate—a common thing in birds thus to have their nostrils open through. The intertrabecula, having served its purpose, is now ready to vanish away; in the old bird it has been absorbed—all but the part which helped the paired trabeculæ to form that part of the balk which is behind the hinge-notch. That notch has a thick, but lessening, isthmus above it; in front of that, the orbito-nasal branch of the fifth nerve supplies the part; behind it, the olfactory nerve is distributed to the slightly folded mucous membrane. Behind the notch, a little higher, there is a bony plate as large as that notch; this is the perpendicular ethmoid, or mesethmoid process. The centre of the gently-swelling alisphenoid (*al.s.*) is ossified; the pituitary region has its borrowed basisphenoidal bony tract (*b.s.*); the occipital arch is now in four centres—the supraoccipital (*s.o.*), once double; the exoccipital (*e.o.*); and the oblong basioccipital (*b.o.*). In front of the exoccipitals a small lanceolate opisthotic (*o.p.*) is seen; and a large, squarish bone—the prootic (*pro.*)—is formed round the holes for the facial and auditory nerves (vii., viii.). Between the side of the supraoccipital and the large arch of the anterior semicircular canal (*a.s.c.*) there is a semicircular space fitted only with membrane; this is the lateral occipital fontanelle which characterizes the skull in so many water and wading birds, not excepting the Anatidæ, which are so unrelated to the rest.*

The articular (*ar.*) is enlarging, but I do not yet see the separate endosteal centre in the articular enlargement of the mandible; the outer centre appears some weeks before the inner; it is some years before the latter appears in the green turtle (*Chelone viridis*); and its ectosteal articulare might

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* The final purpose of these windows in the back of the head, in these birds, which are made and then filled-up, as though they had been taxed, is not possible to conceive. The middle occipital fontanelle, in owls and pigeons, is a mere economy of stuff.

easily be mistaken for a mere parosteal splint by a young and incautious morphologist.

The ectocranium at this stage is seen as an admirable supplemental growth of bony scales over and around the primordial skull and face. The imbrication of these "natural selections" from the inner face of ancient ganoid scales, notwithstanding the extreme degree of specialization that all these parts have undergone, is still as visible as that of the armour of any ancient type of vertebrate. And yet, almost all these superficial bones have their names from human anatomy, and a beginner can see the maxillary, inter-maxillaries, nasals, frontals, parietals, squamosals, vomer, &c. (Plate VI., fig. 8, *mx.*, *px.*, *n.*, *f.*, *p.*, *sq.*, *v.*).

Archaic parts, however, not seen in our own skull, are seen here, namely, the rostral basitemporal parts of the ancient parasphenoid (*pa.s.*, *b.t.*); and on the mandible all the reptilian splints except the coronoid (which also is present in the arboreal birds, but not in these and many other Precoces). But the dentary (*d.*), the splenial (*sp.*), the supra-angulare (*s. ag.*), and the angulare (*ag.*) are well developed here, but little altered from what is seen in ganoid fishes.

From the time of hatching to the first birthday of the bird, in one year nearly every trace of the old landmarks are removed; only in the specifically ornithic jaws and palate are the elements at all kept apart. About half of these are required in this most mobile apparatus.

At this point, my work is supplemented by Dr. R. W. Shufeldt's valuable Papers, especially in that which treats of the skull of the adult guillemot.* In one or two points as to the ossification seen in the skull of the adult Alcidæ, my valued fellow-worker has not quite caught my meaning in certain of my memoirs on this subject.

In his earlier Paper on Alca in which the skeleton of *Alca torda* is described,† Dr. Shufeldt mentions a little bone attached to the lachrymal, and which he supposes is the one called by me "os uncinatum" in my Paper in the Encyclopædia Britannica, vol. 9, art. Birds, p. 714. The bone

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* Jour. of Anat. and Phys., vol. xxiii. (vol. iii. n. s.), pp. 166–171, Plate VII.

† *Ibid.*, vol. xxiii., p. 8, Plate I.

referred to is, however, merely a limited ossification which takes place in the hind part of the coiled inferior turbinal. This bone in my specimens is an elegant open ring, the bony deposit having affected the whole coil to a short extent; it is formed in front of the pars plana, where these two parts are confluent.* But the true remnant of the os uncinatum is formed in the intero-external angle of the pars plana (Plate VII., *p.p.*, Plate VI., fig. 4, *p.p.*), which is the homologue of the ethmo-palatine of the frog.†

Besides the special middle turbinal centre which ossifies nearly all the pars plana of these birds, there is formed in the adult a small milioline bone in the angle just where the lachrymal ends below. There are two such nuclei on the right side, some on the left in one of my specimens of the skull of *Uria troile*, and one in the rest of my Alcidæ, namely, *Alca torda* and *Fratercula arctum*. In gulls of the first year this angle remains unossified; but in old specimens it becomes a distinct os uncinatum, almost as well developed as in the albatross. In an old *Larus argentatus* it is triangular, and the lower and longer side which is notched, is two millims. in extent. In an old laughing-gull (*Gavia ridibunda*) it is a wedge-shaped bone, 1·75 millims. long, and 1 millim. wide above. The ossified ends of the inferior turbinals are very distinct and elegant in all my specimens of Alcidæ; and they have the same development in *Alca impennis*, as my friend Frederic A. Lucas has shown me. In a letter to me, dated January 22nd, 1888, he gives some descriptions and careful drawings of these parts, and also of another important and much larger osseous centre. This larger bone is the ossification of the thick isthmus of cartilage shown in my third stage in *Uria troile* (Plate 6, fig. 8, *c.f.c.*). That isthmus remains, for the segmentation of the wall is not perfect, and the septumnasi (*s.n.*) in front of it is arrested. This fore-wall is feeble in the adult of these Alcidæ. This part is broad and carinate; the perpendicular ethmoid (*p.e.*) stops short at the point it has reached antero-superiorly in my third stage; and the roof and keel in front of it is ossified as a separate thick wedge of bone. This is seen in *Alca impennis*, *A. torda*, *Uria troile*, and *Fratercula arctum*, and

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* See Fowl's Skull, Plate 86, figs. 6 and 8, pp. 1–16.

† See my Paper on "Remnants and Vestiges," Proc. Roy. Soc., vol. 43, Febr. 23, 1888, pp. 400, 401.

is mentioned by Dr. Shufeldt in his description of the skull of Uria (*op. cit.*, p. 170) as existing both in that bird and in Alca. In old species of *Uria troile* I find it 9 millims. wide behind, and 9 millims. long; and in front of these is another bone like it, but only one-fourth the size. In an old *Gavia ridibunda* there is a similar septal bone behind; then a small nucleus; in front, the whole top of the septumnasi is ossified, and has coalesced with the nasal processes of the premaxillaries. This septal ossification, generally in one piece, is found in many of the Grallæ and Palmipeds, to say nothing of arboreal types. I find the main or hinder piece in *Podiceps minor*, *Rallus aquaticus*, *Porphyrio poliocephalus*, *Ardea cinerea*, and in Nycticorax.

The basi-pterygoids are absorbed in the adult;* but the pterygoids retain a little ingrowth towards the place where they existed in the embryo. For the rest the reader is referred to Shufeldt's excellent figures and descriptions.

I have purposely referred to the structure of other types of water-birds and of their grallatorial relatives. Guided by the skull alone, we might tie into one taxonomic bundle many a family of these birds: that is a clear fact, and most important in ontological research. But it is a misleading thing to do this in ornithology;—a gull is one thing, a guillemot is another, and a plover is diverse from both. Let us keep our evolutional speculations apart from our taxonomic work: "there is no need of such varieties" in that field of Science.

The Vertebral Chain and Ribs in Uria troile.

1st, 2nd, and 3rd Stages; and 4th, or *Adult.*

It will be convenient to describe these stages together for the sake of the mutual light shed by them. The vertebral formula in this type is as follows:—

C. 15 (two or three ribs free); D. 7; D. S. 2 (second rib imperfect); L. S. 3; S. 4; U. S. 5 (riblet on first of these fused); Cd. 10 + 3: Total 49.

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* See in *Alca torda*, Shufeldt, *op. cit.*, Plate I.

In the first stage (Plate VIII., fig. 1) there are only twelve vertebræ between the hip-plates instead of fourteen: this is the ornithoscelidan stage. In the second stage there are three distally articulated ribs on the left side, at the end of the cervical region (Plate VII., *c.r.*): the first of these becomes fused in the adult.

It is worthy of remark that these birds, which feed on "small fishes and crustacea,"* should have a very strong neck with short vertebræ that have strongly marked processes, whilst the heron, which, as a rule, deals with large prey, should have long, smooth, slender cervical vertebræ. I suppose it is due to the more hurried manner in which they feed. The meditative heron, when the necessity is laid upon him, suddenly—swift as an arrow—seizes his prey. As compared with the Anatidæ of the same size, the guillemot has fewer cervicals, and each bone is shorter; more dorsals—seven instead of five; fewer dorso-sacrals and uro-sacrals; and a rather longer, but feebler, caudal series. The spines, both upper and under, are strong; the riblets are well developed, but do not exist on the atlas. On the left side the last three, on the right the last two, are free. In the second stage (Plate VII.), in the pre-sacrals, ossification has taken place in the centra, neural arches, and riblets; these latter are losing their distinctness. The odontoid element, already united with the axis, the fore part of the centrum of that joint, and the base of the atlas, are not yet ossified—one centrum and two intercentra. Below, where the ribs are articulated, the cervicals become rapidly approximated to the dorsals; the spines become square and crowded; below, the spaces are bifurcated and dilated, right and left. In the general sacrum, and in the caudal region, the centra are acquiring an osseous deposit in the sheath of the notochord, but not as yet the neural arches.

In Stage 1 the vertebræ are unossified; in the pre-sacral region the notochord, which had shown contractions at the joints, had become largest there, and also was constricted so as to have two new swellings inside the cartilaginous centrum. Behind the dorsal region (Plate VIII., fig. 1, *nc.*) only two moniliform swellings are seen in each centrum, and these are lost

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* Macgillivray, "Manual of Ornithology," 1842, p. 213.

in the caudal region; yet there the notochord has the amphibian character of being largest at the intercentral spaces.*

Hence, this vertebral chain has evidently, like the rest of the organism, been subjected to some dominating force that has fashioned it anew for some further and higher ends in life, so that some unsightly creature, not perhaps dissimilar to Siebold's gigantic salamander, or the eel-like *Siren lacertina*, has been "clothed upon" not only with a warm, soft, feathery and downy vestment, but has had its whole structure metamorphosed into this "rich and strange" type. Nearly half a hundred links have been developed in this cunningly wrought chain, where, perhaps, a hundred did exist in the low quasi-larval ancestor. It is passing strange that a *blind force* should produce such "new things in the earth."

The stunted condition of these post-dorsal vertebræ, the fore half becoming fused and the hind half arrested, is in harmony with the rest of the structure of this Pygopod; nevertheless, had it been necessary, a moderate amount of elongation would have made the eighteen vertebræ that are behind the true sacrals into the tail of a Saururous type as long as the rest of the spine. The last four imperfect segments formed round the notochord become the uropygial joint; the nine in front of that keep distinct; their transverse processes (diapophyses) gradually decrease to the end.

In this first stage the ribs on the first dorso-sacral are developed—are almost complete below; but on the second they are in three pieces, the proximal (Plate VIII., fig. 1, *s.r.*) being a very small bar—simply a rudiment of the capitulum and tuberculum. On the first uro-sacral there is an attempt at the formation of a distinct rib bar. Hence, this part of the axis is seen to be less perfectly developed than in the Anatidæ.

Before hatching, in my third stage (Plate VIII., figs. 2, 3), the whole of the general sacral series is enclosed between the ilia; and the centra, but not the neural arches, except in the first dorso-sacral, are ossifying. These bony patches, formed, at first, round the notochord, are transversely oval: the widest are in the swollen proper sacral region. These tracts are formed

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* See Proceedings, Royal Society, 1888, p. 466; and Foster and Balfour's "Elements of Embryology, 1874," p. 157.

as far back as to the last four imperfect segments. Under the largest of these, and under all the rest of the free caudals, there is, at the fore edge of each centrum, a small milioline intercentrum; above (fig. 3), four vertebræ have a spine, that on the fourth being the smallest. The last lumbo-sacral and those of the four proper sacrals are mere round belts; then a small tubercular spine reappears, and is hardly lost on the last of the four uropygial segments. That the cervicals in the adult are short is seen by the following measurements:—The centrum of the eighth, or longest of this chain, is 11 millims. long, the whole length of the vertebræ, with its oblique processes, being 16 millims., and the width over the prezygapophysis 14 millims. The spines are well developed; the four next behind the atlas have upper and lower spines; the tenth has a large lower spine; then this decreases, and there are three such outgrowths on the fourteenth. On the fifteenth, or last cervical, and on the first two dorsals, the lower spine is double, and dilated transversely, as in the loon (Colymbus), and another fish-eating bird not related, the kingfisher (*Alcedo ispida*). The other five dorsals—the first dorso-sacrals—have long simple spines, pedate below, sloping from before backwards; these spurs are like those of the grebes (Podiceps), but are not so long. In this point the guillemot is intermediate between the loon and the grebe, as Hesperornis is in its general structure.

The upper spine reappears in the last three cervicals. Thus, the last of these, the seven dorsals and the two dorso-sacrals, form a gently arched series of square spines, closely fitting—that is, with only a small tract of elastic ligament between them, and tied together by fine bony tendons. The dorsals, one with another, and the last of these with the first dorso-sacral, are united by opisthocœlous joints, that have paired overlapping processes, such as I have described in the oil bird.* All the cervicals, even the last or fifth in its junction with the first dorsal, are heterocœlous, or cylindroidal. The caudals are feebly amphicœlous, and have no joint cavity.

In the guillemot the atlas has no rib bar enclosing the vertebral artery, as in the duck and its congeners. It has one, however, on the axis, which

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* Steatornis, Proceedings Zoological Society, 1889, Plate XVIII., p. 174.

is not present in birds generally; these riblets are developed into a long style on the 3rd, 4th, and 5th, and these become short, and the retral part is lost. The free rib on the 14th is 8 millims. long; that on the 15th is almost as long as that on the first dorsal, and it has an ossified uncinate cartilage (see Plate VII.); these parts are long, and are present also on all the seven dorsals; thus there are eight pairs of them; they do not become fused with the ribs. The ribs are extremely long, slender, and sinuous in form, and are articulated to equally delicate sternal ribs at an acute angle. The first forms, when at rest, a right angle merely; this is seen in an exaggerated form in the embryo (Plate VII.). Of course they are somewhat opened out in inspiration. The last dorsal rib in *Uria troile* is 95 millims. long, its sternal piece 81·5 millims., a little more than half the length of the same parts in *Alca impennis.** The cinctures formed by the first dorso-sacral rib just fall short below; that of the second dorso-sacral is in three pieces on each side. Above, a delicate bridge of bone is ankylosed to the vertebra at both ends; below a distal piece appears, 40 millims. long, attached to a sternal piece, 50 millims. long; the average breadth of these needles of bone is ·75 millims. Sitting up, in full dress, these birds have a bulky look; but they are much more compressed than the duck or the penguin; and their trunk is not only very long for a bird, but also very deep.

In the loon (*Colymbus septentrionalis*), and in the great diver (*C. glacialis*), as also in the grebes (Podiceps), the body is very flat or depressed, strikingly so; compare *Alca impennis* (*op. cit.*), and Brandt's figures of the skeleton of the loon (*Eudyptes* (*Colymbus*) *septentrionalis*), and of *Podiceps auritus.*† Besides, in these latter birds the ribs are much shorter and stronger than in the Alcidæ.

Altogether, in comparing these water-birds, each family seems to me to be isolated, and they are probably much less nearly related to each other than they seem to be, the similar adaptive modifications giving them a misleading isomorphism.

In my second stage (Plate VII.) the ribs are acquiring a long ectosteal

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* Owen, Transactions Zoological Society, vol. v., Plate LI.

† "Zur Osteologie der Vögel," 1837, Plates XVI. and XIV.

sheath, the sternal ribs (*s.r.*) are not yet ossified; their ossification takes place in the same manner as in the vertebral ribs.

It is evident that sometimes the last cervical rib may join the sternum by a sternal piece, although as a rule in *Uria troile*, *Alca impennis*, and *Alca torda*, there are only seven pairs of sternal ribs. This additional sternal exists in my third stage,* although there are only seven in the first stage (*ibid.*, fig. 10), and in the second stage also (Plate VII. of this memoir).

Also, in the same figure of the thorax of the third stage, the uncinate cartilages (*c.a.*) are seen to have an adze-shaped dilatation above, when they are fully formed. Even this undergoes change, and the enlargement is much less evident in the adult. With regard to the number of perfect cinctures in the thorax in all Dr. Shufeldt's exquisite figures,† there is only one with eight perfect sternal ribs, and this is on both sides (Plate III., fig. 18, and Plate IV., fig. 20, p. 23). My specimen has only seven on each side; and some of the small forms of Alcidæ figured by Dr. Shufeldt (*op. cit.*, Part III., pp. 400–558) are shown as having only six.

The Sternum and Shoulder-girdle of Uria troile, *Embryos and Adult.*

My dissection and drawings of the sternum of the first stage made long ago (*op. cit.*, Plate XVII., figs. 10, 11) show that the metasternum is small at first; at that time it is no longer than the proper costal tract; in the adult it is three times as long (see Shufeldt). Why in these birds, which have a tendency to abort the wing into a mere paddle, and in Tinamous which have short wings that they have scarcely the sense to use, the metasternum should be so extremely long, whilst in gulls, cormorants, the tropic bird (Phaëton), and in the frigate bird (Tachypetes), it should be so short, is to me, not at present engaged in myology, an anomalous fact. The mechanism of flight in all these birds should be studied in reference to this; for the metasternum is, like the sternal keel, a thoroughly avian structure. In Mammals it is a very feeble structure; and in its earlier appearance in Reptiles (Stellio, Crocodilus, *op. cit.*, Plate XI., figs. 1, 2, 7, and 8) it is

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* See "Shoulder-girdle and Sternum," Plate XVII., fig. 14.

† Jour. of Anat. and Phys., vol. xxiii.

scarcely stronger than a rib. The common granular plate in which the rib, at first, ends below, soon chondrifies, and then the right and left moieties meet, unite together, form a keel, and become segmented from the lower costal segments, or sternal ribs (*op. cit.*, Plate XV., fig. 1).

In my first stage all this is complete, the structural relations are perfect; but the relative proportion of the regions undergoes much after-change.

In the second stage (Plate VII.) the rapidly growing embryo has its sternum quite similar to that of the adult, and the metasternum is already twice as long as the costal edge. The pre-costal process (*p.c.p.*) has room on it for two more sternal ribs, which might have grown down from the neck. The rostrum, a special avian outgrowth,* and not a further sternal rudiment, is already formed as a semicircular figure-head, separated from the sharply-produced keel (*st.k.*) by an almost regular semicircular notch. From that point to the flat, thin, keelless hind-part of the middle metasternal process, the outline of the keel forms a large part of a quadrant. This convexity of outline is also seen in the body of the sternum, which at this time bellies downwards, the thoracico-abdominal cavity being pregnant with the copious viscera, and a huge mass of still unused food-yolk. The lateral metasternals (*m.st.*) are separated by a round notch from the middle plate, and are only half as long as its keelless part, behind the fore end of the notch.

In the third stage (*op. cit.*, Plate XVII., fig. 14) the sternum is rapidly approaching the adult form, which is well illustrated in Miss Beatrice Lindsay's Paper (*op. cit.*, p. 690, fig. 1), and still better in Dr. Shufeldt's 4th part (p. 538, fig. 1, and p. 546, fig. 4). The sternum straightens out very much, and the line of junction of the keel and body becomes sinuous, for it rises in the middle of the metasternum. The keel projects its angle in front of the large deep rostrum, and ends behind in a thickened edge, 3 millims. wide; beyond this about 7 or 8 millims. of the rounded end is unossified. The rostrum comes up well between the coracoid grooves. The whole bone is very evenly oblong; it measures 37 millims. across the tips of the pre-costal

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* Lindsay, Proceedings Zoological Society, 1865, p. 707.

processes, and also across the outer metasternal processes, and only 31 millims. behind the last sternal rib. The whole median length is 123 millims.—nearly four times the average width; and the keel is 128 millims. long, measured in a straight line above its gently curved lower limbate edge: its greatest depth is 30 millims. The depth of the notches in the metasternum varies in individuals; in my specimen of an adult they reach half-way to the last sternal rib, and the lateral bars are 20 millims. long and 4 millims. wide. The gently descending series of the seven transverse costal condyles look equally outwards and upwards; thus the costal cinctures swell out above the sternum.

I have noted down this great length and narrowness in the guillemot, both for comparison with the short-breasted gulls,* which come so near the Limicolæ in this respect,† and also with the loons.‡ In the gulls the sternum is both narrow and short; in the loons it is as long, or nearly so, as in the Alcidæ, but much wider. These long sterna had their counterpart in an arrested condition due to the abortion of the wings in the extinct Hesperornis.§ In that bird the sternum, and also the furcula, are almost exactly like those of my third stage of the guillemot.||

Even the skull itself is of less value to the ornithologist than the sternum; it will be seen at once that this statement is somewhat remarkable as coming from one so partial to the skull. And yet, notwithstanding this, the Alcidæ, in several important respects, come nearer to the Laridæ than to the other divers (Urinator, Eudyptes, or Colymbus), for these latter forms, with their quasi-ancestor Hesperornis, and the grebes, have all their pre-sacrals cylindroidal.¶

The ossification of the sternum in the Alcidæ is by a very generalized sort of endostosis, the lophosternum having a very short independence of the

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* Shufeldt, Part i., Plate IV., fig. 2.

† *Ibid.*, figs. 22 and 23.

‡ Shufeldt, Part ii., Plate VIII., fig. 7; and Brandt, *op. cit.*, Plate XVI.

§ Marsh, *op. cit.*, Plate VII.

|| Shoulder-girdle and Sternum, Plate XVII., figs. 10, 11, and 13.

¶ The nomenclature of these birds is very confusing. E. Nitzsch (Pterylography, Ray Soc., 1867, p. 152, Plate X., figs. 10, 11, and 12) calls the grebes Colymbus, and the loons Eudyptes; whilst Macgillivray (Manual, 1842, pp. 200–206) calls the grebes Podiceps, and the loons pleurostea. The shoulder-girdle of the guillemot* has a falciform scapula (*sc.*) nearly twice as long as the coracoid (*cr.*). In the first stage (*op. cit.*) the axes of these two bars are coincident; they are ossifying separately, but are only half free from each other at the shoulder-joint. On the fore part of the head of the coracoid there is a small continuous remnant of the precoracoid, which becomes the clavicular process. In the third stage (*op. cit.*) there is a separate nucleus of cartilage—an external precoracoidal remnant—which becomes part of the ramus of the furcula, after undergoing endostosis; and it forms a shelf, on which the large forwardly-curved head of the coracoid rests; that is a flat synovial joint. This structure can be seen even on the inner aspect.† The shaft of the coracoid is moderately slender, and the epicoracoid below has a dilated hook at its hinder angle.‡ The clavicular rami are largely curved forwards above, and the whole from a side view, with the crescentic interclavicle, forms a rough semicircle; but the rami are not so evenly curved as in the loons,§ which have also a smaller interclavicle. In the loon, in the first stage of Uria,‖ and in Hesperornis,¶ each ramus is much dilated above; and this dilatation is formed in a mass of granular tissue, which is almost cartilaginous, and belongs to the acromial or meso-scapular region. The rami of the furcula, like the little bone at their junction (the interclavicle), are parostoses. This median part was not seen by Marsh in Hesperornis.**

Anyone who will compare together the figures given in the thirteenth Plate of my work on these parts will see at a glance that the reptile has the raw materials out of which the bird's shoulder-girdle might have been made.

Colymbus; whilst Brandt (*op. cit.*) calls the loons Eudyptes, and the grebes Podiceps. To mend the matter, the best and latest authorities, the ornithologists of the American Union (The Code of Nomenclature and Check-List of North American Birds: New York, 1886), have for the grebes the generic terms Æchmophorus, Colymbus, and Podilymbus; and for the loons Urinator (pp. 73–76).

* *Op. cit.*, Plate XVII., figs. 10–4; and Plate VII. of the present Paper.

† Shufeldt, *op. cit.*, Part iii., p. 556, fig. 8.

‡ *Ibid.*

§ Brandt, Plate XVI.; and Shufeldt, Part ii., Plate IX., figs. 2 and 13.

‖ *Op. cit.*, Plate XVII., fig. 13.

¶ Marsh, *op. cit.*, Plate VI., fig. 3.

** *Op. cit.*, Plate VII., fig. 8.

The Wings of Alca torda *and* Uria troile *in Embryos and the Adult.*

The wing in *Alca torda* one-third ripe, and therefore answering to my first stage in the guillemot, is considerably advanced in growth (Plate IX., figs. 1 and 2); it answers very nearly to my third stage in the duck (Plate I., fig. 6). The main parts are already well formed, and the larger rods have their ectosteal sheath; but the parts that form the strangely modified carpus are still cartilaginous.

The radiale and ulnare (*re.*, *ue.*) are large and normal, and the distal carpals (*d.c.*^{1} *d.c.*^{2} *d.c.*^{3}) are well formed. The first of these is on the inner side (fig. 2, *dc.*^{1}); it is ear-shaped, and strives to reach its own short metacarpal (*m.c.*^{1}) which is fused with the great crescentic second metacarpal (*m.c.*^{2}), as also is the oblong third distal carpal (*d.c.*^{3}). The great second metacarpal is four times as long as the first, and one-fourth longer than the third (*m.c.*^{3}), which is also very slender. The proximal phalanx of the large index (*dg.*^{2}) is beginning to ossify; all the rest are cartilaginous. The two phalanges of the pollex are equal in size to the two distal ones of the index; the one distal or undivided phalanx of the third digit (*dg.*^{3}) is two-thirds the length of the proximal phalanx of the pollex.

In the second stage *Uria troile* (Plate VII. and Plate VIII., figs. 7 and 8) shows some new parts besides increase in size and development of two new bony sheaths, one in the proximal phalanx of the pollex, and another in the middle phalanx of the index. The distal phalanx of the pollex is now very small, and the claw is dying out; and that of the index is almost fused with the middle piece. The displaced and greatly masked first distal carpal (*d.c.*^{1}) has its base, on the ulnar side, dilated and fused with the parts on which it lies: a little beyond it, inside the head of the third metacarpal (*m.c.*^{3}) there is an oval segment of cartilage half the size of the first distal carpal; that is the remnant of the fourth metacarpal (*m.c.*^{4}). On the ulnar, or hinder, side of the large proximal phalanx of the index—between it and the lessened phalanx of the third digit (*dg.*^{3})—there is a new lanceolate cartilage, which is already receiving bony deposit from the ectosteal sheath of the large primary bar to which it is attached; this is a proximal secondary phalanx (*dg.*$^{2'}$). Above, in the outer or extensor face of the manus (Plate VIII., fig. 8, *mc.*$^{2'}$), there is a semi-lanceolate tract of cartilage outside the ectosteal sheath of the great second metacarpal (*m.c.*^{2})—a secondary metacarpal; a weak fork of the index. That attempt at bifurcation of the great second ray of the hand is connected by a distinct but slender isthmus with a fork of the great second distal carpal (*d.c.*^{2}). I can find no teleological reasons for these multiplications or forkings of the contracted and aborted manus of the bird.*

In *Alca torda*, also, the second stage (Plate IX., figs. 3, 4) is illustrated. It shows the same parts as the similar embryo of the guillemot. In this embryo the pollex and index have both kept their distal joint distinct; and in the third digit there is a very small grain of cartilage distinct from the proximal part. The first distal carpal and the fourth metacarpal (figs. 3, *d.c.*^{1}, *m.c.*^{4}) are clearly seen; and, on the outer side, the second distal carpal has sent on a styloid fork, which is connected by a membranous isthmus with the secondary second metacarpal (fig. 4, *m.c.* $^{2'}$).

In both *Uria troile* and *Alca torda*, the third stage, or almost ripe embryos, show a still further growth of the wing. In Uria (Plate IX., fig. 7) the changes from Stage 2 are merely those of growth. In Alca (Plate IX., figs. 5, 6) I have shown the parts on a larger scale; in these we see that the cartilages are becoming vascular, ready for ossification. The great proximal carpals (*re.*, *ue.*) show by their lobes that they represent more than one normal nucleus; and the distal carpals (*d.c.*$^{1-3}$) are still sufficiently distinct to illustrate their peculiar forms and relations. On the fore edge of the first metacarpal (*m.c.*^{1}) there is a suspicion of a pre-pollex

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* If anyone studying these parts does not see in them a repetition of what occurs in the fore paddle of an Ichthyosaurus; and if, looking at both, he is not irresistibly carried into ontological speculation, there must be some weak spot in his mind. All minds are not so timid: whilst writing the above I have received a very valuable Paper on this subject, by M. Alfred Tschan ("Recherches sur l'Extrémité Antérieure des Oiseaux et des Reptiles." Geneva, 1889). Both as to personal research and as to Bibliography, this Paper comes to me very opportunely, and I am grateful for it. I cannot, however, quite see with M. Tschan as to the manus of birds; he would make the normal third ray to be the fourth digit—the third, in that case, being my intercalary post-index (p. 59).

in the peculiar form of the trochanter. The ventrally displaced first distal carpal (*d.c.*^{1}) is attached by a large base to the second and third metacarpals; and, on the postero-internal face of the latter, the fourth metacarpal (*mc.*^{4}) is clearly seen as an oval milioline nucleus of solid cartilage. But these unhatched Alcidæ are not all that is needed for the interpretation of the adult wing. Happily, however, through the kindness of Frederic A. Lucas, Esq., of Washington, I am able to show the structure of the wing in a half-grown bird—the smallest of the family, namely, *Ciceronia pusilla.**

In this *relatively* large bird of the first summer I found an explanation of what is remarkable in the pollex (in many cases it is seen in the index also) of water-birds—Alcidæ, Procellariidæ, and Phalacrocoracidæ.

In the long manus of the smallest auk (Plate VIII., figs. 9–13) the ossifications are, in this immature bird, nearly all distinct, and thus very instructive. The distal carpals (figs. 9 and 12, *d.c.*^{1}, *d.c.*^{2}, *d.c.*^{3}) are bounded by sutural lines that are just becoming obliterated, and the three metacarpals are not yet fused. There is no appearance of a distal joint in the third digit (*dg.*^{3}), but those of the pollex and index (*dg.*^{1}, *dg.*^{2}) are ossifying as a separate endosteal patch. The latter have become fused with the middle phalanx, as in *Uria troile* (fig. 7); the last phalanx in the pollex keeps its distinctness, as in the large bird. The semi-lanceolate secondary second metacarpal (*m.c.* $^{2\prime}$) is getting some bony deposit from the main shaft; that of the proximal phalanx is completely fused with the main piece, and is largely ossified. Another very distinct segment of cartilage has appeared in the ulnar side of the proximal joint of the pollex, near its distal end (*dg.* ^{1}). This is a perfectly distinct semi-oval cartilage, which is ossifying from its own proper endosteal centre, just as the secondary metacarpal of the index does in passerine birds, when it is most perfectly developed. The ungual phalanx of the pollex has a delicate claw upon it. This post-pollex is accompanied with a post-index in these Alcidæ and some other Palmipeds; for, in the adult *Uria troile*, *Alca torda*, and *Fratercula indica*, the same flange is seen in both of those digits (see in *Uria troile*, Plate IX., figs. 11, *dg.* 1^1, and fig. 12, *dg.* 2^1).

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* *Simorhynchus pusillus* (see Check-List of North American Birds, p. 79).

All the secondary parts, or feeble forks, of these digits or rays here described, are on the ulnar side of the primary rays; that, however, is not an absolute rule, as many passerine birds have a pre-index nearly as large, and quite as independent, as their large post-index; and both these supplementary rays are attached to the main metacarpal, the one on the front or radial side being attached much further down than that on the ulnar side. These unexpected complexities of the transformed fore-paw in birds are being traced out in the whole class, and will be published in due time.*

I have one word more to say about these secondary forkings of the rays of the fore-limb. If they were merely adaptive enlargements for the sake of the setting in of the quills, why did Nature create new cartilaginous rays, ossify them autogenously, and then obliterate all signs of their temporary independence? Any slight extension of periosteal bone from the normal rays would have sufficed to produce these flanges and interosseous bridges. No expenditure of the morphological force was needed for such after-touches as these. Thus the teleologist is quite at fault here: there is no scent: another hound may cry upon the right track, but he will have to be one of the ontological breed.

Hip-girdle of Uria troile, *Embryos and Adult.*

This part of the skeleton, including the sacral vertebræ, is of great interest; both the pelvis and the dorsal vertebræ are in accord; both suggest a nearer relationship of the Alcidæ to the gulls on one hand, and to the penguins on the other, than to those important Pygopods, the Colymbidæ and Podicipitidæ, that seem to be the true descendants of the extinct Hesperornithidæ. I shall return to this subject in describing the pelvis of the adult.

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* With regard to secondary rays in the fore-paw of extinct reptiles, Dr. G. Baur (see my reference to his views, Proceedings, Royal Society, 1888, p. 323) insists upon their presence on the ulnar side, only, of the primary rays. Mentioning this to Professor H. G. Seeley, I obtained from him a distinct denial of the truth of Dr. Baur's assertion. I must say that what I have seen in so many passerine birds makes me feel sure that they may occur on both sides.

In the first stage of *Uria troile* the hip-plate (Plate VIII., fig. 1) is, as to form, in the struthious condition; the three main bars, or plates, are distinct rays behind, the ischium (*isc.*) not having become fused with the post-ilium (*pt.i.*). At this stage the hip-girdle is just in extreme contrast with that of the adult loon (*Colymbus septentrionalis*), in which the post-ilium is two and a-half times the length of the pre-ilium. In this embryo of the guillemot the post-ilium is not two-thirds the length of the pre-ilium, and, in the adult, is only three-fourths its length—exactly the same proportion as in *Eudyptes chrysocome.** This pelvis (Plate VIII., fig. 1) has dilated pre-ilia, and contracted post-ilia.†

Behind the rounded free ends of the pre-ilia the plates contract, and then dilate to form the fore part of the acetabulum; beyond which they grow along the sides of the sacrum for some distance, and then diverge and end in a pointed process, whose lower margin is notched. Below the post-ilium the ischium (*isc.*) runs backwards as a broadening flap of cartilage, which also ends in a point at some distance behind the post-ilium. The pubis (*pb.*) is less than half the breadth of the ischium; and it goes still further back, so as to be almost twice the length of the post-ilium; it is terete, not flat, and ends in a point. Nearly the middle third of the pubis is ossified; the ilium is ossifying along its outer edge; and the ischium has a small bony patch over the proper obturator space.

Some curious changes are seen in the hip-plate in Stage 2 (Plate VII.). The two moieties are strongly clamped upon the sacrum, and contract in upon the caudal vertebræ also. The osseous centres are much enlarged, and the iliac bone is now some distance behind the acetabulum; the three rays are all distinct behind. But the most remarkable change has taken place in the pubis; it is crumpled in exactly the same manner as the inter-trabecular rostrum and the meckelian rods in the same stage (Plate VI., figs. 4 and 6). This crumpling is apparently due to the faster growth of

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* Morrison Watson: "Challenger Reports" (*Spheniscidæ*), Zoology, vol. vii., Plate VII., figs. 7 and 8.

† The figure is from an outspread preparation. This is corrected in Stage 2, Plate VII., and in Stage 3, Plate VIII., figs. 2, 3.

this part as compared with the structure with which it is bound up; in the adult the pubis is very long. In Stage 3 (Plate VIII., figs. 2, 3) the general growth has gone on, and one of the pubes—the left—has become dilated at its end; in the adult both are dilated, as in the Anatidæ. The ilia coalesce with the sacrum, but leave a large groove open, right and left, in the fore-part of the pelvis, above; the post-ilia reach the third caudal vertebra, so independent is the boundary between the uro-sacral and the caudal region. The slender pubes keep free from the ischia; they are arched upwards, and the lower edge of the ischia is concave, parallel with that arching.

If we compare the pelvis of one of these Alcidæ with that of a gull and of the plovers,* it is evident that the Alcine pelvis is but a contraction of the Larine, as the latter is but that of a plover made narrower. But the pelvis of the razor-bill and penguin are still more alike; † whilst the pelvis of Colymbus ‡ is seen at once to be a modern form of that of Hesperornis.§ Also, let it be noted, that, whilst the Anatidæ agree with the grebes, loons, and Hesperornis, in having cylindroidal dorsal vertebræ, they also agree in having the post-ilium much longer than the pre-ilium.||

These are only a few of the difficulties that rise up to confuse the classifier of the Palmipeds; they are more than doubled when we bring in the Procellariidæ and the Pelecaniidæ, using the latter term in its widest sense.

Hind-limb in Uria troile; *Embryos and Adult.*

In Stage 1 this part is still in its archaic or dinosaurian condition. Most of the primary elements of the limb are uncombined, but they are placed together ready for confluence (Plate 8, figs. 4, 5). The fibula has retreated upwards; the tibia (*t.*) having drawn the nourishment out of it, this latter rod has the upper part of the tarsus articulated with it. The

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* See Shufeldt, *op. cit.*, Part ii., Plates X. and XI.

† Watson: *op. cit.* Plate VII., figs. 7, 8.

‡ Brandt: *op. cit.*, Plate XVI.

§ Marsh: *op. cit.*, Plates X. and XI.

|| See Plates III.–V. of the present Paper; and Shufeldt, Proceedings, U. S. Nat. Mus., vol. xi., pp. 225, 226, figs. 6–8.

three proximal tarsals, tibiale, fibulare, and intermedium (*tb.*, *fbe.*, *i.*) are traceable, but are not now distinct nuclei; the supero-anterior element, the intermedium, is short, as in the common chick, not long, as in the goose tribe and the Ratitæ; it is an obliquely-placed diamond-shaped plate attached below to the fibulare, and overlapping the outer part of the tibia above.

Below these the single distal tarsal forms (*d.t.*) a sinuous cap to the three developed metatarsals ($m.t.^{2-4}$); and behind and between the two masses on the inner tibial side, there is a small nucleus answering to the scaphoid or centrale (*c.*), and a small elevation on the fibular side of the distal tarsal and fourth metatarsal (*d.t.*, $m.t.^{4}$); this is all that is left of the fifth metatarsal ($m.t.^{5}$). At the lower third of the second metatarsal ($m.t.^{2}$) a small milioline grain of cartilage is all that is left of the first metatarsal ($m.t.^{1}$), and thus the outer and inner digits are suppressed. The other three are normal, with their three, four, and five phalanges (Plate VII.); but their metatarsals ($m.t.^{2-4}$) are distinct, and diverge so as to produce a sprawling or reptilian foot; more than the middle third of these metatarsals is ossified. In *Alca torda* at this stage (Plate IX., fig. 8) the proximal tarsal mass is shown, and the separate tendon-bridge. In Stage 2 (Plate VII., and Plate VIII., fig. 6) the parts are larger and more ossified: the characteristic change is seen in the metatarsals ($m.t.^{2-4}$) which have been squeezed together, so to speak, closely faggoted into a single shank, and flattened when they adhere to each other. In Stage 1 the third was a little behind the other two; it is the largest, and has the largest head, which projects considerably behind the other. Above these rods the distal tarsal has grown up a front to form the very avian intercondyloid knob. The small oval intermedium (*i.*) is still markedly separate from the fibulare or outer condyle. The centrale (*c.*) is now merely a thickening in the inner part of the growth of the general tendon-sheaths for the plantar tendons.

In Stage 3 (Plate IX., figs. 9, 10) the common mass of the tibiale and fibulare (*tb.*, *fbe.*), and the tendon-bridge are still cartilaginous, and will be for a good while to come; but the intermedium is now ossified by ectostosis, and overlaps the tibia antero-externally. The arrested first metatarsal ($m.t.^{1}$) is still unossified.

In the adult these parts are all ossified and ankylosed together; even the secondary tendon-bridge; the intermedium can be traced as a small triangular projection above the inner condyle. Even in old Alcidæ, the first metatarsal is visible as a small, flattish grain of bone. In *Fratercula arctica* it is 1 millim. in diameter.

In the old guillemot (*Uria troile*) the patella is large and thick, 5 millims. high, and the same in width. The cnemial ridges of the tibia are strong and high, the fibula one-third shorter than the tibia, and the femur moderately long and gently curved. The shank is only three-fourths the length of the middle toe. The length of the toes is as follows:—Second, 35 millims.; third, 49 millims.; fourth, 46 millims.

The position of the guillemot, somewhere between the loon and the gull, may be illustrated by a comparison of the relative length of the three main divisions of the hind-limb:—

Femur.	Tibio-tarsus.	Tarso-metatarsus.
Larus argentatus, 59 millims.	109 millims.	64 millims.
Uria troile, 47 millims.	91 millims.	36 millims.
Colymbus septentrionales, 37 millims.	165 millims.	71 millims.

In each case the tibia has had about 5 millims. of its length added to it by the proximal tarsal mass, whilst the cnemial process has added: in the gull, 6 millims.; in the guillemot, 7 millims.; and in the loon, 42 millims. Here we see that in the loon the femur is so short that the tibio-tarsus is four and a-half times its length. The proportion in the gull is less than twice; and in the guillemot the femur is somewhat shorter relatively than in the gull.

I do not wish to lay too much stress on these measurements; I must remark on the extreme modification of the hind-limbs and pelvis in the loon, making it the isomorph of the seal (Phoca). But what is pertinent to the subject is, that it is not a modern specialization; it is as "old as the (Cretaceous) hills," and probably much older; for Hesperornis, that almost wingless and toothed loon, must have existed long enough to abort his wings and lose his sternal keel.

SUMMARY.

(a) *The Anatidæ and Alcidæ considered from an ornithological standpoint.*

Continuing my observations on the relationship of these two widely separated families of birds, I would reiterate the remarkable fact that the Anatidæ manifestly converge towards the gallinaceous group; that they have the struthious division of the Ratitæ obliquely below them; whilst the Alcidæ are related to a large and varied group of existing families, but, in their ancestry, belong somewhere between those two extremely dissimilar extinct families, the Hesperornithidæ and the Ichthyornithidæ. The revelation made by the precious remains of those two ancient toothed types throws a bright light on one side of these questions of origin and relationship, but intensifies the darkness on the other side. The glare makes some things appear darker than they were before those treasures were unearthed.

The loss of teeth is evidently a comparatively modern specialization, as compared with the general structure of the bird; the Anatidæ, however, have had time, not only to lose their true teeth, but also to gain false teeth, or horny imitations—*succedanea*—in their place. The Alcidæ, however, are no losers; their shorter cultrate elastic beak is a most mobile and strong pair of fish scissors, much more effective than the long, toothed jaws of an Ichthyornis could have been.

Higher up in the class the gain has been exceedingly great: the house-martin, the chaffinch, the long-tailed titmouse, and the tailor-bird owe the possibility of their exquisite architectural skill to their toothless jaws. But maxillary armature is but a small part of a vertebrated organism; the morphologist has much more to do than to study teeth.

Diagrams of "family trees" do not help us much; they are easy to make; the real difficulty lies in proving that they illustrate anything that ever actually took place in Nature.

I am under the impression that penguins never possessed quills, and that their adaptation to aquatic life, and their great power of diving, took place much earlier in their ancestral history than in the case of the auks and guillemots—birds that tend to become a sort of palæarctic penguin, but never quite lose the marks of their former adaptation to a more terrestrial life. I conceive of their ancestors in amphibious or limicolous birds; and I imagine the forefathers of gulls, plovers, rails—the auk tribe—as being very much alike, and very nearly related.

I am the more led to this way of thinking by what is seen in those remarkable Limicolæ, the sheath-bills (Chionis), and also in their near relatives Thinocorus and Attagis. These archaic neotropical plovers (Limicolæ) are aberrant and almost extinct types. In the case of *Chionis alba* the skull is extremely like that of the razor-bill (*Alca torda*)—so much so that, if it had come to me as a fossil, nothing more being known of the bird but the remains of its skull, I should unhesitatingly have put it amongst the Alcidæ. I have already referred to the pelvis of this genus, and of the plovers and gulls, in describing that of Uria.* But the penguins, with their extreme specialization as the highest form of divers, must, it appears to me, have been penguins since the day they acquired their peculiar mantle. They were *amphibio-Dipnoans;* they became transformed into what we now see—perchance they were somewhat clumsier at first.

It is in the hind-quarters that the extinct ornithoscelidan reptiles approach the bird in their organization; in the penguin those parts are, even in the adult, least modified from the condition seen in these reptiles. Their spine, in the dorsal region, has the archaic opisthocœlian articulations; their skull is of a generalized form, a little more primitive than that of a razor-bill; and the appearance of the head in its feathers is much like that of the large embryo of the guillemot (Plate IX., fig. 18).

All the penguins are alike in everything that is important;† of the

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* See Shufeldt, *op. cit.*, Part x., xi., for figures of the pelvis in *Chionis minor*.

† It is remarkable that the gigantic extant penguin (Palæeudyptes—see Huxley, Proceedings, Geological Society, 1859, pp. 670–676) should, like the great ostrich, have only two toes.

Alcidæ only one, *Alca impennis,* became transformed into the likeness of a penguin; the specialization of the family has been imperfect, as compared with the penguins, and, as I believe, took place later in time.

Returning to the duck tribe, and again referring to the fact that they evidently come from a stock closely related to that from which the fowl-tribe sprung, we must either give up the doctrine of the evolution of all these various types, in time, or make ourselves satisfied that some low, unsightly amphibious fowl—a wader of some sort—gave rise to two tribes, the Anatine and the Gallinaceous; and was thus, at once, the ancestor of the swan, on one hand, and of the peafowl on the other. This is enough to stagger the faith of the most robust Darwinian; but true faith laughs at impossibilities—that is, at what seem to be such to our scant knowledge and limited reason.

Without losing ourselves in the past, there is much in the present to interest us. The two groups treated of in the present Paper are, for ornithological purposes, very instructive, being so sharply defined from each other, albeit they are both made up of forms that are adapted to aquatic life. The Anatidæ, which are more or less terrestrial also, are mainly swimmers, and some of them, as the swans, are sailors. The Alcidæ are not more fit for land than the eared seals (Otariæ); but they can fly, and they can dive—are equally at home and at ease in the rarer or the denser medium. For taxonomic use the skeletal parts come in very usefully; Professor Huxley has shown us how to turn these parts to account.

Now, these two families are, in respect of their osteological structure, sharply divided from each other: the points in which they agree are fewer than those in which they disagree:—(*a*) The whole skeleton is much stronger, and more pneumatic, in the Anatidæ than in the Alcidæ. (*b*) The Anatidæ are desmognathous and holorhinal; they have permanent anterior basipterygoids, an azygous vomer, massive basitemporals, produced posterior angular processes to their mandible, dilated jaws covered with horny lamellæ, cylindroidal dorsals, a furcula composed of clavicles only, and the post-ilium much longer than the pre-ilium. The Alcidæ are schizognathous and schizorhinal; they have temporary middle basi-pterygoids, a double vomer, delicate basitemporals, arrested posterior angular processes, contracted and cultrate jaws, opisthocœlous dorsals, a considerable interclavicle in the furcula, and their post-ilium is much shorter than their pre-ilium. Now, if the ornithologist will add these differences to those which are familiar to him in the superficial structure of these birds, they will greatly strengthen and enrich his taxonomy. Also, looking on this picture and on that, he will be able to judge where these two families should be set in the class, so that his grouping of the plumy tribes may be as "goodly as the tents of Jacob."

We can now leave the fowler, and turn to that other labourer, who works with a spade and a pickaxe: the palæontologist is asking what all this modification of a reptilian type means, and how it bears on his special work.

(*b*) *The Anatidæ and Alcidæ considered from an ontological standpoint.*

If it has become clear that the birds are not sharply separated from the reptiles, it has also become equally clear that the reptiles are not sharply separated from the amphibians.

As to its hind-quarters,* the humming-bird is but a Dinosaurian—a sort of Iguanodon, intensely ossified, albeit the latter may be as large as a whale, and the former no larger than a "bumming bee." But vertebrated animals have fore-quarters as well as hind-quarters; they have also a neck and a head; and, if we are to grow our bird from a true reptile, lessening its size, warming its blood, and dotting it with feathers, we must graft the head of the Ichthyosaurus, and the neck of the Plesiosaurus, on to the hind-quarter of the Iguanodon. Now, I contend that Nature did not work in this fashion. The bird had its own ancestors as much as Man had his: *he* is not indebted to an archaic gorilla for his existence; and the bird owes nothing, in that way, to your Iguanodon, Plesiosaurus, and Ichthyosaurus. So much is clear. It is not clear as to how Nature did work: it is a perfect work, but she has concealed her art. If, however, her

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* See Huxley, Proceedings Geological Society, 1869, p. 31.

beginnings were mean and small, her latter end has greatly increased. We dream, scientifically, of the primordial amphibio-Dipnoan—the imagined common ancestor of all the reptiles and of all the birds; we see and handle the results; and, if the blind, unconscious morphological force could see and speak, it would pronounce all these forms "very good."

These remarks are general; we may, however, make some special attempt at showing that they are "words of soberness."

The development of the bird is not a process that takes place suddenly, at a leap; but is a long, slow, metamorphic process. Each stage in the development of a chick shows us the isomorph of some low adult form; each point gained gives us a quasi-historical record of some ancient type that must have belonged to a far lower platform of life than the creature whose growth we are tracing.* Then naked, dry teleology is of very little use to the morphologist; it serves him so badly that he is in danger of casting it aside altogether. Nature will not form her high and noble type all at once; she will "spin her yarn" slowly and with solemnity, working as with a needle in the dark. When the "tapestry" is perfected, then we have the pheasant and the pea-fowl, the trogon and the humming-bird.

That which has dominated the whole form is the wing. Yet, embryology shows us that this is merely the modified fore-paddle of a low gill-breathing amphibian—a nailless fore-paw. But the nails or claws do appear; yet, in the wing, they are out of place; and this reptilian stage is only transient. If the bird is, indeed, the child of the reptile, it must forget its father's house; it must proceed beyond its progenitor. But the reptile, as a rule, has a most perfect and typical "hand" or fore-foot, with accurate rows of carpals and metacarpals, and with digits in fixed order and number; in front two, then three, four, five, and once again, four in the hinder side.

We have no sign of atavism or degradation, of abortion or of suppression, in the perfect fore-foot of a lizard: in a bird all these things turn up, and startle the morphologist, whose hard duty it is to interpret them.

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* See Philosophical Transactions, 1869, pp. 803, 804.

But, if we are willing to see the bird's wing grow, not out of a perfect and typical cheiropterygium, but out of an ichthyopterygium in an unsettled state, ready for transformation into the higher type of limb, then the difficulty is solved. It was a fish-paddle; it was not to become a fore-foot; it did change into the framework of a bird's wing; in that respect it is a perfect thing; as a paw, it is an abortion.

But an organism moves together in all its parts, if it moves at all; and thus we see that, in correlation to the profoundly modified fore-limb, every other part of this feathered creature has suffered changes. I need not here recapitulate the details of this beautiful metamorphosis.*

As bearing upon the evolution of both the bird's wing and the fore-paw of the mammal, including the human hand, the most complete cheiropterygium in existence, I would again refer to M. Dollo's memoir on *Iguanodon beruissastensis*,† in which the five digits of the fore-arm have their normal number of reptilian segments (phalanges) in the first and second, whilst, as in mammals, the fourth and fifth keep to three only. This type also shows how a digit may become a spur; for the ungual phalanx of the pollex turns inwards and upwards, and forms a large defensive spur. And this is so closely set upon the very solid and simple carpus as to be little different from the spur of Palamedea and Chauna, among modern birds. Indeed, it is difficult to say whether the small bone at the base of the ungual phalanx

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* Besides the references to works and papers in the body of this memoir, I would here especially refer to some invaluable pieces of morphological work:—Morse, Dr. Edward S., "On the Tarsus and Carpus of Birds."—Ann. Lyc. Nat. Hist. New York. Vol. x., 1878; pp. 141–158, Plates IV., V. Do., "On the Identity of the Ascending Process of the Astragalus in Birds with the Intermedium."—Ann. Mem. Bost. Soc. Nat. Hist., 1880, pp. 1–10, Plate I. Kehrer, Gustav, "Beiträge zur Kenntniss des Carpus und Tarsus der Amphibien, Reptilien, und Säuger," Berichte der naturforschenden Gesellschaft zu Freiburg, i. B., Band i., pp. 1–14, Plate IV. Howes, Professor G. B., "On the Carpus and Tarsus of the Anura."—Proceedings, Zoological Society, 1888, pp. 141–182, Plates VII.–IX. Bardeleben, Professor Karl, "On the Pre-pollex and Pre-hallux, with observations on the Carpus of *Theriodesmus phylarchus*."—Proceedings, Zoological Society, 1889, pp. 259–262, Plate XXX. Baur, Dr. G., "Ueber den Ursprung der Extremitäten der Ichthyopterygia. Bericht über die xx. Versammlung des Oberrheinischen geologischen Vereins," pp. 1–4, figs. 1–4.

† Bull. Mus. Roy. Hist. Nat. Belg., t. i., Plate IX.; and t. ii., Plates III.–V.

in that reptile is a metacarpal or a proximal phalanx, or both in one, either fused or primarily connate. But some of these Dinosaurs have the normal number of phalanges in their fore-paw, as in the existing Lacertilia.*

I refer to these valuable Papers of Marsh and Dollo both as regards the limbs and the limb-girdles; the foreshadowing of the remarkable rotation of the pubis and ischium, so characteristic of birds, being seen also to a less degree in these huge reptiles, which seem, in this respect, to have had a tendency bird-ward, but missed their mark in respect of flying, a function for which they were just as little adapted as the existing whales.

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* See Amer. Jour. of Science and Art, vol. xvii., 1879, pp. 85–92, Plates III.–X.; *ibid.*, vol. xviii., Plate III., pp. 501–505; and *ibid.*, vol. xix., Plates VI.–XI., pp. 83–87, and 253–259.

PLATE I.

MORPHOLOGY OF THE DUCK AND THE AUK TRIBES.

EXPLANATION OF PLATE I.

Fig.		Number of times magnified.
1.	*Anas boschas;* 1st stage, after nine days' incubation (less mature); left wing, inner side inverted; drawn with pollex downwards, ...	15 diameters.
2.	The same; 1st stage; right leg, outer side inverted, ...	15 diameters.
3.	The same; 2nd stage, after nine days' incubation (more mature); right wing, inner side, natural position, ...	15 diameters.
4.	The same; 2nd stage; left leg, outer side, natural position, . . .	15 diameters.
5.	The same; 1st stage; left moiety of shoulder-girdle and sternum, outer view, ...	15 diameters.
6.	The same; 3rd stage, after twelve days' incubation; distal part of left wing, outer view, ...	15 diameters.
6*a*.	The same; distal part of index of right wing, ...	15 diameters.
7.	The same; part of the same wing as fig. 6, inner view, . . .	15 diameters.
8.	The same; 4th stage, after fourteen days' incubation; distal part of left wing, outer view, ...	12 diameters.
9.	The same; part of same wing, inner view, ...	12 diameters.
10.	The same; 3rd stage; front view of right ankle-joint, dislocated, . .	20 diameters.
11.	The same; lower part of same preparation, hinder view, . . .	20 diameters.
12.	The same; 4th stage; front view of right ankle-joint, dislocated at joint,	14 diameters.
13.	The same; 5th stage, after eighteen days' incubation; upper part of right ankle-joint, front view, ...	14 diameters.
14.	The same; 6th stage, duckling third day after hatching; left ankle; section through tibiale, ...	4 diameters.
15.	The same; same preparation; section through fibulare, ...	4 diameters.

[For LIST OF ABBREVIATIONS used on this Plate, *vide* over.]

LIST OF ABBREVIATIONS.

[*The Roman Numerals indicate Nerves and their Foramina.*]

ac.	Acetabulum.
ac.p.	Acromial process of scapula.
ag.	Angulare.
al.e.	Aliethmoid.
al.n.	Alinasal.
ar.	Articulare.
al.s.	Alisphenoid.
al.sp.	Aliseptal.
a.o.	Antorbital.
a.s.c.	Anterior semicircular canal.
at.	Atlas.
a.t.r.	Anterior tympanic recess.
au.	Auditory capsule.
ax.	Axis.
b.h.br.	Basi-hyobranchial.
b.hy.	Basihyal.
b.o.	Basioccipital.
b.pg.	Basipterygoid.
br.	Ceratobranchial.
b.s.	Basisphenoid.
b.t.	Basitemporal.
c.	Centrum and centrale.
c.u.	Uncinate process.
cd.v.	Caudal vertebra.
c.f.c.	Cranio-facial cleft.
c.hy.	Cerato-hyal.
cl.	Clavicle.
co.	Columella.
cp.	Carpal.
cr.	Coracoid and cervical rib.
cr.g.	Crista galli.
c.ty.	Tympanic cavity.
c.u.	Centralo-ulnare.
c.v.	Cervical vertebræ.
d.	Dentary.
d.c.	Distal carpal.
dg.	Digit.
d.t.	Distal tarsal.
d.r.	Dorsal rib.
d.s.v.	Dorso-sacral vertebræ,
d.v.	Dorsal vertebra.
e.eth.	Ectoethmoid.
e.n.	External nostril.
e.o.	Exoccipital.
Eu.	Eustachian opening.
f.	Frontal and femur.
fb.	Fibula.
fbe.	Fibulare.
f.m.	Foramen magnum.
fr.	Furcula.
g.	Ganglion.
h.	Humerus.
h.s.c.	Horizontal semicircular canal.
i.	Intermedium.
i.a.c.	Interarcticular cartilage.
i.a.p.	Internal angular process.
ic.	Intercentrum.
i.c.	Internal carotid foramen.
i.cl.	Interclavicle.
il.	Ilium.
i.o.f.	Inter-orbital fenestra.
i.pa.	Inter-palatine.
i.r.	Intermedio-radiale.
isc.	Ischium.
i.tb.	Inferior turbinal.
i.tr.	Inter-trabecula.
j.	Jugal.
l.	Lachrymal
l.c.	Lachrymal canal.
l.s.v.	Lumbo-sacral vertebræ.
m.	Mouth.
mk.	Meckel's cartilage.
m.st.	Metasternum.
mt.c.	Metacarpal.
mt.t.	Metatarsal.
mx.p.	Maxillo-palatine.
n.	Nasal.
n.a.	Neural arch.
nc.	Notochord.
n.f.	Nasal floor.
n.px.	Nasal process of pre-maxillary.
ob.f.	Obturator fenestra.
oc.c.	Occipital condyle.
od.p.	Odontoidprocess.
op.	Opisthotic.
o.s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p.a.p.	Posterior angular process.
pa.s.	Parasphenoid.
pb.	Pubis.
p.cl.	Posterior clinoid process.
pc.p.	Postcoracoid process of sternum.
pcr.	Precoracoid.
p.c.s.	Pre-costal process of sternum.
p.e.	Perpendicular ethmoid.
pg.	Pterygoid.
ph.	Phalanx.
p.n.	Prenasal rostrum.
pr.i.	Pre-ilium.
pro.	Prootic.
pr.z.	Pre-zygaphophysis.
p.s.	Presphenoid.
p.s.c.	Posterior semicircular canal.
pt.i.	Post-ilium.
pt.z.	Post-zygapophysis.
px.	Premaxilla.
q.	Quadrate.
q.j.	Quadrato-jugal.
r.	Radius.
r.b.s.	Rostrum of basisphenoid (= rostrum of parasphenoid).
re.	Radiale.
r.st.	Rostral process of sternum.
s.ag.	Supra-angulare.
sc.	Scapula.
s.n.	Septum nasi.
s.i.f.	Sacro-ischiatic fenestra.
s.o.	Supra-occipital.
sp.	Splenial.
sp.o.	Sphenotic.
sq.	Squamosal.
s.r.	Sacral rib.
s.sc.	Supra-scapula.
st.	Sternum.
st.k.	Sternal keel.
s.v.	Sacral vertebra.
tb.	Tibial.
t.c.	Tendon-canal.
te.	Tibiale.
t.eo.	Tympanic wing of occipital.
ts.	Tarsal.
u.	Ulna.
ue.	Ulnare.
u.s.v.	Uro-sacral vertebræ.
v.	Vomer.
v.a.	Vertebral artery.
v.b.	Vestibule.

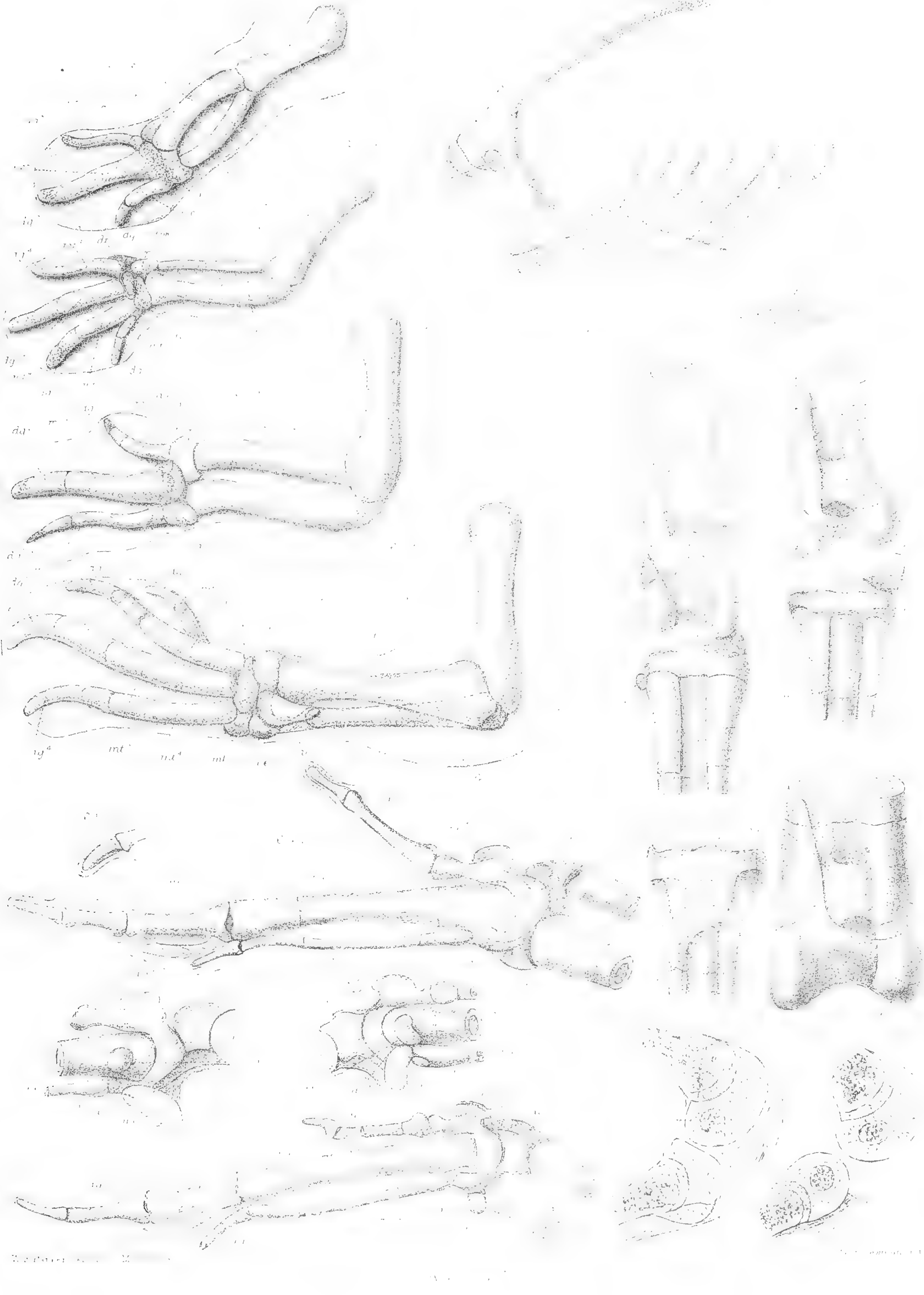
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PLATE II.

MORPHOLOGY OF THE DUCK AND THE AUK TRIBES.

EXPLANATION OF PLATE II.

Fig.		Number of times magnified.
1.	*Anas boschas;* 1st stage; left side of pelvis and hinder part of spine, outer view,	16 diameters.
2.	The same; 2nd stage; a similar view of the same parts,	12 diameters.
3.	The same; 3rd stage; twelve days' incubation; a similar view of the same parts, with the pelvis somewhat dislocated from the spinal column,	9½ diameters.
4.	The same; 5th stage; eighteen days' incubation; distal part of left wing, outer view,	9½ diameters.
5.	The same; part of same object, inner view,	19 diameters.
6.	The same; part of the same as fig. 4,	29 diameters.
7.	The same; 6th stage; ripe embryo distal part of wing, outer view,	8 diameters.
8.	The same; part of same preparation, outer view,	16 diameters.
9.	The same; same object; inner view,	16 diameters.
10.	The same; 7th stage; proximal part of manus, outer view,	10 diameters.
11.	The same; same object; inner view,	10 diameters.
12.	The same; 7th stage; another specimen; coccygeal tract of spine; side view,	5 diameters.
13.	*Chauna chavaria;* adult; distal end of ulnar, with carpals,	¾ Natural size.
14.	*Cygnus atratus;* part of palate,	¾ Natural size.
15.	*Anser palustris* six weeks old; vomer and antero-superior additional ossicle; lateral and upper views,	2½ diameters.

[For List of Abbreviations used on this Plate, *vide* over.]

LIST OF ABBREVIATIONS.

[*The Roman Numerals indicate Nerves and their Foramina.*]

ac.	Acetabulum.
ac.p.	Acromial process of scapula.
ag.	Angulare.
al.e.	Aliethmoid.
al.n.	Alinasal.
ar.	Articulare.
al.s.	Alisphenoid.
al.sp.	Aliseptal.
a.o.	Antorbital.
a.s.c.	Anterior semicircular canal.
at.	Atlas.
a.t.r.	Anterior tympanic recess.
au.	Auditory capsule.
ax.	Axis.
b.h.br.	Basi-hyobranchial.
b.hy.	Basihyal.
b.o.	Basioccipital.
b.py.	Basipterygoid.
br.	Ceratobranchial.
b.s.	Basisphenoid.
b.t.	Basitemporal.
c.	Centrum and centrale.
c.a.	Uncinate process.
cd.v.	Caudal vertebra.
c.f.c.	Cranio-facial cleft.
c.hy.	Cerato-hyal.
cl.	Clavicle.
co.	Columella.
cp.	Carpal.
cr.	Coracoid and cervical rib.
cr.g.	Crista galli.
c.ty.	Tympanic cavity.
c.u.	Centralo-ulnare.
c.v.	Cervical vertebræ.
d.	Dentary.
d.c.	Distal carpal.
dg.	Digit.
d.t.	Distal tarsal.
d.r.	Dorsal rib.
d.s.v.	Dorso-sacral vertebræ,
d.v.	Dorsal vertebra.
e.eth.	Ectoethmoid.
e.n.	External nostril.
e.o.	Exoccipital.
Eu.	Eustachian opening.
f.	Frontal and femur.
fb.	Fibula.
fbe.	Fibulare.
f.m.	Foramen magnum.
fr.	Furcula.
g.	Ganglion.
h.	Humerus.
h.s.c.	Horizontal semicircular canal.
i.	Intermedium.
i.a.c.	Interarcticular cartilage.
i.a.p.	Internal angular process.
ic.	Intercentrum.
i.c.	Internal carotid foramen.
i.cl.	Interclavicle.
il.	Ilium.
i.o.f.	Inter-orbital fenestra.
i.pa.	Inter-palatine.
i.r.	Intermedio-radiale.
isc.	Ischium.
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i.tr.	Inter-trabecula.
j.	Jugal.
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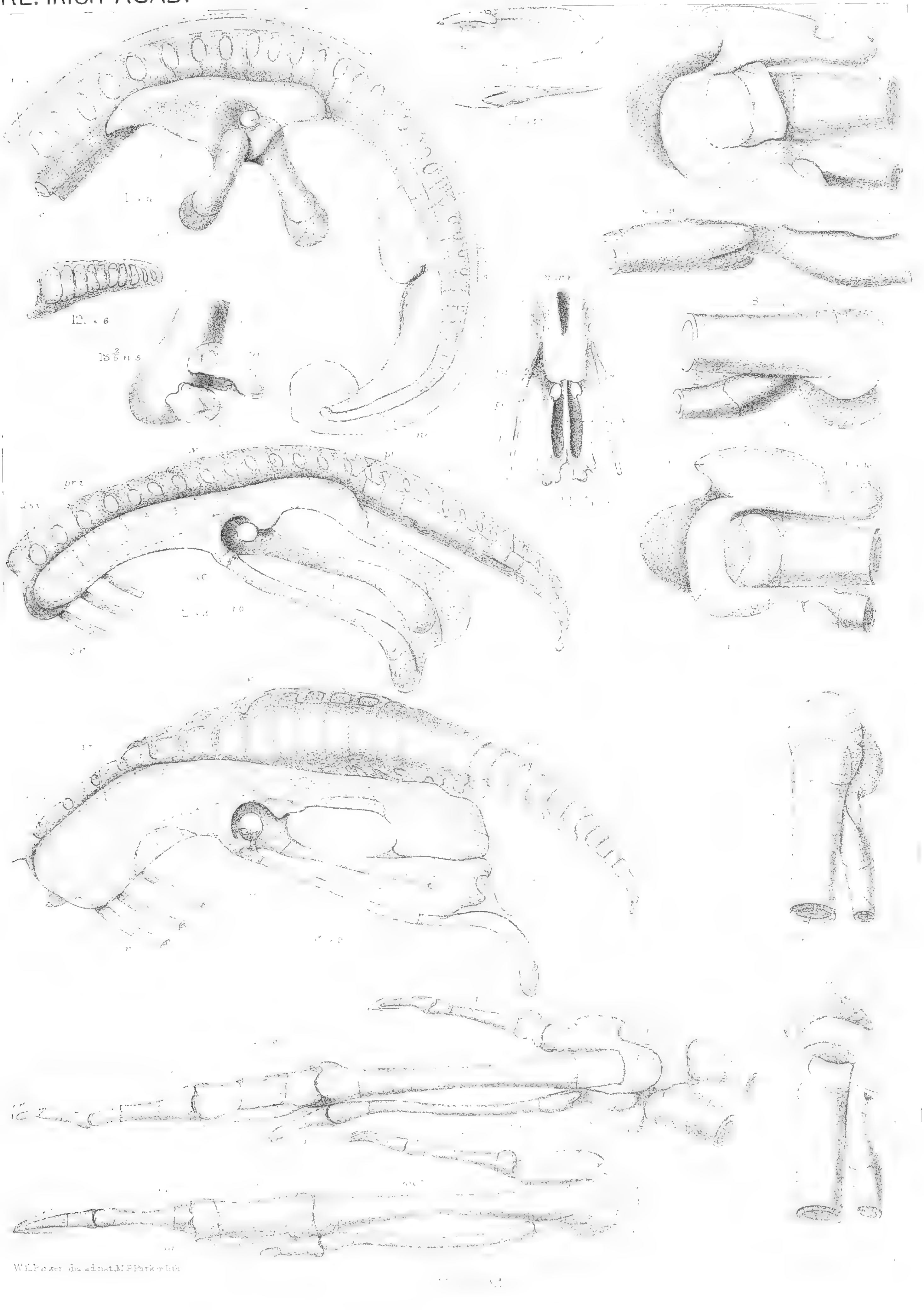
l.c.	Lachrymal canal.
l.s.v.	Lumbo-sacral vertebræ.
m.	Mouth.
mk.	Meckel's cartilage.
m.st.	Metasternum.
mt.c.	Metacarpal.
mt.t.	Metatarsal.
mx.p.	Maxillo-palatine.
n.	Nasal.
n.a.	Neural arch.
nc.	Notochord.
n.f.	Nasal floor.
n.px.	Nasal process of pre-maxillary.
ob.f.	Obturator fenestra.
oc.c.	Occipital condyle.
od.p.	Odontoidprocess.
op.	Opisthotic.
o.s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p.a.p.	Posterior angular process.
pa.s.	Parasphenoid.
pb.	Pubis.
p.cl.	Posterior clinoid process.
pc.p.	Postcoracoid process of sternum.
pcr.	Precoracoid.
p.c.s.	Pre-costal process of sternum.
p.e.	Perpendicular ethmoid.
pg.	Pterygoid.
ph.	Phalanx.
p.n.	Prenasal rostrum.
pr.i.	Pre-ilium.
pro.	Prootic.
pr.z.	Pre-zygaphophysis.
p.s.	Presphenoid.
p.s.c.	Posterior semicircular canal.
pt.i.	Post-ilium.
pt.z.	Post-zygapophysis.
px.	Premaxilla.
q.	Quadrate.
q.j.	Quadrato-jugal.
r.	Radius.
r.b.s.	Rostrum of basisphenoid (= rostrum of parasphenoid).
rc.	Radiale.
r.st.	Rostral process of sternum.
s.ag.	Supra-angulare.
sc.	Scapula.
s.n.	Septum nasi.
s.i.f.	Sacro-ischiatic fenestra.
s.o.	Supra-occipital.
sp.	Splenial.
sp.o.	Sphenotic.
sq.	Squamosal.
s.r.	Sacral rib.
s.sc.	Supra-scapula.
st.	Sternum.
st.k.	Sternal keel.
s.v.	Sacral vertebra.
tb.	Tibial.
t.c.	Tendon-canal.
te.	Tibiale.
t.eo.	Tympanic wing of occipital.
ts.	Tarsal.
u.	Ulna.
ue.	Ulnare.
u.s.v.	Uro-sacral vertebræ.
v.	Vomer.
v.a.	Vertebral artery.
v.b.	Vestibule.



W.K.Parker del. ad nat. M.P.Parker lith.

PLATE III.

MORPHOLOGY OF THE DUCK AND THE AUK TRIBES.

LIST OF ABBREVIATIONS.

[*The Roman Numerals indicate Nerves and their Foramina.*]

ac.	Acetabulum.
ac.p.	Acromial process of scapula.
ag.	Angulare.
al.e.	Aliethmoid.
al.n.	Alinasal.
ar.	Articulare.
al.s.	Alisphenoid.
al.sp.	Aliseptal.
a.o.	Antorbital.
a.s.c.	Anterior semicircular canal.
at.	Atlas.
a.t.r.	Anterior tympanic recess.
au.	Auditory capsule.
ax.	Axis.
b.h.br.	Basi-hyobranchial.
b.hy.	Basihyal.
b.o.	Basioccipital.
b.pg.	Basipterygoid.
br.	Ceratobranchial.
b.s.	Basisphenoid.
b.t.	Basitemporal.
c.	Centrum and centrale.
c.u.	Uncinate process.
cd.v.	Caudal vertebra.
c.f.c.	Cranio-facial cleft.
c.hy.	Cerato-hyal.
cl.	Clavicle.
co.	Columella.
cp.	Carpal.
cr.	Coracoid and cervical rib.
cr.g.	Crista galli.
c.ty.	Tympanic cavity.
c.u.	Centralo-ulnare.
c.v.	Cervical vertebræ.
d.	Dentary.
d.c.	Distal carpal.
dg.	Digit.
d.t.	Distal tarsal.
d.r.	Dorsal rib.
d.s.v.	Dorso-sacral vertebræ,
d.v.	Dorsal vertebra.
e.eth.	Ectoethmoid.
e.n.	External nostril.
e.o.	Exoccipital.
Eu.	Eustachian opening.
f.	Frontal and femur.
fb.	Fibula.
fbe.	Fibulare.
f.m.	Foramen magnum.
fr.	Furcula.
g.	Ganglion.
h.	Humerus.
h.s.c.	Horizontal semicircular canal.
i.	Intermedium.
i.a.c.	Interarcticular cartilage.
i.a.p.	Internal angular process.
ic.	Intercentrum.
i.c.	Internal carotid foramen.
i.cl.	Interclavicle.
il.	Ilium.
i.o.f.	Inter-orbital fenestra.
i.pt.	Inter-palatine.
i.r.	Intermedio-radiale.
isc.	Ischium.
i.tb.	Inferior turbinal.
i.tr.	Inter-trabecula.
j.	Jugal.
l.	Lachrymal.
l.c.	Lachrymal canal.
l.s.v.	Lumbo-sacral vertebræ.
m.	Mouth.
mk.	Meckel's cartilage.
m.st.	Metasternum.
mt.c.	Metacarpal.
mt.t.	Metatarsal.
mx.p.	Maxillo-palatine.
n.	Nasal.
n.a.	Neural arch.
nc.	Notochord.
n.f.	Nasal floor.
n.px.	Nasal process of pre-maxillary.
ob.f.	Obturator fenestra.
oc.c.	Occipital condyle.
od.p.	Odontoidprocess.
op.	Opisthotic.
o.s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p.a.p.	Posterior angular process.
pa.s.	Parasphenoid.
pb.	Pubis.
p.cl.	Posterior clinoid process.
pc.p.	Postcoracoid process of sternum.
pcr.	Precoracoid.
p.c.s.	Pre-costal process of sternum.
p.e.	Perpendicular ethmoid.
pg.	Pterygoid.
ph.	Phalanx.
p.n.	Prenasal rostrum.
pr.i.	Pre-ilium.
pro.	Prootic.
pr.z.	Pre-zygaphophysis.
p.s.	Presphenoid.
p.s.c.	Posterior semicircular canal.
pt.i.	Post-ilium.
pt.z.	Post-zygapophysis.
px.	Premaxilla.
q.	Quadrate.
q.j.	Quadrato-jugal.
r.	Radius.
r.b.s.	Rostrum of basisphenoid (= rostrum of parasphenoid).
re.	Radiale.
r.st.	Rostral process of sternum.
s.ag.	Supra-angulare.
sc.	Scapula.
s.n.	Septum nasi.
s.i.f.	Sacro-ischiatic fenestra.
s.o.	Supra-occipital.
sp.	Splenial.
sp.o.	Sphenotic.
sq.	Squamosal.
s.r.	Sacral rib.
s.sc.	Supra-scapula.
st.	Sternum.
st.k.	Sternal keel.
s.v.	Sacral vertebra.
tb.	Tibial.
t.c.	Tendon-canal.
te.	Tibiale.
t.eo.	Tympanic wing of occipital.
ts.	Tarsal.
u.	Ulna.
ue.	Ulnare.
u.s.v.	Uro-sacral vertebræ.
v.	Vomer.
v.a.	Vertebral artery.
v.b.	Vestibule.

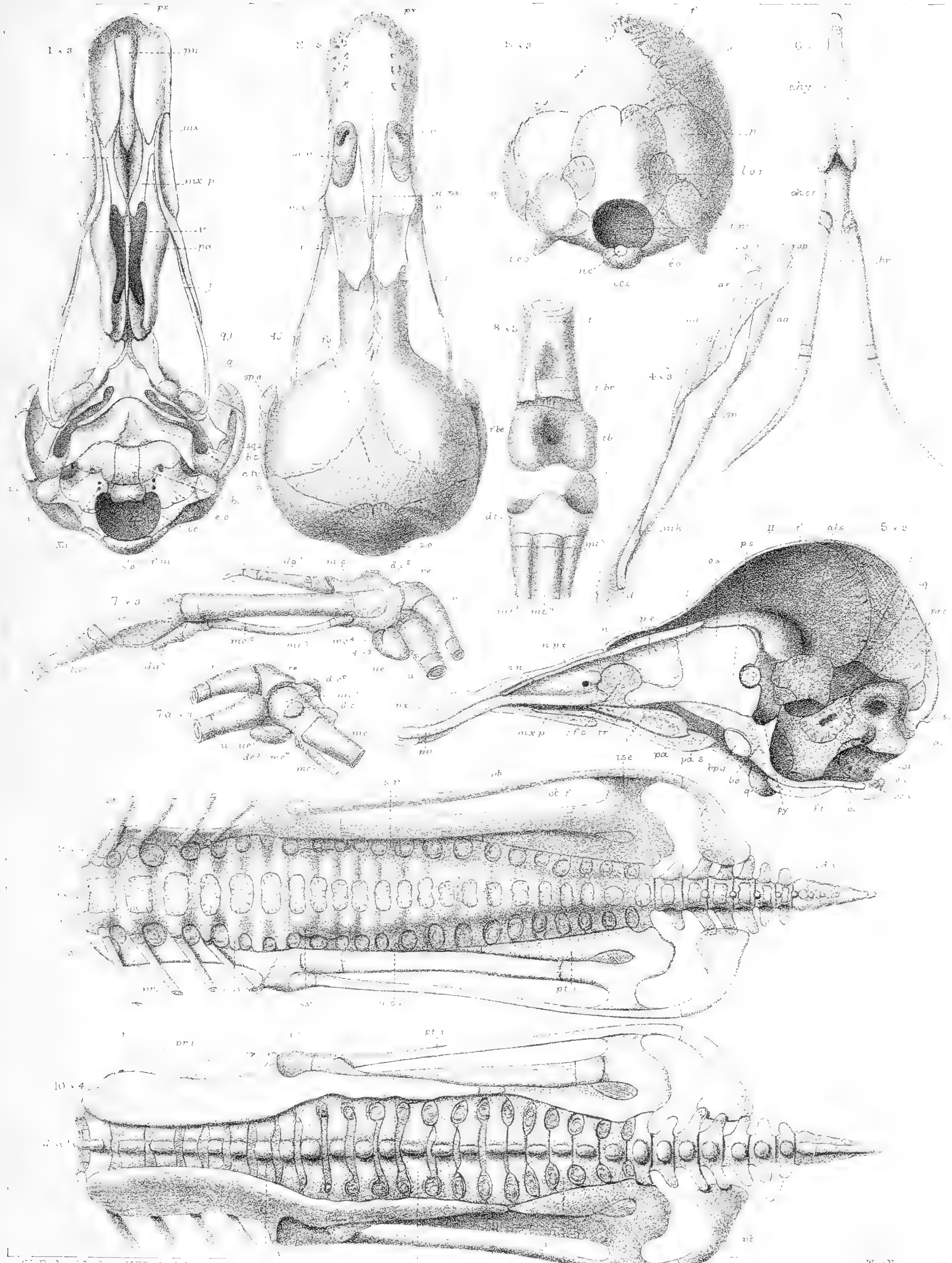


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PLATE IV.

MORPHOLOGY OF THE DUCK AND THE AUK TRIBES.

EXPLANATION OF PLATE IV.

Fig.		Number of times magnified.
1.	*Cygnus nigricollis;* nearly ripe skeleton; side view, . . .	3 diameters.

[For List of Abbreviations used on this Plate, *vide* over.]

LIST OF ABBREVIATIONS.

[*The Roman Numerals indicate Nerves and their Foramina.*]

ac.	Acetabulum.
ac.p.	Acromial process of scapula.
ag.	Angulare.
al.e.	Aliethmoid.
al.n.	Alinasal.
ar.	Articulare.
al.s.	Alisphenoid.
al.sp.	Aliseptal.
a.o.	Antorbital.
a.s.c.	Anterior semicircular canal.
at.	Atlas.
a.t.r.	Anterior tympanic recess.
au.	Auditory capsule.
ax.	Axis.
b.h.br.	Basi-hyobranchial.
b.hy.	Basihyal.
b.o.	Basioccipital.
b.pg.	Basipterygoid.
br.	Ceratobranchial.
b.s.	Basisphenoid.
b.t.	Basitemporal.
c.	Centrum and centrale.
c.a.	Uncinate process.
cd.v.	Caudal vertebra.
c.f.c.	Cranio-facial cleft.
c.hy.	Cerato-hyal.
cl.	Clavicle.
co.	Columella.
cp.	Carpal.
cr.	Coracoid and cervical rib.
cr.g.	Crista galli.
c.ty.	Tympanic cavity.
c.u.	Centralo-ulnare.
c.v.	Cervical vertebræ.
d.	Dentary.
d.c.	Distal carpal.
dg.	Digit.
d.t.	Distal tarsal.
d.r.	Dorsal rib.
d.s.v.	Dorso-sacral vertebræ,
d.v.	Dorsal vertebra.
e.eth.	Ectoethmoid.
e.n.	External nostril.
e.o.	Exoccipital.
Eu.	Eustachian opening.
f.	Frontal and femur.
fb.	Fibula.
fbe.	Fibulare.
f.m.	Foramen magnum.
fr.	Furcula.
g.	Ganglion.
h.	Humerus.
h.s.c.	Horizontal semicircular canal.
i.	Intermedium.
i.a.c.	Interarcticular cartilage.
i.a.p.	Internal angular process.
ic.	Intercentrum.
i.c.	Internal carotid foramen.
i.cl.	Interclavicle.
il.	Ilium.
i.o.f.	Inter-orbital fenestra.
i.pt.	Inter-palatine.
i.r.	Intermedio-radiale.
isc.	Ischium.
i.th.	Inferior turbinal.
i.tr.	Inter-trabecula.
j.	Jugal.
l.	Lachrymal.
l.c.	Lachrymal canal.
l.s.v.	Lumbo-sacral vertebræ.
m.	Mouth.
mk.	Meckel's cartilage.
m.st.	Metasternum.
mt.c.	Metacarpal.
mt.t.	Metatarsal.
mx.p.	Maxillo-palatine.
n.	Nasal.
n.a.	Neural arch.
nc.	Notochord.
n.f.	Nasal floor.
n.px.	Nasal process of pre-maxillary.
ob.f.	Obturator fenestra.
oc.c.	Occipital condyle.
od.p.	Odontoidprocess.
op.	Opisthotic.
o.s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p.a.p.	Posterior angular process.
pa.s.	Parasphenoid.
pb.	Pubis.
p.cl.	Posterior clinoid process.
pc.p.	Postcoracoid process of sternum.
pcr.	Precoracoid.
p.c.s.	Pre-costal process of sternum.
p.e.	Perpendicular ethmoid.
pg.	Pterygoid.
ph.	Phalanx.
p.n.	Prenasal rostrum.
pr.i.	Pre-ilium.
pro.	Prootic.
pr.z.	Pre-zygaphophysis.
p.s.	Presphenoid.
p.s.c.	Posterior semicircular canal.
pt.i.	Post-ilium.
pt.z.	Post-zygapophysis.
px.	Premaxilla.
q.	Quadrate.
q.j.	Quadrato-jugal.
r.	Radius.
r.b.s.	Rostrum of basisphenoid (= rostrum of parasphenoid).
re.	Radiale.
r.st.	Rostral process of sternum.
s.ag.	Supra-angulare.
sc.	Scapula.
s.n.	Septum nasi.
s.i.f.	Sacro-ischiatic fenestra.
s.o.	Supra-occipital.
sp.	Splenial.
sp.o.	Sphenotic.
sq.	Squamosal.
s.r.	Sacral rib.
s.sc.	Supra-scapula.
st.	Sternum.
st.k.	Sternal keel.
s.v.	Sacral vertebra.
tb.	Tibial.
t.c.	Tendon-canal.
te.	Tibiale.
t.co.	Tympanic wing of occipital.
ts.	Tarsal.
u.	Ulna.
ue.	Ulnare.
u.s.v.	Uro-sacral vertebræ.
v.	Vomer.
v.a.	Vertebral artery.
v.b.	Vestibule.

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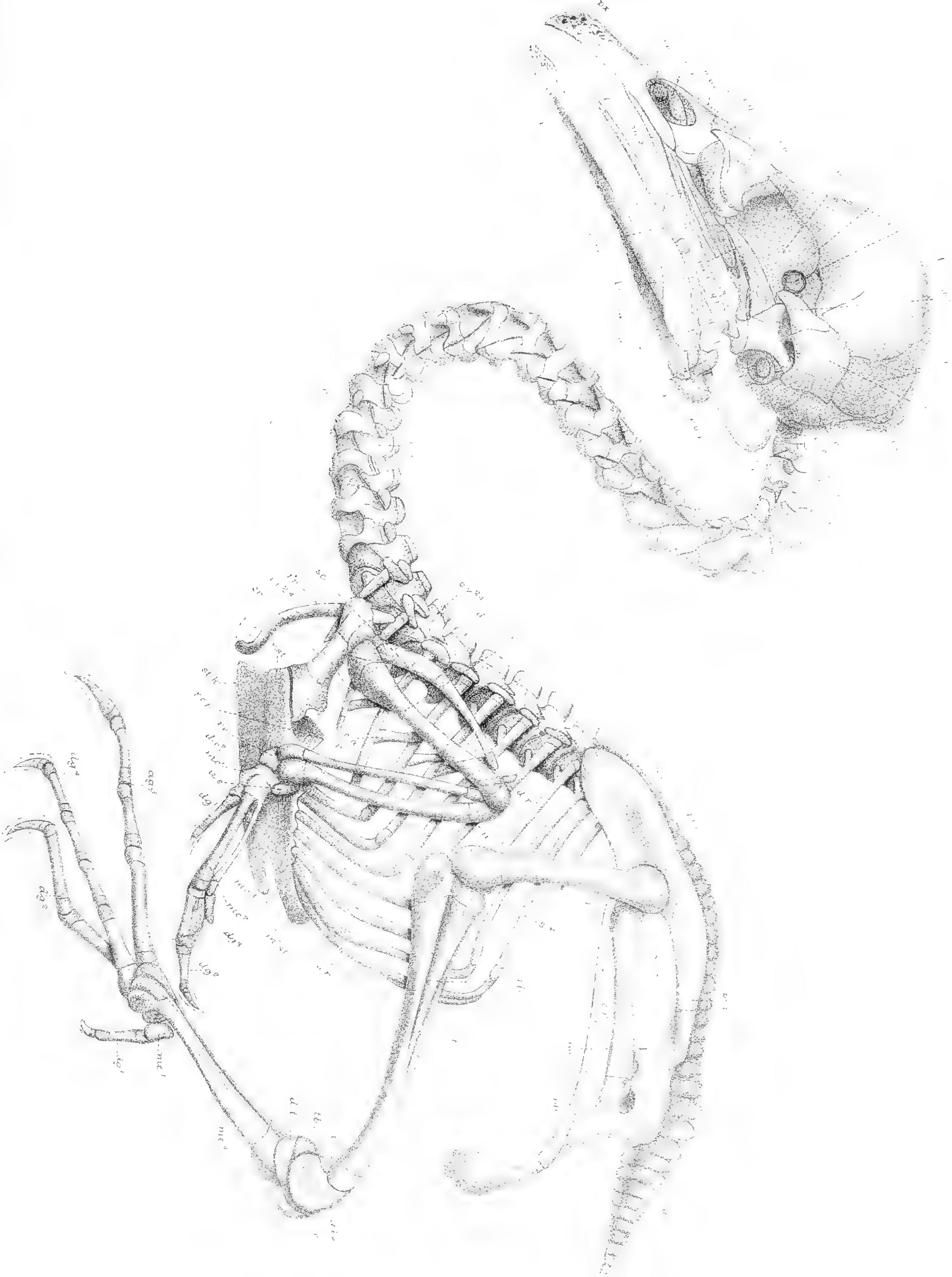


a d nat. M P Parker lith.

West, Newman imp.

PLATE V.

MORPHOLOGY OF THE DUCK AND THE AUK TRIBES.

EXPLANATION OF PLATE V.

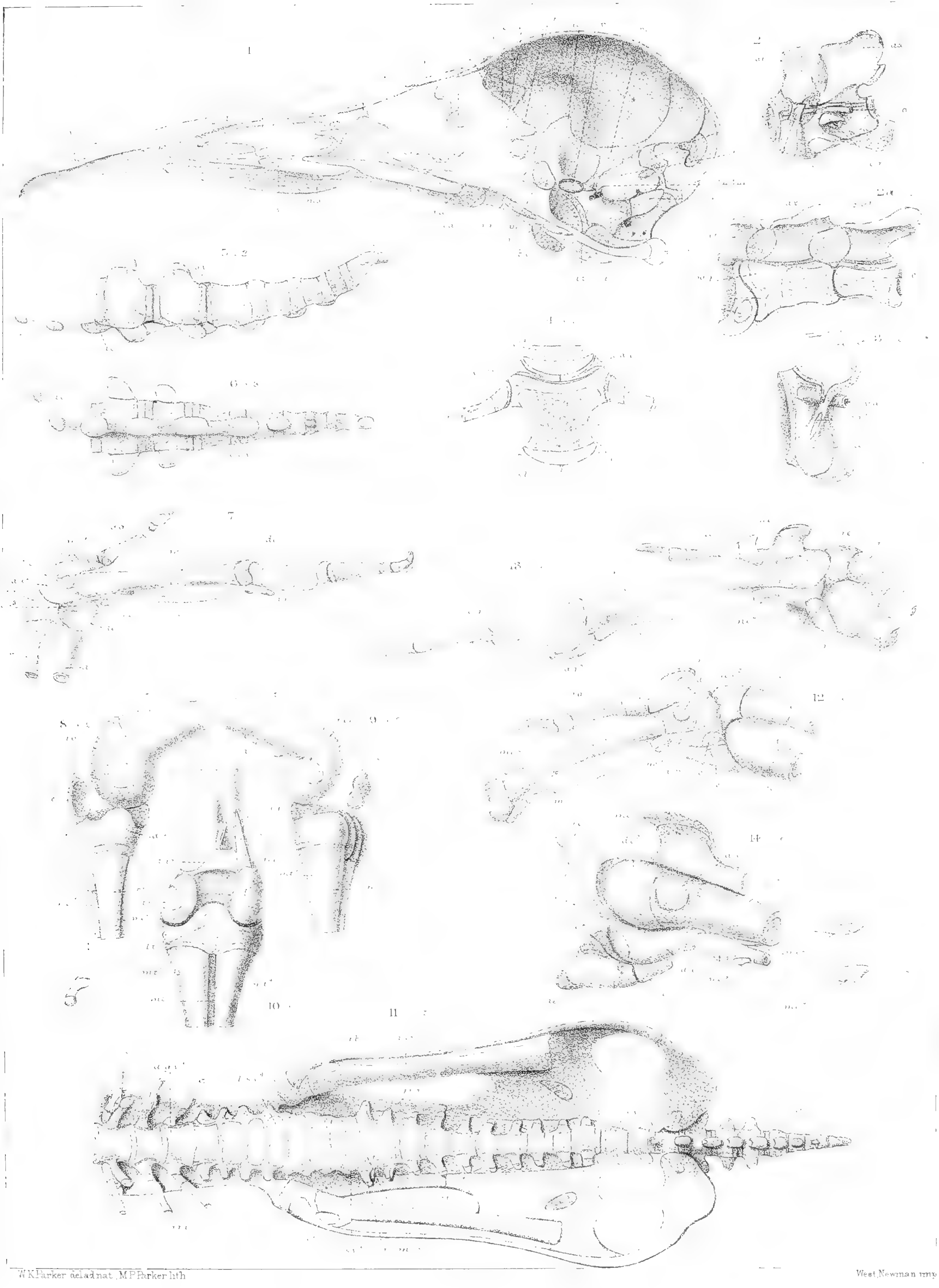
Fig.		Number of times magnified.
1.	*Cygnus olor ;* (*a*) cygnet 14½ inches long ; skull in vertical section, .	2 diameters.
2.	The same ; (*a*) atlas and axis ; side view, ...	3 diameters.
2*a*.	The same ; (*a*) section of the first three cervical vertebræ, . . .	3 diameters.
3.	The same ; (*b*) cygnet 15 inches long ; part of atlas ; side view, . .	6 diameters.
4.	The same ; (*a*) centrum of 25th part of 24th cervical vertebræ ; horizontal section near lower surface, ...	3 diameters.
5.	The same ; (*b*) terminal part of spinal column ; side view, . . .	3 diameters.
6.	The same ; same object ; lower view, ...	3 diameters.
7.	The same ; (*a*) distal part of wing ; inner view, ...	3 diameters.
8.	The same ; (*a*) ankle-joint ; inner view, ...	2 diameters.
9.	The same ; same object ; outer view, ...	2 diameters.
10.	The same ; same object ; front view, ...	2 diameters.
11.	The same ; (*b*) pelvis ; lower view, ...	1½ diameters.
12.	*Chloëphaga poliocephala*, ripe embryo ; distal part of wing ; outer view, .	3 diameters.
13.	The same ; same object ; inner view, ...	3 diameters.
14.	The same ; part of fig. 13, ...	6 diameters.

[For List of Abbreviations used on this Plate, *vide* over.]

LIST OF ABBREVIATIONS.

[*The Roman Numerals indicate Nerves and their Foramina.*]

ac.	Acetabulum.
ac.p.	Acromial process of scapula.
ag.	Angulare.
al.e.	Aliethmoid.
al.n.	Alinasal.
ar.	Articulare.
al.s.	Alisphenoid.
al.sp.	Aliseptal.
a.o.	Antorbital.
a.s.c.	Anterior semicircular canal.
at.	Atlas.
a.t.r.	Anterior tympanic recess.
au.	Auditory capsule.
ax.	Axis.
b.h.br.	Basi-hyobranchial.
b.hy.	Basihyal.
b.o.	Basioccipital.
b.pg.	Basipterygoid.
br.	Ceratobranchial.
b.s.	Basisphenoid.
b.t.	Basitemporal.
c.	Centrum and centrale.
c.a.	Uncinate process.
cd.v.	Caudal vertebra.
c.f.c.	Cranio-facial cleft.
c.hy.	Cerato-hyal.
cl.	Clavicle.
co.	Columella.
cp.	Carpal.
cr.	Coracoid and cervical rib.
cr.g.	Crista galli.
c.ty.	Tympanic cavity.
c.u.	Centralo-ulnare.
c.v.	Cervical vertebræ.
d.	Dentary.
d.c.	Distal carpal.
dg.	Digit.
d.t.	Distal tarsal.
d.r.	Dorsal rib.
d.s.v.	Dorso-sacral vertebræ,
d.v.	Dorsal vertebra.
ec.th.	Ectoethmoid.
e.n.	External nostril.
e.o.	Exoccipital.
Eu.	Eustachian opening.
f.	Frontal and femur.
fb.	Fibula.
fbe.	Fibulare.
f.m.	Foramen magnum.
fr.	Furcula.
g.	Ganglion.
h.	Humerus.
h.s.c.	Horizontal semicircular canal.
i.	Intermedium.
i.a.c.	Interarcticular cartilage.
i.a.p.	Internal angular process.
ic.	Intercentrum.
i.c.	Internal carotid foramen.
i.cl.	Interclavicle.
il.	Ilium.
i.o.f.	Inter-orbital fenestra.
i.pt.	Inter-palatine.
i.r.	Intermedio-radiale.
is.	Ischium.
i.tb.	Inferior turbinal.
i.tr.	Inter-trabecula.
j.	Jugal.
l.	Lachrymal.
l.c.	Lachrymal canal.
l.s.v.	Lumbo-sacral vertebræ.
m.	Mouth.
mk.	Meckel's cartilage.
m.st.	Metasternum.
mt.c.	Metacarpal.
mt.t.	Metatarsal.
mx.p.	Maxillo-palatine.
n.	Nasal.
n.a.	Neural arch.
nc.	Notochord.
n.f.	Nasal floor.
n.px.	Nasal process of pre-maxillary.
ob.f.	Obturator fenestra.
oc.c.	Occipital condyle.
od.p.	Odontoidprocess.
op.	Opisthotic.
o.s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p.a.p.	Posterior angular process.
pa.s.	Parasphenoid.
pb.	Pubis.
p.cl.	Posterior clinoid process.
pc.p.	Postcoracoid process of sternum.
pcr.	Precoracoid.
p.c.s.	Pre-costal process of sternum.
p.e.	Perpendicular ethmoid.
pg.	Pterygoid.
ph.	Phalanx.
p.n.	Prenasal rostrum.
pr.i.	Pre-ilium.
pro.	Prootic.
pr.z.	Pre-zygaphophysis.
p.s.	Presphenoid.
p.s.c.	Posterior semicircular canal.
pt.i.	Post-ilium.
pt.z.	Post-zygapophysis.
px.	Premaxilla.
q.	Quadrate.
q.j.	Quadrato-jugal.
r.	Radius.
r.b.s.	Rostrum of basisphenoid (= rostrum of parasphenoid).
ra.	Radiale.
r.st.	Rostral process of sternum.
s.ag.	Supra-angulare.
sc.	Scapula.
s.n.	Septum nasi.
s.i.f.	Sacro-ischiatic fenestra.
s.o.	Supra-occipital.
sp.	Splenial.
sp.o.	Sphenotic.
sq.	Squamosal.
s.r.	Sacral rib.
s.sc.	Supra-scapula.
st.	Sternum.
st.k.	Sternal keel.
s.v.	Sacral vertebra.
tb.	Tibial.
t.c.	Tendon-canal.
te.	Tibiale.
t.eo.	Tympanic wing of occipital.
ts.	Tarsal.
u.	Ulna.
ue.	Ulnare.
u.s.v.	Uro-sacral vertebræ.
v.	Vomer.
v.a.	Vertebral artery.
v.b.	Vestibule.



W.K.Parker del.ad nat. M.P.Parker lith.

West, Newman imp.

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PLATE VI.

MORPHOLOGY OF THE DUCK AND THE AUK TRIBES.

EXPLANATION OF PLATE VI.

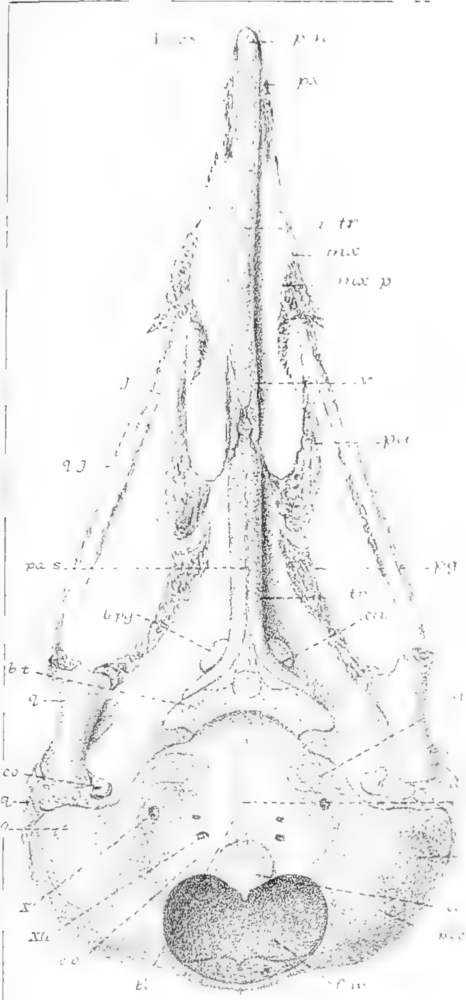
Fig.		Number of times magnified.
1.	*Uria troile;* 1st stage; embryo, one-third ripe; skull; lower view, .	6½ diameters.
2.	The same; mandible of same stage; inner view, ...	6½ diameters.
3.	The same; hyoid arch; upper view, ...	6½ diameters.
4.	The same; 2nd stage; embryo two-thirds ripe; skull; lower view, .	4 diameters.
5.	The same; same skull; upper view, ...	4 diameters.
6.	The same; mandible of same skull; inner view, ...	4 diameters.
7.	The same; hyoid arch of same skull; upper view, ...	4 diameters.
8.	The same; 3rd stage; embryo, nearly ripe; section of skull, and inner view of mandible, ...	4 diameters.

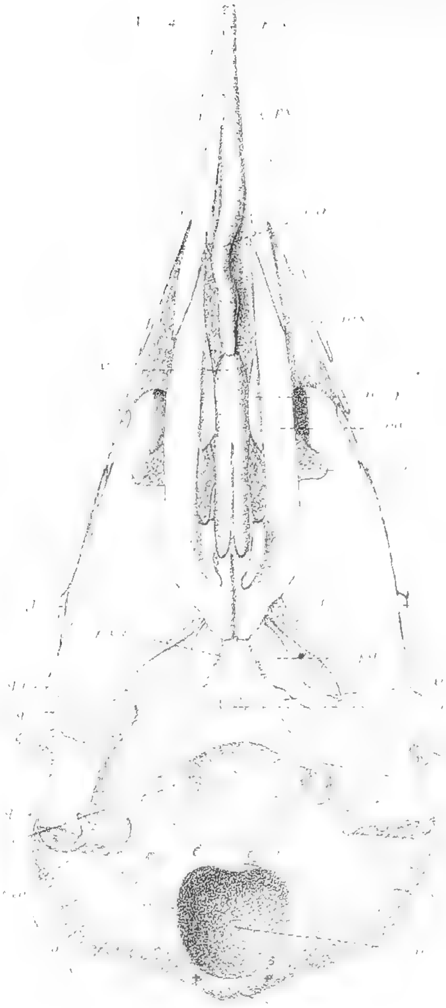
[For List of Abbreviations used on this Plate, *vide* over.]

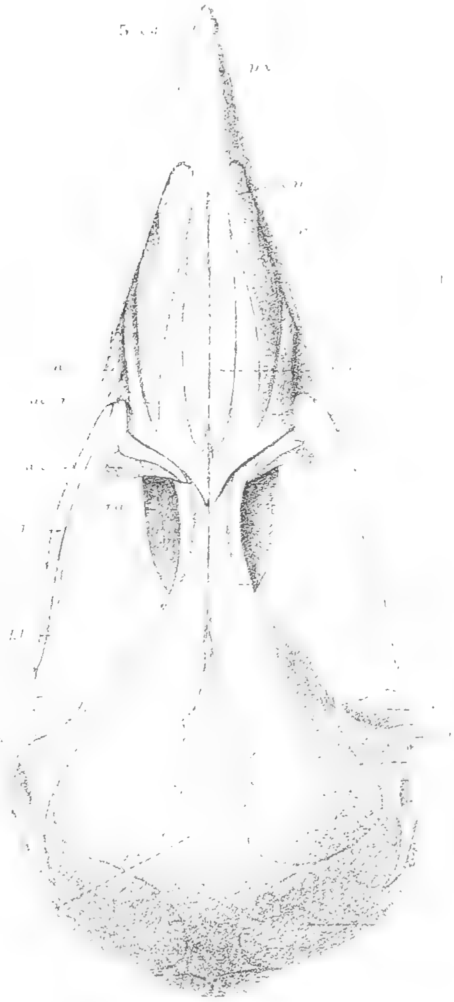
LIST OF ABBREVIATIONS.

[*The Roman Numerals indicate Nerves and their Foramina.*]

ac.	Acetabulum.
ac.p.	Acromial process of scapula.
ag.	Angulare.
al.e.	Aliethmoid.
al.n.	Alinasal.
ar.	Articulare.
al.s.	Alisphenoid.
al.sp.	Aliseptal.
a.o.	Antorbital.
a.s.c.	Anterior semicircular canal.
at.	Atlas.
a.t.r.	Anterior tympanic recess.
au.	Auditory capsule.
ax.	Axis.
b.h.br.	Basi-hyobranchial.
b.hy.	Basihyal.
b.o.	Basioccipital.
b.pg.	Basipterygoid.
br.	Ceratobranchial.
b.s.	Basisphenoid.
b.t.	Basitemporal.
c.	Centrum and centrale.
c.u.	Uncinate process.
cd.v.	Caudal vertebra.
c.f.c.	Cranio-facial cleft.
c.hy.	Cerato-hyal.
cl.	Clavicle.
co.	Columella.
cp.	Carpal.
cr.	Coracoid and cervical rib.
cr.g.	Crista galli.
c.ty.	Tympanic cavity.
c.u.	Centralo-ulnare.
c.v.	Cervical vertebræ.
d.	Dentary.
d.c.	Distal carpal.
dg.	Digit.
d.t.	Distal tarsal.
d.r.	Dorsal rib.
d.s.v.	Dorso-sacral vertebræ,
d.v.	Dorsal vertebra.
e.eth.	Ectoethmoid.
e.n.	External nostril.
e.o.	Exoccipital.
Eu.	Eustachian opening.
f.	Frontal and femur.
fb.	Fibula.
fbe.	Fibulare.
f.m.	Foramen magnum.
fr.	Furcula.
g.	Ganglion.
h.	Humerus.
h.s.c.	Horizontal semicircular canal.
i.	Intermedium.
i.a.c.	Interarcticular cartilage.
i.a.p.	Internal angular process.
ic.	Intercentrum.
i.c.	Internal carotid foramen.
i.cl.	Interclavicle.
il.	Ilium.
i.o.f.	Inter-orbital fenestra.
i.pt.	Inter-palatine.
i.r.	Intermedio-radiale.
isc.	Ischium.
i.th.	Inferior turbinal.
i.tr.	Inter-trabecula.
j.	Jugal.
l.	Lachrymal.
l.c.	Lachrymal canal.
l.s.v.	Lumbo-sacral vertebræ.
m.	Mouth.
mk.	Meckel's cartilage.
m.st.	Metasternum.
mt.c.	Metacarpal.
mt.t.	Metatarsal.
mx.p.	Maxillo-palatine.
n.	Nasal.
n.a.	Neural arch.
nc.	Notochord.
n.f.	Nasal floor.
n.pr.	Nasal process of pre-maxillary.
ob.f.	Obturator fenestra.
oc.c.	Occipital condyle.
od.p.	Odontoidprocess.
op.	Opisthotic.
o.s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p.a.p.	Posterior angular process.
pa.s.	Parasphenoid.
pb.	Pubis.
p.cl.	Posterior clinoid process.
pc.p.	Postcoracoid process of sternum.
pcr.	Precoracoid.
p.c.s.	Pre-costal process of sternum.
p.e.	Perpendicular ethmoid.
pg.	Pterygoid.
ph.	Phalanx.
p.n.	Prenasal rostrum.
pr.i.	Pre-ilium.
pro.	Prootic.
pr.z.	Pre-zygaphophysis.
p.s.	Presphenoid.
p.s.c.	Posterior semicircular canal.
pt.i.	Post-ilium.
pt.z.	Post-zygapophysis.
px.	Premaxilla.
q.	Quadrate.
q.j.	Quadrato-jugal.
r.	Radius.
r.b.s.	Rostrum of basisphenoid (= rostrum of parasphenoid).
re.	Radiale.
r.st.	Rostral process of sternum.
s.ag.	Supra-angulare.
sc.	Scapula.
s.n.	Septum nasi.
s.i.f.	Sacro-ischiatic fenestra.
s.o.	Supra-occipital.
sp.	Splenial.
sp.o.	Sphenotic.
sq.	Squamosal.
s.r.	Sacral rib.
s.sc.	Supra-scapula.
st.	Sternum.
st.k.	Sternal keel.
s.v.	Sacral vertebra.
tb.	Tibial.
t.c.	Tendon-canal.
te.	Tibiale.
t.co.	Tympanic wing of occipital.
ts.	Tarsal.
u.	Ulna.
ue.	Ulnare.
u.s.v.	Uro-sacral vertebræ.
v.	Vomer.
v.a.	Vertebral artery.
v.b.	Vestibule.







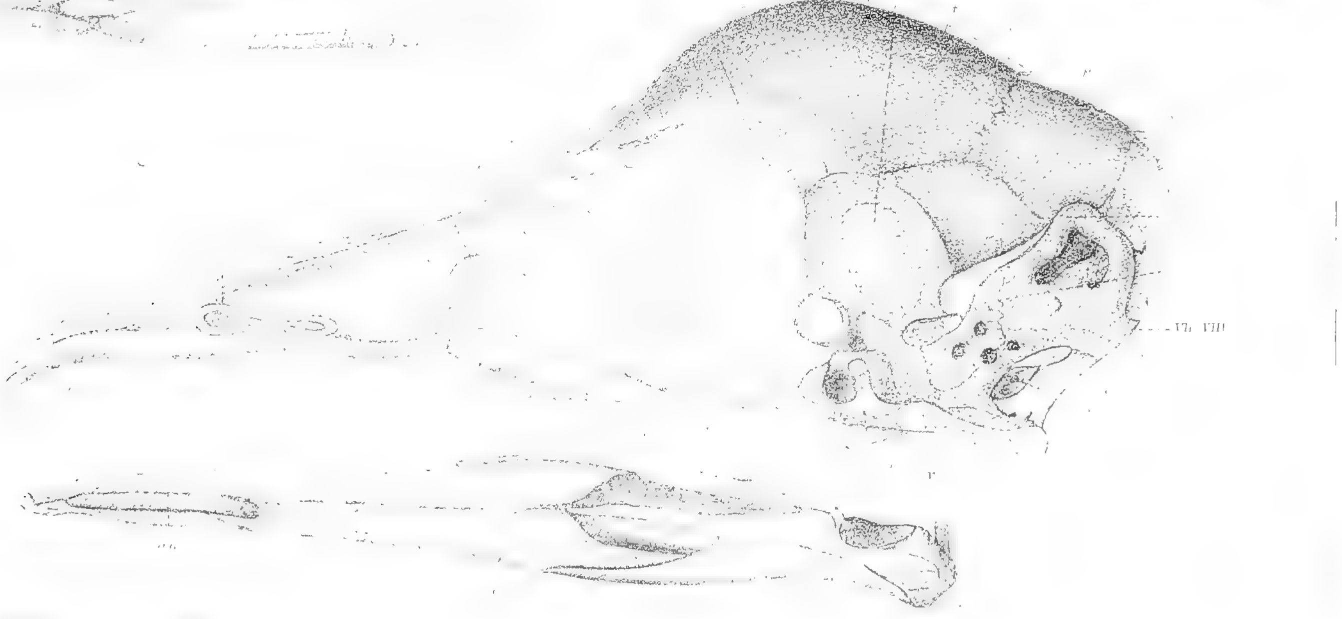


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PLATE VII.

MORPHOLOGY OF THE DUCK AND THE AUK TRIBES.

EXPLANATION OF PLATE VII.

Fig.		Number of times magnified.
1.	*Uria troile;* 2nd stage ; embryo two-thirds ripe ; skeleton ; side view, .	3½ diameters.

[For List of Abbreviations used on this Plate, *vide* over.]

LIST OF ABBREVIATIONS.

[*The Roman Numerals indicate Nerves and their Foramina.*]

ac.	Acetabulum.
ac.p.	Acromial process of scapula.
ag.	Angulare.
al.e.	Aliethmoid.
al.n.	Alinasal.
ar.	Articulare.
al.s.	Alisphenoid.
al.sp.	Aliseptal.
a.o.	Antorbital.
a.s.c.	Anterior semicircular canal.
at.	Atlas.
a.t.r.	Anterior tympanic recess.
au.	Auditory capsule.
ax.	Axis.
b.h.br.	Basi-hyobranchial.
b.hy.	Basihyal.
b.o.	Basioccipital.
b.pg.	Basipterygoid.
br.	Ceratobranchial.
b.s.	Basisphenoid.
b.t.	Basitemporal.
c.	Centrum and centrale.
c.a.	Uncinate process.
cd.v.	Caudal vertebra.
c.f.c.	Cranio-facial cleft.
c.hy.	Cerato-hyal.
cl.	Clavicle.
co.	Columella.
cp.	Carpal.
cr.	Coracoid and cervical rib.
cr.g.	Crista galli.
c.ty.	Tympanic cavity.
c.u.	Centralo-ulnare.
c.v.	Cervical vertebræ.
d.	Dentary.
d.c.	Distal carpal.
dg.	Digit.
d.t.	Distal tarsal.
d.r.	Dorsal rib.
d.s.v.	Dorso-sacral vertebræ,
d.v.	Dorsal vertebra.
e.eth.	Ectoethmoid.
e.n.	External nostril.
e.o.	Exoccipital.
Eu.	Eustachian opening.
f.	Frontal and femur.
fb.	Fibula.
fbe.	Fibulare.
f.m.	Foramen magnum.
fr.	Furcula.
g.	Ganglion.
h.	Humerus.
h.s.c.	Horizontal semicircular canal.
i.	Intermedium.
i.a.c.	Interarticular cartilage.
i.a.p.	Internal angular process.
ic.	Intercentrum.
i.c.	Internal carotid foramen.
i.cl.	Interclavicle.
il.	Ilium.
i.o.f.	Inter-orbital fenestra.
i.pt.	Inter-palatine.
i.r.	Intermedio-radiale.
isc.	Ischium.
i.tb.	Inferior turbinal.
i.tr.	Inter-trabecula.
j.	Jugal.
l.	Lachrymal.
l.c.	Lachrymal canal.
l.s.v.	Lumbo-sacral vertebræ.
m.	Mouth.
mk.	Meckel's cartilage.
m.st.	Metasternum.
mt.c.	Metacarpal.
mt.t.	Metatarsal.
mx.p.	Maxillo-palatine.
n.	Nasal.
n.a.	Neural arch.
nc.	Notochord.
n.f.	Nasal floor.
n.px.	Nasal process of pre-maxillary.
ob.f.	Obturator fenestra.
oc.c.	Occipital condyle.
od.p.	Odontoidprocess.
op.	Opisthotic.
o.s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p.a.p.	Posterior angular process.
pa.s.	Parasphenoid.
pb.	Pubis.
p.cl.	Posterior clinoid process.
pc.p.	Postcoracoid process of sternum.
pcr.	Precoracoid.
p.c.s.	Pre-costal process of sternum.
p.e.	Perpendicular ethmoid.
pg.	Pterygoid.
ph.	Phalanx.
p.n.-	Prenasal rostrum.
pr.i.	Pre-ilium.
pro.	Prootic.
pr.z.	Pre-zygaphophysis.
p.s.	Presphenoid.
p.s.c.	Posterior semicircular canal.
pt.i.	Post-ilium.
pt.z.	Post-zygapophysis.
px.	Premaxilla.
q.	Quadrate.
q.j.	Quadrato-jugal.
r.	Radius.
r.b.s.	Rostrum of basisphenoid (= rostrum of parasphenoid).
re.	Radiale.
r.st.	Rostral process of sternum.
s.ag.	Supra-angulare.
sc.	Scapula.
s.n.	Septum nasi.
s.i.f.	Sacro-ischiatic fenestra.
s.o.	Supra-occipital.
sp.	Splenial.
sp.o.	Sphenotic.
sq.	Squamosal.
s.r.	Sacral rib.
s.sc.	Supra-scapula.
st.	Sternum.
st.k.	Sternal keel.
s.v.	Sacral vertebra.
tb.	Tibial.
t.c.	Tendon-canal.
te.	Tibiale.
t.eo.	Tympanic wing of occipital.
ts.	Tarsal.
u.	Ulna.
ue.	Ulnare.
u.s.v.	Uro-sacral vertebræ.
v.	Vomer.
v.a.	Vertebral artery.
v.b.	Vestibule.

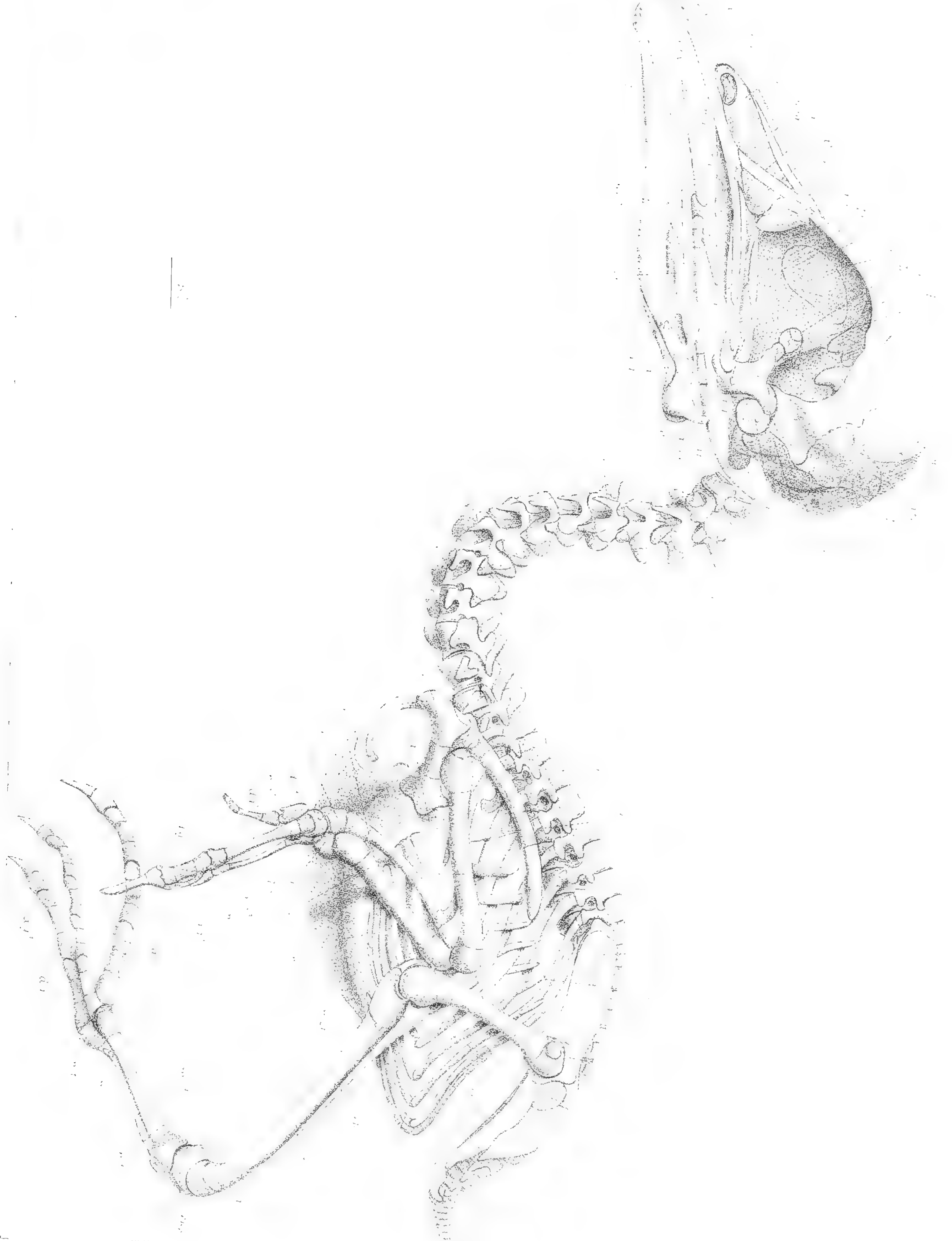

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PLATE VIII.

MORPHOLOGY OF THE DUCK AND THE AUK TRIBES.

EXPLANATION OF PLATE VIII.

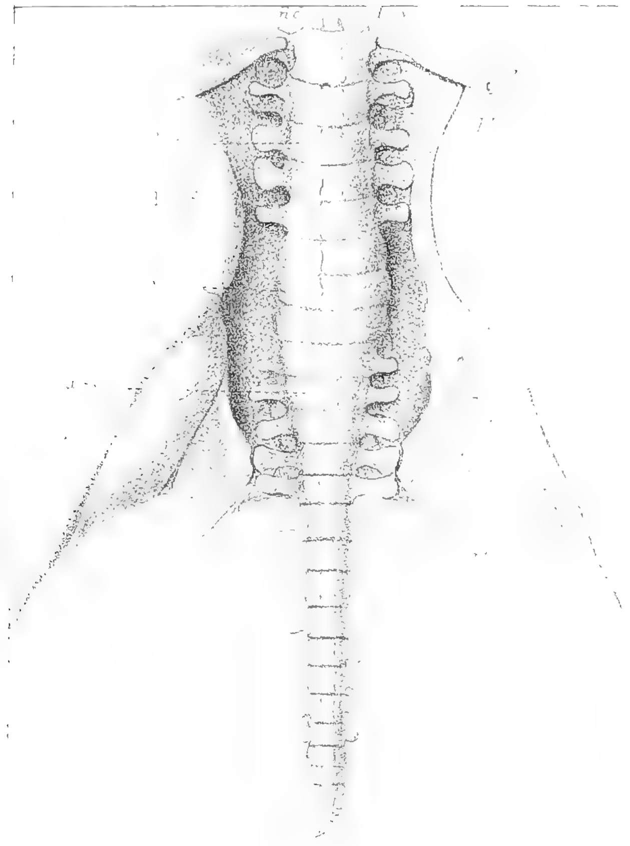
Fig.		Number of times magnified.
1.	*Uria troile;* 1st stage; pelvis; lower view,	7½ diameters.
2.	The same; 3rd stage; pelvis; lower view,	3¾ diameters.
3.	The same; same object; upper view,	3¾ diameters.
4.	The same; 1st stage; distal part of leg; front view,	8 diameters.
5.	The same; same object; hind view,	8 diameters.
6.	The same; 3rd stage; part of leg; front view,	3¾ diameters.
7.	The same; manus of 2nd stage; inner view,	7½ diameters.
8.	Part of same; outer view,	11 diameters.
9.	*Ciceronia pusilla;* distal part of wing; outer view,	4½ diameters.
10.	The same; distal part of pollex,	13½ diameters.
11.	The same; distal part of index,	13½ diameters.
12.	The same; proximal part of manus; inner view,	4½ diameters.
13.	The same; part of fig. 9,	13½ diameters.

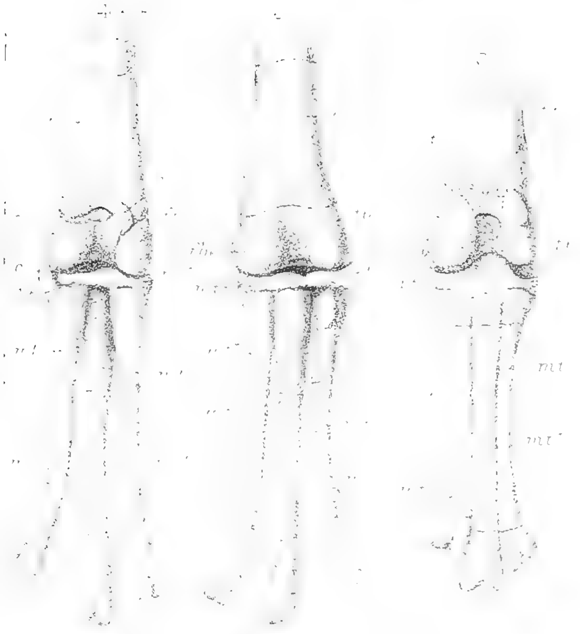
[For List of Abbreviations used on this Plate, *vide* over.]

LIST OF ABBREVIATIONS.

[*The Roman Numerals indicate Nerves and their Foramina.*]

ac.	Acetabulum.
ac.p.	Acromial process of scapula.
ag.	Angulare.
al.e.	Aliethmoid.
al.n.	Alinasal.
ar.	Articulare.
al.s.	Alisphenoid.
al.sp.	Aliseptal.
a.o.	Antorbital.
a.s.c.	Anterior semicircular canal.
at.	Atlas.
a.t.r.	Anterior tympanic recess.
au.	Auditory capsule.
ax.	Axis.
b.h.br.	Basi-hyobranchial.
b.hy.	Basihyal.
b.o.	Basioccipital.
b.py.	Basipterygoid.
br.	Ceratobranchial.
b.s.	Basisphenoid.
b.t.	Basitemporal.
c.	Centrum and centrale.
c.u.	Uncinate process.
cd.v.	Caudal vertebra.
c.f.c.	Cranio-facial cleft.
c.hy.	Cerato-hyal.
cl.	Clavicle.
co.	Columella.
cp.	Carpal.
cr.	Coracoid and cervical rib.
cr.g.	Crista galli.
c.ty.	Tympanic cavity.
c.u.	Centralo-ulnare.
c.v.	Cervical vertebræ.
d.	Dentary.
d.c.	Distal carpal.
dg.	Digit.
d.t.	Distal tarsal.
d.r.	Dorsal rib.
d.s.v.	Dorso-sacral vertebræ,
d.v.	Dorsal vertebra.
ecth.	Ectoethmoid.
e.n.	External nostril.
e.o.	Exoccipital.
Eu.	Eustachian opening.
f.	Frontal and femur.
fb.	Fibula.
fbe.	Fibulare.
f.m.	Foramen magnum.
fr.	Furcula.
g.	Ganglion.
h.	Humerus.
h.s.c.	Horizontal semicircular canal.
i.	Intermedium.
i.a.c.	Interarcticular cartilage.
i.a.p.	Internal angular process.
ic.	Intercentrum.
i.c.	Internal carotid foramen.
i.cl.	Interclavicle.
il.	Ilium.
i.o.f.	Inter-orbital fenestra.
i.pa.	Inter-palatine.
i.r.	Intermedio-radiale.
is.	Ischium.
i.tb.	Inferior turbinal.
i.tr.	Inter-trabecula.
j.	Jugal.
l.	Lachrymal.
l.c.	Lachrymal canal.
l.s.v.	Lumbo-sacral vertebræ.
m.	Mouth.
mk.	Meckel's cartilage.
m.st.	Metasternum.
mt.c.	Metacarpal.
mt.t.	Metatarsal.
mx.p.	Maxillo-palatine.
n.	Nasal.
n.a.	Neural arch.
nc.	Notochord.
n.f.	Nasal floor.
n.px.	Nasal process of pre-maxillary.
ob.f.	Obturator fenestra.
oc.c.	Occipital condyle.
od.p.	Odontoid process.
op.	Opisthotic.
o.s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p.a.p.	Posterior angular process.
pa.s.	Parasphenoid.
pb.	Pubis.
p.cl.	Posterior clinoid process.
pc.p.	Postcoracoid process of sternum.
pcr.	Precoracoid.
p.c.s.	Pre-costal process of sternum.
p.e.	Perpendicular ethmoid.
py.	Pterygoid.
ph.	Phalanx.
p.n.	Prenasal rostrum.
pr.i.	Pre-ilium.
pro.	Prootic.
pr.z.	Pre-zygaphophysis.
p.s.	Presphenoid.
p.s.c.	Posterior semicircular canal.
pt.i.	Post-ilium.
pt.z.	Post-zygapophysis.
px.	Premaxilla.
q.	Quadrate.
q.j.	Quadrato-jugal.
r.	Radius.
r.b.s.	Rostrum of basisphenoid (= rostrum of parasphenoid).
re.	Radiale.
r.st.	Rostral process of sternum.
s.ag.	Supra-angulare.
sc.	Scapula.
s.n.	Septum nasi.
s.i.f.	Sacro-ischiatic fenestra.
s.o.	Supra-occipital.
sp.	Splenial.
sp.o.	Sphenotic.
sq.	Squamosal.
s.r.	Sacral rib.
s.sc.	Supra-scapula.
st.	Sternum.
st.k.	Sternal keel.
s.v.	Sacral vertebra.
tb.	Tibial.
t.c.	Tendon-canal.
te.	Tibiale.
t.o.	Tympanic wing of occipital.
ts.	Tarsal.
u.	Ulna.
ue.	Ulnare.
u.s.v.	Uro-sacral vertebræ.
v.	Vomer.
v.a.	Vertebral artery.
v.b.	Vestibule.





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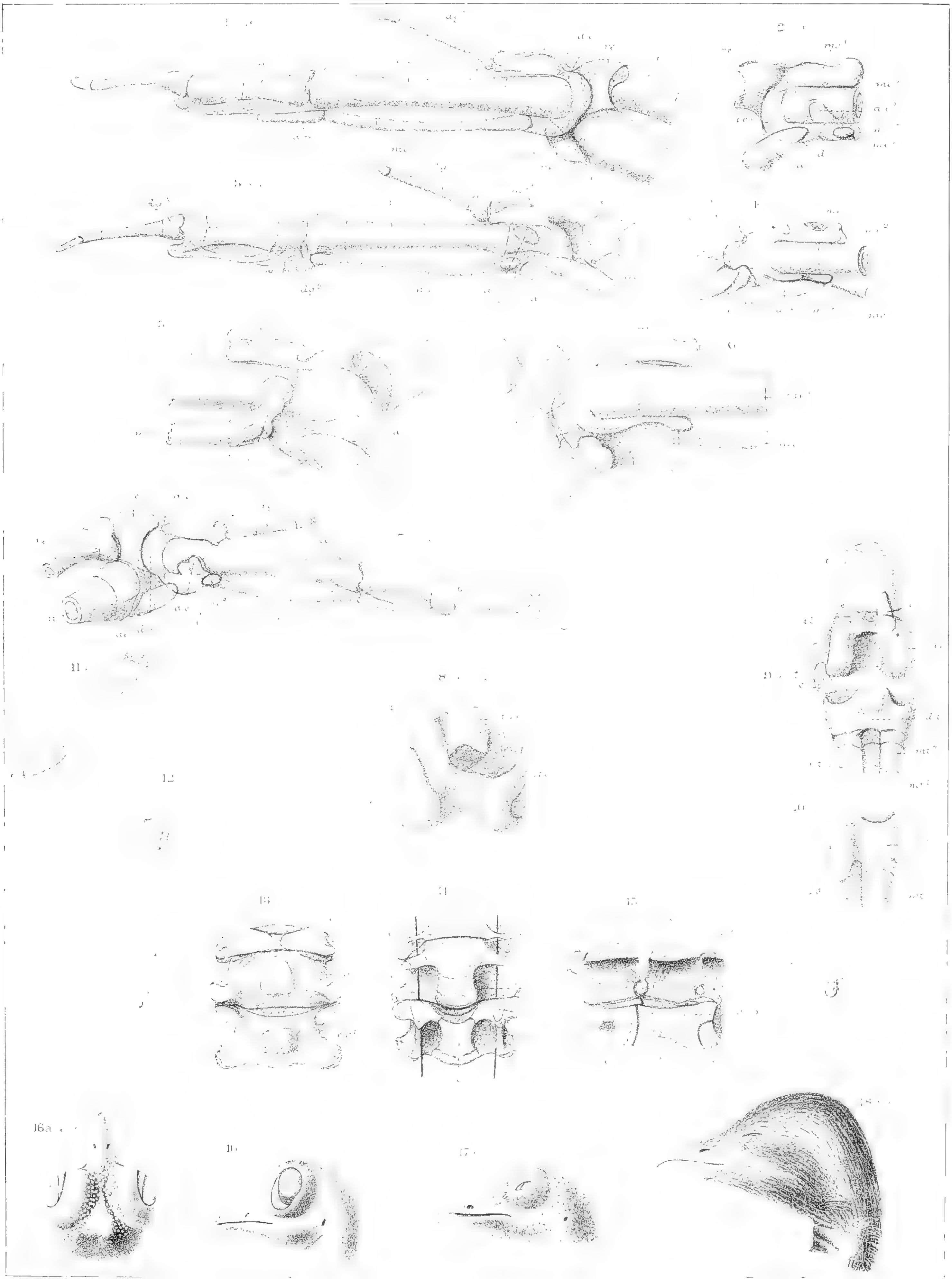
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PLATE IX.

MORPHOLOGY OF THE DUCK AND THE AUK TRIBES.

EXPLANATION OF PLATE IX.

Fig.		Number of times magnified.
1.	*Alca torda;* 1st stage; one-third ripe embryo; distal part of wing; outer view,	15 diameters.
2.	The same; part of same object; inner view,	15 diameters.
3.	The same; 2nd stage; three-quarter ripe embryo distal part of wing; inner view,	6 diameters.
4.	The same; same object; outer view,	6 diameters.
5.	The same; 3rd stage; nearly ripe embryo proximal part of manus; inner view,	8 diameters.
6.	The same; same object; outer view,	8 diameters.
8.	The same; 1st stage; upper part of tarsus; front view,	22½ diameters.
7.	*Uria troile;* 3rd stage; distal part of wing; inner view,	5 diameters.
9.	The same; 3rd stage; ankle-joint; front view,	3¾ diameters.
10.	The same; lower part of same object; inner view,	3¾ diameters.
11.	The same; adult; distal part of pollex,	2 diameters.
12.	The same; same skeleton; distal part of index,	2 diameters.
16, 16*a*.	The same; head of embryo, one-third ripe; 1st stage,	1½ diameters.
17.	The same; do. do. two-thirds ripe; 2nd stage,	Natural size.
18.	The same; do. do. nearly ripe; 3rd stage,	Natural size.
13.	*Casuarius bennettii;* ripe embryo; first three vertebræ; upper view,	3 diameters.
14.	The same; same object; lower view,	3 diameters.
15.	The same; same object; vertical section,	3 diameters.

[For List of Abbreviations used on this Plate, *vide* over.

LIST OF ABBREVIATIONS.

[*The Roman Numerals indicate Nerves and their Foramina.*]

ac.	Acetabulum.
ac.p.	Acromial process of scapula.
ag.	Angulare.
al.e.	Aliethmoid.
al.n.	Alinasal.
ar.	Articulare.
al.s.	Alisphenoid.
al sp.	Aliseptal.
a.o.	Antorbital.
a.s.c.	Anterior semicircular canal.
at.	Atlas.
a.t.r.	Anterior tympanic recess.
au.	Auditory capsule.
ax.	Axis.
b.h.br.	Basi-hyobranchial.
b.hy.	Basihyal.
b.o.	Basioccipital.
b.pg.	Basipterygoid.
br.	Ceratobranchial.
b.s.	Basisphenoid.
b.t.	Basitemporal.
c.	Centrum and centrale.
c.a.	Uncinate process.
cd.v.	Caudal vertebra.
c.f.c.	Cranio-facial cleft.
c.hy.	Cerato-hyal.
cl.	Clavicle.
co.	Columella.
cp.	Carpal.
cr.	Coracoid and cervical rib.
cr.g.	Crista galli.
c.ty.	Tympanic cavity.
c.u.	Centralo-ulnare.
c.v.	Cervical vertebræ.
d.	Dentary.
d.c.	Distal carpal.
dg.	Digit.
d.t.	Distal tarsal.
d.r.	Dorsal rib.
d.s.v.	Dorso-sacral vertebræ,
d.v.	Dorsal vertebra.
e.eth.	Ectoethmoid.
e.n.	External nostril.
e.o.	Exoccipital.
Eu.	Eustachian opening.
f.	Frontal and femur.
fb.	Fibula.
fbe.	Fibulare.
f.m.	Foramen magnum.
fr.	Furcula.
g.	Ganglion.
h.	Humerus.
h.s.c.	Horizontal semicircular canal.
i.	Intermedium.
i.a.c.	Interarticular cartilage.
i.a.p.	Internal angular process.
ic.	Intercentrum.
i.c.	Internal carotid foramen.
i.cl.	Interclavicle.
il.	Ilium.
i.o.f.	Inter-orbital fenestra.
i.pa.	Inter-palatine.
i.r.	Intermedio-radiale.
isc.	Ischium.
i.tb.	Inferior turbinal.
i.tr.	Inter-trabecula.
j.	Jugal.
l.	Lachrymal.
l.c.	Lachrymal canal.
l.s.v.	Lumbo-sacral vertebræ.
m.	Mouth.
mk.	Meckel's cartilage.
m.st.	Metasternum.
mt.c.	Metacarpal.
mt.t.	Metatarsal.
mx.p.	Maxillo-palatine.
n.	Nasal.
n.a.	Neural arch.
nc.	Notochord.
n.f.	Nasal floor.
n.px.	Nasal process of pre-maxillary.
ob.f.	Obturator fenestra.
oc.c.	Occipital condyle.
od.p.	Odontoidprocess.
op.	Opisthotic.
o.s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p.a.p.	Posterior angular process.
pa.s.	Parasphenoid.
pb.	Pubis.
p.cl.	Posterior clinoid process.
pc.p.	Postcoracoid process of sternum.
pcr.	Precoracoid.
p.c.s.	Pre-costal process of sternum.
p.e.	Perpendicular ethmoid.
pg.	Pterygoid.
ph.	Phalanx.
p.n.	Prenasal rostrum.
pr.i.	Pre-ilium.
pro.	Prootic.
pr.z.	Pre-zygaphophysis.
p.s.	Presphenoid.
p.s.c.	Posterior semicircular canal.
pt.i.	Post-ilium.
pt.z.	Post-zygapophysis.
px.	Premaxilla.
q.	Quadrate.
q.j.	Quadrato-jugal.
r.	Radius.
r.b.s.	Rostrum of basisphenoid (= rostrum of parasphenoid).
re.	Radiale.
r.st.	Rostral process of sternum.
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sc.	Scapula.
s.n.	Septum nasi.
s.i.f.	Sacro-ischiatic fenestra.
s.o.	Supra-occipital.
sp.	Splenial.
sp.o.	Sphenotic.
sq.	Squamosal.
s.r.	Sacral rib.
s.sc.	Supra-scapula.
st.	Sternum.
st.k.	Sternal keel.
s.v.	Sacral vertebra.
tb.	Tibial.
t.c.	Tendon-canal.
te.	Tibiale.
t.eo.	Tympanic wing of occipital.
ts.	Tarsal.
u.	Ulna.
ue.	Ulnare.
u.s.v.	Uro-sacral vertebræ.
v.	Vomer.
v.a.	Vertebral artery.
v.b.	Vestibule.

NOVEMBER, 1890.]

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No. VI.

ON THE MORPHOLOGY

OF

THE DUCK AND THE AUK TRIBES.

BY

W. KITCHEN PARKER, F.R.S.

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