a less degree, in the Great Auk, the humerus becomes flattened from side to side, the proximal end is singularly modified, and at the narrow distal end the articular surface for the radius lies completely in front of, and rather above, that for the ulna.

The ulna, which often presents a series of tubercles, indicating the attachment of the secondary quill feathers, is usually a stronger and a longer bone than the radius. There are only two carpal bones, one radial and one ulnar. There is one exception to this, namely, in the Screamer (*Chauna chavaria*), which has three carpals on the left side, the lower arcuate bone having two representatives.

In the *Apterygidæ* and in the *Casuariidæ* there is but one complete digit in the manus. It appears to answer to the second of the pentadactyle limb, and is provided with a claw. In the *Struthionidæ* and *Rheidæ*, and in all the *Carinatæ*, there are three digits in the manus, which answer to the pollex and the second and third digits of the pentadactyle fore-limb; and the metacarpal bones of these digits are ankylosed together. As a rule the metacarpal of the pollex is much shorter than the other two; that of the second digit is strong and straight; that of the third is more slender and bowed, so as to leave an interspace between itself and the second, which is often filled up by bony matter. The pollex has two phalanges, and the second of them is, in many birds—*Rhea*, the Screamer, &c.—pointed, curved, and ensheathed in a horny claw. The second digit has two and sometimes three phalanges, as in the Swan; and the terminal phalanx is similarly provided with a claw in sundry birds, *e.g.*, the Swan and *Rhea*. In the Ostrich both the pollex and the second digit are unguiculate. The third digit possesses one phalanx, besides its ankylosed metacarpal, and is always devoid of a claw.

It is a singular circumstance that the relative proportions of the humerus and the manus should present the most marked contrast in two groups of birds which are alike remarkable for their powers of flight. These are the Swifts and Humming-birds, in which the humerus is short and the manus long, and the Albatrosses, in which the humerus is long and the manus relatively short.

In the Penguins the pollex has two free phalanges, and its metacarpal bone (which is distinct in the young birds) ankyloses with that of the second digit. The third metacarpal is slender and straight. The bones of the manus are singularly elongated and flattened.

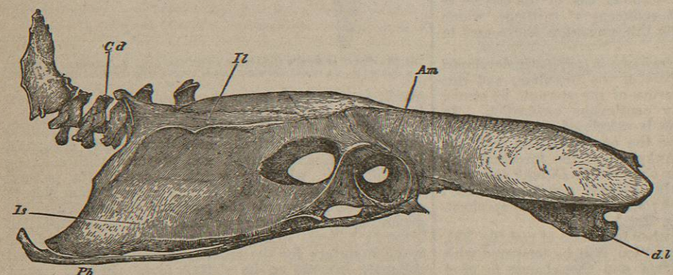

Fig. 34.—Pelvis and caudal vertebræ of adult *Fossil*, side view, natural size. *il.*, ilium; *is.*, ischium; *pb.*, pubis; *d.l.*, dorso-lumbar vertebræ; *cd.*, caudal vertebræ; *am.*, acetabulum.

The *pelvis* of a Bird (fig. 34) is remarkable for the great elongation, both anteriorly and posteriorly, of the iliac bones (*il.*), which unite with the whole length of the edges of the sacrum, and even extend forwards over the posterior ribs of the dorsal region. Below, each iliac bone forms a wide arch over the acetabulum (*am.*), the centre of which is always closed by fibrous tissue, so that in the dry skeleton the bottom of the acetabulum is always perforated by a wide foramen. An articular surface on the ilium, on which the great trochanter of the femur plays, is called the *antitrochanter*. In all ordinary birds the ischium (*is.*), which broadens towards its hinder end, extends back nearly parallel with the hinder part of the ilium, and is united with it by ossification posteriorly. The ischiosciatic interval is thus converted into a foramen. The pubis (*pb.*) enters by its dorsal or acetabular end into the formation of the acetabulum, and then passes backwards and downwards as a comparatively slender, curved bone, nearly parallel with the ischium. It is united with its fellow only by fibrous tissue. Very few birds present any important variation from this structure of the pelvis. In *Tinamus*,[1] *Casuarius*, *Dromæus*, *Apteryx*, *Dinornis*, the ischium is not united with the backward extension of the ilium by bone. In *Rhea* the ischia unite with one another beneath the vertebral column; and the vertebræ in this region, that is, from the true sacral to the end of the iliac roof, become undistinguishable, being formed into a long slender *uro-sacral* style. In *Struthio* alone, among Birds, do the pubes unite in a median ventral symphysis (see Mivart, *T. Z. S.*, vol. i. part 7, pp. 434, 435, figs. 72, 73). Another not less remarkable circumstance in the Ostrich is that the 31st to the 35th vertebræ inclusively (counting from the atlas) develop five lateral tuberosities. The three middle tuberosities are large, and abut against the pubis and the ischium. In these vertebræ, as in the dorsal vertebræ of the *Chelonia*, the neural arch of each vertebra shifts forward, so that half its base articulates with the centrum of the next vertebra in front, and the tuberosities in question are outgrowths, partly of the neural arch, and partly of the juxtaposed vertebral centra between which it is wedged. Hence in young Ostriches the face of each tuberosity exhibits a triradiate suture. A small bone is sometimes found on the ventral edge of the pubis, at its middle; this has been supposed to represent a *marsupial bone* (Garrod, *P. Z. S.*, Mar. 1872, p. 359).

The upper articular head of the *femur* is rounded, and its axis is almost at right angles with the body of the bone; a structure which is not found in ordinary *Reptilia*, but exists in the *Iguanodon* and other *Ornithoscelida*. The shaft is relatively short and thick, and the two terminal condyles are large and elongated antero-posteriorly. A prominent ridge, which plays between the proximal ends of the tibia and fibula, is apparent upon the posterior and inferior surface of the outer condyle. A similar ridge is faintly developed in some *Lacertilia*, and is well marked in the Dinosaurian Reptiles. A patella is usually present, but it is sometimes absent, and may be double.

The *fibula* of Birds (fig. 36, *F.*) is always imperfect,

[1] Parker, *Trans. Zool. Soc.*, vol. v. plate 39.

ending in a mere style below. Generally, it is decidedly shorter than the tibia, but it has the same length as that bone in some Penguins. The *tibia* (*t.*), or rather "tibio-tarsus," is a highly characteristic bone. Its proximal end is expanded, and produced anteriorly, into a great *cnemial* process (which may be variously subdivided), as in *Dinosauria*. The distal end is terminated by a well-marked pulley-like articular surface, which is inclined somewhat forwards as well as downwards. Not unfrequently there is an oblique bar of bone on the anterior face, just above the pulley, beneath which the long extensor tendons pass.

Fig. 35.—Right thigh bone of *Fowl*, adult, front view, natural size. *u.c.*, upper condyle; *l.c.*, lower condyles; *t.m.*, trochanter major. The ledge for the fibula on the outside of the outer lower condyle is not seen in this view.

The extremity of the cnemial process in *Struthio*, *Rhea*, and *Dromæus* is ossified as an *epiphysis*; and in young birds the whole of the distal articular end of the bone is separated from the rest by a suture, and also appears to be an epiphysis. But it is, in fact, as Professor Gegenbaur[1] has proved, the proximal division of the tarsus (apparently representing only the astragalus of the other *Vertebrata*), which exists in the embryo as a separate cartilage, and, as it ossifies, ankyloses with the tibia. The so-called tibia of a bird is therefore, properly speaking, a tibio-tarsus.

In all Birds, even in *Archæopteryx*, the fifth digit of the *pes* remains undeveloped;[2] and the second, third, and fourth metatarsals are ankylosed together, and by their proximal ends, with a bone, which is a distinct cartilage in the fœtus, and represents the distal division of the tarsus. Thus a *tarso-metatarsus* is formed (fig. 37). The distal ends of the metatarsals remain separate, and offer convex articular surfaces to the proximal phalanges of the digits.

In the Penguins, large apertures lie between the several metatarsals of the adult *tarso-metatarsus*; and in other birds more or less considerable passages persist between the middle and lateral metatarsals proximally, and the middle and outer distally. In most birds the middle metatarsal does not remain parallel with the others, but its proximal end inclines a little backward, and its distal end a little forward. Hence the two apertures on each side of its proximal end may lie at the bottom of a fossa, or run into one in front, while they remain distinct behind.

Again, in most Birds the posterior face of the proximal end of the middle metatarsal, and the adjacent surface of the tarsal bone, grow out into a process which is commonly, but improperly, termed "calcaneal." The inferior surface of this *hypo-tarsus* is sometimes simply flattened, sometimes traversed by grooves or canals for the flexor tendons of the digits.

When a hallux exists, its metatarsal bone is usually incomplete above, and is united to the ligament by the inner or the posterior surface of the tarso-metatarsus. In the Frigate-bird (*Phaethon*), and in *Steatornis*, the hallucal metatarsal is remarkably long. The genus *Phaethon* stands alone, as far as we know, in having the hallucal metatarsal ankylosed with the others.

In many of the *Alectoromorphæ* a spur (*calcar*), consisting of a bony core ensheathed in horn, is developed on the inner side of the metatarsus, and becomes ankylosed with the metatarsal of the second digit: in some there are

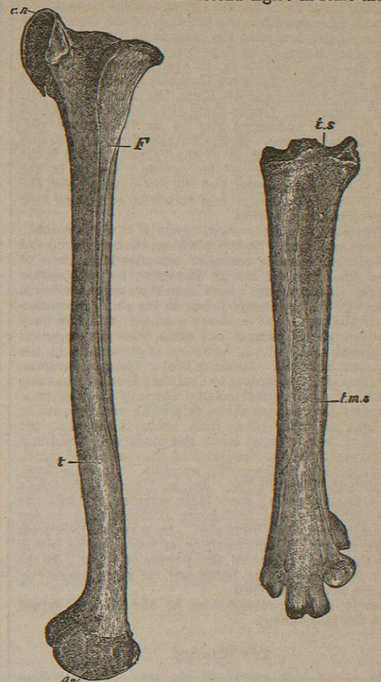

Fig. 36.—Left tibia and fibula of a large young *Fowl*, side view. *t.*, tibia; *F.*, fibula; *As.*, astragalus; *cn.*, cnemial process.

Fig. 37.—Tarso-metatarsi of a large young *Fowl*, front view, natural size. *ts.*, tarsal bone; *t.m.s.*, triple tarso-metatarsal rod, with the first metatarsal seen below on the right hand, but partly out of view on account of its backward position.

two spurs. In a few birds, similar spurs (Palamedea), or osseous excrescences (*Pezophaps*), are developed in relation with the metacarpus.

The normal number of the pedal phalanges in Birds is (as in ordinary *Lacertilia*) two, three, four, five, reckoning from the hallux to the fourth digit. Among the few Birds which constitute exceptions to the rule are the Swifts, in which the third and fourth toe have only three phalanges each (2, 3, 3, 3), and the Goatsuckers, in which the fourth toe only has the number reduced (2, 3, 4, 4)—not 2, 3, 4, 3, as Professor Huxley (*op. cit.*) puts it for *Caprimulgus*. Mr Parker has figured the fourth toe of the Sand-grouse (*Syrrhaptes*) with only *three*, but he speaks (*op. cit.*, p. 203) of only *one* as wanting in that toe.

Many Birds have only three toes by suppression of the hallux. In the Ostrich, not only the hallux, but the phalanges of the second digit, are suppressed, and the distal end of the second metatarsal is reduced to a mere

[1] See "Archiv für Anat.," in *Phys. Jahrgang*, 1863, and Huxley, on "Dinosaurs," *Q. Jour. Geol. Soc.*, Nov. 10, 1869.

[2] In his earlier papers, Mr Parker mistook the bony core of the cock's spur for the first thus making the proper *hallux* the second toe.

rudiment. Hence the Ostrich has only two toes (which answer to the third and fourth of the pentadactyle foot), with four phalanges in the inner and five in the outer, though the inner toe is far the longer and the stronger.

In most four-toed Birds the hallux is turned more or less completely backwards, and the other three digits forwards. But in many *Aetomorphæ* (especially the Owls) the outer toe can be turned outwards, or even backwards, at will. And in the Parrots, Toucans, Cuckoos, Woodpeckers, and other so-called "Scansorial" Birds, the outer toe is permanently reversed. Under these circumstances the distal end of the outer metatarsal may be divided into two distinct articular surfaces. In the Trogons there are two toes in front and two behind, as in the Parrots; but it is the second toe which is turned backwards. Lastly, in the Swifts, the *Dysporomorphæ*, and the *Sphenicomorphæ*, the hallux is directed more or less forwards, so that all four toes are turned to the front.

As a general rule, the osseous tissue of Birds is remarkably dense and hard. Before hatching, the bones are solid and filled with vascular medulla; but after birth, more or fewer of the bones are always excavated by prolongation of cavities containing air, which lie in their neighbourhood. Such air cavities are always found in the skull, in connection with the nasal and auditory passages, and they may extend through all parts of the skull, with the exception of the jugal arch, which, however, is pneumatic in the Toucan and Hornbill. In many birds, *Apteryx*, Penguin, Divers (and Gulls, according to Professor Huxley; but this is a mistake, their spinal column far into the sacrum is pneumatic; *Larus canus* shows this well), and the smaller Song-birds, no other bones than those of the skull are pneumatic; but in most birds the air-sacs of the lungs send prolongations into the bones of the rest of the trunk-skeleton, seldom into the caudal vertebræ, as in *Balæniceps*, the Adjutant, Hornbill, &c. In the Hornbills the whole skeleton is pneumatic; in a large number of birds the humerus alone of the limb-bones contains air; in the diurnal *Raptores*, the femur also. It is proper to remark that the amount of pneumaticity of bones by no means follows the development of the powers of flight. In the Ostrich, for example, the bones are far more extensively pneumatic than in the Gull.

In some cases, prolongations of the air-sacs extend beneath the integument.

The Muscles.

In the space allotted to the writer, there is merely room for justice to be done to one category of organs; and as the skeleton, and especially the skull, is of most direct importance to the zoologist and palæontologist, and as its form determines, as it were, all other organs, they being correlated with it and answering to it, it seemed to be that on which election should fall for the fuller treatment. An *impartial* description of all the systems of organs would have resulted in the merest outline for each. For the muscles, Professor Huxley's abstract must serve.[1]

The cutaneous muscles of Birds are well developed, and form broad expansions in various parts of the body. Special bundles of muscular fibres pass to the great quill feathers of the tail and wings, and others to the *patagium*, a fold of integument which stands between the trunk and brachium behind and between the brachium and ante-brachium in front. In correspondence with the slight mobility of the dorsal vertebræ, the episkeletal and hyposkeletal muscles of the spine attain a considerable development only in the neck and in the tail. Owing to the great size of the sternum, the abdominal muscles are usually small, and the internal oblique may be absent. A diaphragm, consisting of bundles of muscular fibre,[2] which pass from the ribs to the aponeurosis, covering the ventral face of the lungs, is developed in all Birds, but attains to the greatest degree of completeness in the *Ratitæ*, and especially in *Apteryx*. The muscles of the limbs are remarkably modified by the excessive development of some of those found in other *Vertebrata*, and the suppression of others.

Thus in all birds possessing the power of flight, the *pectoralis major*, the chief agent of the downward stroke of the wing, is very large and thick, taking its origin from the whole length, and a great part of the depth, of the keel of the sternum. The elevation of the wing is chiefly effected by the *pectoralis secundus* (*levator humeri*; or *p. medius*, Macg., plate 3, figs. 4, 5), which arises beneath (*within* and *over*, in the standing bird) the foregoing muscle, and passes over the inner side of the scapulo-coracoid articulation as over a pulley, to reach the humerus. The muscles of the fore-arm and digits are reduced, in accordance with the peculiar modification of the skeleton of these parts. In the hind limb of most birds there is a singular extensor muscle, which arises from the pubis, and ends in a tendon which passes to the outside of the knee-joint and terminates in the leg by uniting with the *flexor digitorum perforatus*. The result of this arrangement is that the toes are flexed whenever the leg is bent upon the thigh, and consequently the roosting bird is held fast upon his perch by the weight of his own body.[3]

The Brain.

In Birds, as in Reptiles, the cerebro-spinal axis is angulated at the junction of the spinal cord with the medulla oblongata, the latter being bent down towards the ventral side of the body. The region on which the nerves of the anterior and posterior extremities originate is enlarged in Birds. In the lumbar enlargement the posterior columns of the cord diverge and give rise to the *sinus rhomboidalis*, which is a sort of repetition of the fourth ventricle, the dilated central canal of the spinal cord being covered merely by a thin membrane, consisting chiefly of the ependyma and arachnoid. The brain fills the cavity of the skull, and presents a well-developed cerebellum; a mesencephalon, divided above into two optic lobes; and relatively large prosencephalic hemispheres, which attain a considerable size but never conceal the optic lobes. The transverse fissures of the cerebellum are distinct, and the lateral appendages of the cerebellum, or *flocculi*, become well defined, and are wedged, as in many of the lower *Mammalia*, in cavities of the side walls of the skull, arched over by the anterior vertical semicircular canal.

There is no *pons Varolii*, in the sense of transverse fibres connecting the two halves of the cerebellum, visible upon the ventral surface of the mesencephalon. The optic lobes contain ventricles; these are thrown down to the sides of the base of the brain, and are connected over the *aquæductus Sylvii* by a broad commissural band. Each prosencephalic lobe contains a lateral ventricle (continuous through the foramen of Munro with the third ventricle), which is little more than a fissure between the very thin inner wall of the lobe and its thick outer part, which contains the corpus striatum. The corpora striata are united by an anterior commissure, which is not of large size. The thinning of the inner wall of the lobes, from the margin of the foramen of Munro backwards, which gives rise to the fissure of Bichat in the *Mammalia*, extends for a very short distance in the *Sauropsida*, even in Birds. The olfactory lobes are usually elongated, and contain ventricles continuous with those of the prosencephalic hemispheres. In all the *Sauropsida* the motor nerves of the tongue pass through a foramen in the occipital bone. Hence twelve pairs of cranial nerves are present, except in the *Ophidia*, which possess no spinal accessory nerves. The lateral cutaneous branches, so generally sent to the trunk by the pneumogastric in the *Ichthyopsida*, are absent, but the pneumogastric gives a recurrent branch to the larynx. The third, fourth, and sixth nerves arise quite independently of the fifth. The sympathetic is well developed.[1]

Organs of Sense.

Birds possess nasal glands, which attain a large size, and lie more usually upon the frontal bone, or in the orbits, than in the nasal cavity. In the Snakes and Lizards these bones lie between the septo-maxillaries above and the vomers below. In Birds, wherever placed, the duct opens near the same region as in the Reptiles. In many kinds, especially Passerines, the bones that should cover them are really present, but are rudimentary and attached to the vomer. These are the septo-maxillaries.

The eye in many Birds, as in the extinct *Ichthyosauria*, attains very great absolute and relative dimensions. Birds possess, like many Reptiles, a nictitating membrane.[2] In the Lizards a short, thick muscle (*tursalis*) is attached to the inner and posterior wall of the orbit, and ends in a fibrous sheath. A tendon, one end of which is attached to the presphenoidal region of the inner wall of the orbit, passes backwards through the sheath, and then forwards, to be attached to the nictitating membrane. When the muscle contracts, it necessarily pulls the latter over the eye. A Harderian gland is always developed, and a lachrymal gland very generally, but not always. In the *Chelonia*, muscular fibres (forming the so-called *pyramidalis* muscle) arise from the inner side of the eyeball, and, arching over it at the optic nerve, are inserted partly into the outer edge of the nictitating membrane, partly into the lower eyelid. The *Crocodilia* have a *pyramidalis* muscle taking the same origin and course; but it sends no fibres to the lower eyelid, its tendon being inserted altogether into the nictitating membrane. The third arrangement, which in a manner brings together the first and the second, is that seen in Birds. A *pyramidalis* muscle, arising from the inner and under surface of the eyeball, soon ends in a tendon which sweeps round the upper and outer surfaces of the sclerotic to the nictitating membrane, as in the Crocodiles. But there is also a *bursalis* muscle, which however arises, not, as in Lizards, from the wall of the orbit, but from the upper surface of the sclerotic itself, whence it passes backwards and ends in a fibrous sheath which encloses the tendon of the *pyramidalis*. The contraction of the muscle necessarily tends to draw the tendon of the *pyramidalis* away from the optic nerve. A tubercle is sometimes developed from the sclerotic above the entrance of the optic nerve, and prevents the tendon of the *pyramidalis* from shifting forwards and inwards. The eyeball is always turned by four *recti* and two *obliqui* muscles. The superior oblique does not pass over a pulley. The *Chelonia* and most *Lacertilia* have a more or less completely developed retractor or choanoid muscle. A ring formed of bony plates is developed in the fore-part of the sclerotic in *Lacertilia*, *Chelonia*, *Ichthyosauria*, *Dicynodontia*, *Pterosauria*, and *Aves*; but not in *Ophidia*, *Plesiosauria*, or *Crocodilia*. The iris and *tensor choroidei* contain striated muscular fibres. A pecten is very generally developed. It attains a large size, and becomes much plaited in *Aves*. Even in Birds, the sclerotic is cartilaginous.

In the organs of hearing, also, the Bird is best studied as a culmination of the *Sauropsida*.

Only *Crocodilia* and *Aves* possess a rudiment of an external ear. The *Ophidia* and the *Amphisbænoïdea* have no tympanic cavity. In some *Chelonia*, in *Sphenodon*, and in the Chameleons, the tympanic membrane is covered by integument, but a tympanic cavity exists. In *Lacertilia* the tympanic cavities communicate by wide openings with the pharynx; but in *Chelonia*, *Crocodilia*, and *Aves*, the communicating passages, reduced in size, become eustachian tubes. In the *Chelonia* these curve backwards, downwards, and inwards, round the quadrate bones, and open separately on the roof of the mouth. In the *Crocodilia* there are three eustachian tubes—one median, and two lateral. In *Aves* there is but one eustachian aperture, answering to the median of the *Crocodilia*; and, as in the latter group, each eustachian tube usually traverses the osseous base of the skull to join its fellow in the common aperture.

The stapes is a columelliform bone, the outer end of which is attached to the tympanic membrane when the latter is developed, but lies among the muscles when there is no tympanic cavity (Snakes and *Amphisbænæ*). All *Sauropsida* possess a *fenestra rotunda*, as well as a *fenestra ovalis*; and all have a cochlea, which is never coiled spirally, and is more rudimentary in the *Chelonia* than in other groups. Three semicircular canals, an anterior and a posterior vertical and an external horizontal, are connected with the membranous vestibule. In *Aves*, the anterior vertical canal is very large in proportion to the others, and the adjacent crura of the two vertical canals overlap before they unite with one another.[3]

Alimentary Organs.

Well-developed sub-lingual, sub-maxillary, and parotid glands appear in Birds, and the sub-lingual glands attain an immense size in the Woodpeckers (Macg., *Brit. Birds*, vol. iii. plate 15). The tongue varies greatly, being sometimes obsolete (as in the Crocodile). It is small in the *Totipalmatæ* and in *Balæniceps*. It is generally sagittiform and papillate at the base; but it is thick, and even emarginate in the *Rapaces* (Macg., *Brit. Birds*, vol. iii. plates 19, 20). In the *Picidæ* (*op. cit.*, plate 15), where the hyoid bones are extremely elongated and the tongue prehensible to a marvellous degree, the true lingual part is a small arrow-head, covered with a prickly, horny sheath; these prickles are reverted, like a Snake's teeth.

The alimentary canal of Birds may have several dilata-

[1] *Anat. Vert. Anim.*, p. 300. For an almost exhaustive bibliography of writings on the muscular system of birds, see M. Edmond Alix's *Essai sur l'Appareil locomoteur des Oiseaux*, pp. 367–373. This list begins with Aldrovandus, 1581, and ends with Goverod, 1873. 1874. We miss, however, Macgillivray's excellent description, with figures, of the muscles of flight, *Brit. Birds*, vol. i. plate 3, pp. 35–46; and another by Professor Rolleston, "On Muscles connected with the Shoulder-joint," *Trans. Linn. Soc.*, vol. xxvi. pp. 610–629. See also Owen "On the *Apteryx*," *Trans. Zool. Soc.*, vol. vii. p. 381, pl. 46. But the most important work for reference is that of M. Alix himself (*op. cit.*, pp. 373–471, plates 1–3, "Appareil actif de la Locomotion")

[2] See Macgillivray, *Brit. Birds*, vol. ii. plate 11, fig. 1, *v.v.v.*

[3] See J. Alph. Borelli, *De Motu Animalium*, Romæ, 1680–1682, Lugd. Bat. 1865; and *Bibliotheca Anatomica*, Geneva, 1685, plate 22, figs. 4–7.

[1] See Owen, Art. "Aves," *Cyclop. Anat. Phys.*, pp. 298, 299; Macgillivray, *Brit. Birds*, vol. i. p. 48, and vol. iii. plate 18; Owen "On Brain of *Apteryx*," *Trans. Zool. Soc.*, vol. vii. plates 45 and 46, p. 381. For the development of the Fowl's brain, see Foster and Balfour's *Elem. of Embryology*; see also Huxley, *Anat. Vert. Anim.*, p. 301, figs. 90, 91.

[2] See Macgillivray, *Brit. Birds*, vol. iii., plate 17, p. 146, for excellent figures and descriptions of the Bird's eye; also Owen, article "Aves," *Cyclop. Anat. and Phys.*, p. 303. For its development, Foster and Balfour's work, p. 97. The Bird's eye being a more highly specialized *Reptilian* organ, its condition in the lower types of the *Sauropsida* is also given in the text.

[3] See Macgillivray, *Brit. Birds*, vol. iii. plate 18, figs. 2 and 3, p. 156; Owen, article "Aves," in *Cyclop. Anat. and Phys.*, p. 308, fig. 141. For development, see Foster and Balfour's work, p. 111; Huxley on "Incus and Stapes," p. 398; and Parker, *var. loc.*

tions above the intestine; the latter is divisible into small and large, and the last always terminates in a cloaca. It is invested by a peritoneal coat, which follows the curvatures of the intestine. In most Birds, as in the Crocodiles, the pyloric and cardiac apertures are approximated. In many *Crocodilia* and *Aves* (*e.g.*, *Ardeidæ*) there is a pyloric dilatation before the commencement of the duodenum. In the *Alectoromorphæ*, in Eagles and Hawks amongst the *Aetomorphæ*, and in Pigeons, the œsophagus is enlarged into a "crop." In the latter it is bilobate and symmetrical (Macg., *op. cit.*, vol. i. plate 7).

In the *Crocodilia* and in *Aves* the walls of the stomach are very muscular, and the muscular fibres of each side radiate from a central tendon or aponeurosis. The thickening of the muscular tissue of the stomach attains its maximum in the Graminivorous Birds; and it is accompanied by the development of the epithelium into a dense and hard coat, adapted for crushing the food of these animals. Birds commonly aid the triturating power of this gastric mill by swallowing stones; but the habit is not confined to them, Crocodiles having been observed to do the same thing.[1] Birds are further remarkable for the development of a broad zone of glands in the lower part of the œsophagus, which is usually dilated, and forms a proventriculus, connected by a narrow neck with the gizzard (*gigerium*). In *Sula alba* and *Phalacrocorax carbo*, the writer, long ago, saw this zone to be imperfect. In these birds the gullet is very capacious from the pharynx downwards, but the proventriculus is still more so,—it is a large "paunch."

Some *Ophidia* have a cæcum at the junction of the small intestine with the large; and two such cæca, which sometimes attain a large size, are generally developed in *Aves*. In this class, also, the small intestine not unfrequently presents a cæcal appendage, the remains of the vitelline duct. The writer's drawings show this in *Gallinula chloropus*, *Ardea cinerea*, and *Colymbus septentrionalis*. The duodenum of Birds constantly makes a loop, within which the pancreas lies, as in the *Mammalia*.

The liver in the *Sauropsida* almost always possesses a gall bladder, which is usually attached to the under surface of the right lobe, but in *Ophidia* is removed to some distance from it.

A peculiar glandular sac, the *bursa Fabricii*, opens into the anterior and dorsal region of the cloaca in Birds.[2]

The Heart.

In Birds, the venous and arterial blood currents communicate only in the pulmonary and systemic capillaries. The auricular and ventricular septa are complete (see Owen, "Aves," p 330), as in the *Crocodilia;* but the right ventricle only gives off the pulmonary artery, the left aortic arch has disappeared, and the right arch (the 4th of that side in the embryo) becomes the most important of all the arches. The septum of the *cavum pulmonale* becomes a great muscular fold, and takes on the function of an auriculo-ventricular valve. At the origin of the pulmonary artery, and at that of the aortic arch, three semilunar valves are developed

In *Aves* there is no renal portal system, and the anterior abdominal vein opens into the inferior vena cava, close to the heart. Nevertheless, a median trunk, which is given off from the caudal vein, carries a considerable proportion of its blood directly into the hepatic portal system. The pericardium of the Bird is thin, but of a firm texture, and adheres by its external surface to the surrounding air-cells. (Owen, "Aves," p. 330.)

Respiratory and Vocal Organs.[3]

"In Birds there are distinct thyroid, cricoid, and arytenoid cartilages, which may be more or less completely ossified. Sometimes an epiglottis is added.[4] The voice of Birds, however, is not formed in the larynx, but in the *syrinx* or lower larynx, which may be developed in three positions:—1. At the bottom of the trachea, from the trachea alone; 2. At the junction of the trachea and bronchi, and out of both; 3. In the bronchi alone. The syrinx may be altogether absent, as in the *Ratitæ* and the *Cathartidæ* or American Vultures. The commonest form of syrinx is the second mentioned above, or the *bronchi-tracheal* syrinx. It is to be met with in all our common Song Birds, but is also completely developed in many Birds, such as the Crows, which have no song. In its commonest condition this form of syrinx presents the following characters: The hindermost rings of the trachea coalesce, and form a peculiarly formed chamber, the *tympanum*. Immediately beyond this the bronchi diverge, and from their posterior wall, where one bronchus passes into the other, a vertical fold of the lining membrane rises in the middle line towards the tympanum, and forms a vertical *septum* between the anterior apertures of the two bronchi. The anterior edge of this septum is a free and thin *membrana semilunaris*, but in its interior a cartilaginous or osseous frame is developed, and becomes united with the tympanum. The base of the frame is broad, and sends out two cornua, one along the ventral, and the other along the dorsal edge of the inner wall of the bronchus of its side, which in this part of its extent is membranous and elastic, and receives the name of the *membrana tympaniformis interna*.

"The bronchial 'rings' opposite this are necessarily incomplete internally, and have the form of arches embracing the outer moiety of the bronchus. The second and third of these bronchial arcs are freely movable, and elastic tissue accumulated upon their inner surfaces gives rise to a fold of the mucous membrane, which forms the outer boundary of a cleft, bounded on the inner side by the *membrana semilunaris*.

"The air forced through these two clefts from the lungs sets these elastic margins vibrating, and thus gives rise to a musical note, the character of which is chiefly determined by the tension of the elastic margins and the length of the tracheal column of air. The muscles, by the contraction of which these two factors of the voice are modified, are extrinsic and intrinsic. The former are possessed by Birds in general, and are usually two pairs, passing from the trachea to the furcula and to the sternum (Macg., vol. ii. plate 12, fig. 8, *d.d.*, *e.e.*; and vol. iii. plate 15, *m.m.*, *n.n.*) Some Birds possessing a broncho-tracheal syrinx such as has been described, as the *Alectoromorphæ* (see Macg., vol. ii. plate 12, fig. 8, *f.*), *Chenomorphæ*, and *Dysporomorphæ*, have no intrinsic muscles. Most others have one pair, attached on one side to the rings of the trachea above, and to the tympanum, or the proximal bronchial arcs below (Macg., vol. ii. plate 12, figs. 1, 2; and vol. iii. plate 19). The majority of the *Coracomorphæ* (Macg., vol. ii. plates 10, 11) have five or six pairs of intrinsic syringeal muscles, which pass from the trachea and its tympanum to the movable bronchial arcs.[5] The Parrots have no septum, and only three pairs of intrinsic muscles.

"The *tracheal* syrinx only occurs in some American *Coracomorphæ*. The hinder end of the trachea is flattened, and six or seven of its rings above the last are interrupted at the sides, and held together by a longitudinal ligamentous band. These rings are excessively delicate, so that the part of the trachea is in great part membranous. The *bronchial* syrinx occurs only in *Steatornis* and *Crotophaga*.

[1] See Sir S. Baker's *Ismailia*, vol. i. p. 295 "The stomach contained about five pounds' weight of pebbles (in a Crocodile 12 feet 3 inches long in its entire length), as though it had fed upon flesh resting upon a gravel bank, and had swallowed the pebbles that adhered." This intrepid traveller seems to be unaware that the Crocodile has a strong gizzard.

[2] Besides copious unpublished materials on this subject from his own dissections, the writer is largely indebted to Macgillivray's most valuable work, so full of illustrations of the digestive organs of Birds; also to Prof. Owen's article "Aves" (*op. cit.*); to Prof. Huxley he owes *form* and *order*. For the development of these parts the reader is still directed to Foster and Balfour's work, as also of the parts yet to be described.

[3] We shall here give Professor Huxley's excellent abstract of what is known upon this subject up to this time; but the reader is referred to Joh. Müller's work, "Researches on the Comparative Anatomy of the Vocal Organs of Birds," *Berlin Acad.*, June 1845, and *Ann. and Mag. N. H.*, vol. xvii. p. 499. Macgillivray has many excellent illustrations and descriptions of these parts; and the writer followed him step by step many years ago.

[4] For a clear description of the exquisite structure of the tracheal rings in Birds, see Macg., vol. ii. p. 34. They are often thoroughly ossified, and are notched above and below, both before and behind; and alternate ridges allow a marvellous amount of overlapping, the edges being well bevelled; each ring is an ellipse.

[5] Macgillivray (*op. cit.*, vol. ii. pp. 26, 28) was afraid to be thought *overstating* the number of these intrinsic muscles. He understated them, not thoroughly making out their divisional lines.

"In the genus *Cinyzis*, among the *Chelonia*, and in some species of *Crocodilus* (*C. acutus*, *a.g.*), the trachea is bent upon itself. Similar flexures attain an extraordinary development in many Birds, and may lie outside the thorax under the integument (*Tetrao urogallus*, some species of *Crax* and *Penelope*); in the cavity of the thorax (some Spoonbills); under the body of the sternum, in a large chamber hollowed out of the keel (some Swans and Cranes); even in a sort of cup formed by the median process of the furcula (*Numida cristata*). In the Emeu some of the rings of the trachea are incomplete in front, and bound the aperture of an air-sac which lies in front of the trachea. Some Birds (*Aptenodytes*, *Procellaria*) have the trachea divided by a longitudinal septum, as in *Sphargis* among the *Chelonia*. The tracheal tympanum is greatly enlarged in *Cephalopterus*, and in many Ducks, Geese, and Divers; and in these aquatic birds the enlargement is more marked in the males, and is usually symmetrical, the left side being generally the larger."

"In *Aves* the lungs are firmly fixed on each side of the vertebral column, the dorsal surface of each lung being moulded to the superjacent vertebræ and ribs. The muscular fibres of the diaphragm arise from the ribs outside the margins of the lungs, and form the vertebral column, and end in an aponeurosis upon the ventral surface of the lungs. Each bronchus enters its lung nearer the centre than the anterior edge, and, immediately losing its cartilaginous or bony rings, dilates, and then traverses the lung, gradually narrowing to the posterior edge of that viscus, where it terminates by opening into the posterior air-sac, which generally lies in the abdomen. From the inner side of the bronchus canals are given off, one near its distal end, and others near its entrance into the lung, which pass directly to the ventral surface of the lung, and there open into other air-sacs. Of these there are four. Two, the *anterior* and the *posterior thoracic*, lie in the ventral face of the lung in the thorax. The other two are situated in front of its anterior end, and are extra-thoracic. The external and superior is the cervical; the internal and inferior the *inter-clavicular* (Macg., vol. ii., p. 17, fig. 107). This last unites into one cavity with its fellow of the opposite lung. Thus there are altogether nine air-sacs; two posterior or abdominal, four thoracic, two cernical, and one inter-clavicular. Other large canals given off from the bronchus do not end in air-sacs, but those which pass from the inner side of the bronchus run along the ventral surface, and those on the outer side along the dorsal surface of the lung. Here they give off at right angles a series of secondary canals, and these similarly emit still smaller tertiary canals, and thus the whole substance of the lung becomes inter-penetrated by tubuli, the walls of the finest of which are minutely sacculated. The different systems of tubuli are placed in communication by perforations in their walls. In most birds these air-sacs (except the anterior and posterior thoracic, which never communicate with any cavity but that of the lungs) are in communication with a more or less extensively ramified system of air passages, which may extend through a great many of the bones, and even give off subcutaneous sacs. Thus the inter-clavicular air-sac generally sends a prolongation into each axilla, which opens into the proximal end of the humerus, and causes the cavity of that bone to be full of air. When the sternum, the ribs, and the bones of the pectoral girdle are pneumatic, they also receive their air from the inter-clavicular air-sacs. The cervical air-sacs may send prolongations along the vertebral canal of each side; which supply the bodies of the cervical vertebræ, and communicate with elongated air-chambers in the spinal canal itself. When the dorsal vertebræ are pneumatic they communicate with the system of the cervical air-sacs. The abdominal air-sacs send prolongations above the kidneys to the sacral vertebræ and to the femora, whence these bones, when they are pneumatic, receive their air. The pulmonary air-sacs and their prolongations do not communicate with the air cavities of the skull, which receive their air from the tympana and the nasal chambers. In some Birds (*Passerinæ*) the air is conducted from the tympanum to the articular piece of the mandible by a special bony tube, the *siphonium* [the largest of the tympanic chain, and having the general anatomical relations of the ichthyic 'interopercular.']"

Renal and Reproductive Organs.

The kidneys of Birds are composed of a number of lobules of unequal sizes, and these are packed in the concavities of the pelvis, in the same manner as the lungs are packed in the regular intercostal spaces of the upper part of the thorax. The ureters, as in the Reptiles, open directly into the cloaca; but there is no urinary bladder. The *bursa Fabricii* opens into the cloaca above its hinder part.

The testes lie on each side the foremost lobes of the kidneys. They are very small in mid-winter, and largest by the middle of April. In the embryo Bird there are two oviducts. "The duct of Müller on the right side (that on the left side with the corresponding ovary generally disappearing) remains in the female as the oviduct. In the male it is almost entirely obliterated on both sides" (Foster and Balfour, p. 168).

Integument and Feathers.[1]

"The exoskeleton of Birds consists almost entirely of epidermic structures in the form of horny sheaths, scales, plates, or feathers. No Bird possesses dermal ossifications, unless the spurs, which are developed upon the legs and wings of some species, may be regarded as such.

The feathers are of various kinds. Those which exhibit the most complicated structure are called *pennæ*, or *contour feathers*, because they lie on the surface and determine the contour of the body. In every penna the following parts are to be distinguished:—a main stem (*scapus*) forming the axis of the feather, and divided into a proximal hollow cylinder, partly imbedded in a sac of the derm, called the *calamus*, or quill; and a distal *vexillum*, or vane, consisting of a four-sided solid shaft, the *rachis*, which extends to the extremity of the feather, and bears a number of lateral processes, the *barbs*. The calamus has an inferior aperture (*umbilicus inferior*), into which the vascular pulp penetrates, and a superior aperture (*umbilicus superior*), situated on the under surface of the feather at the junction of the calamus with the scapus. The barbs are narrow plates, tapering to points at their free ends, and attached by their bases on each side of the rachis. The edges of these barbs are directed upwards and downwards, when the *vexillum* of the feather is horizontal. The interstices between the barbs are filled up by the *barbules*,—pointed processes, which stand in the same relation to the barbs as the barbs do to the rachis. The barbules themselves may be laterally serrated and terminated by little hooks, which interlock with the hooks of the opposed barbules. In very many Birds each quill bears two vexilla; the second, called the *after-shaft* (*hyporachis*), being attached on the underside of the first close to the superior umbilicus. The after-shaft is generally much smaller than the chief vexillum; but in some Birds, as the *Casuariidæ*, the two are of equal size, or nearly so. Muscles pass from the adjacent integuments to the feather sac, and by their contraction erect the feather. The other kinds of feathers differ from the pennæ, in having the barbs soft and free from one another, when they constitute *pennoplumæ*, or *plumulæ* (down), according as the scapus is much or little developed. When the scapus is very long, and the vexillum very small or rudimentary, the feather is termed a *filopluma*.

The contour feathers are distributed evenly over the body only in a few Birds, as the *Ratitæ*, the Penguins, and some others. Generally, the pennæ are arranged in definitely circumscribed patches or bands, between which the integument is either bare or covered only with down. These series of contour feathers are termed *pterylæ*, and their interspaces *apteria*.

In some Birds, such as the Herons, plumulæ of a peculiar kind, the summits of which break off into a fine dust or powder as fast as they are formed, are developed upon certain portions of the integument, which are termed *powder-down patches*.[2]

[1] This abstract is taken (by the author's permission) from Professor Huxley's *Anatomy of Vertebrated Animals*, pp. 274, 275. For a full account of these structures, see Nitzsch's *Pterylography*, translated from the German by Dr P. L. Sclater, F.R.S., Ray Soc., 1867.

[2] See Bartlett, "On the Balæniceps," *Proc. Zool. Soc.*, March 26, 1861, pp. 1–4; and Murie "On the Dermal and Visceral Structures of the Kagu, Sun-Bittern, and Boat-Bill," *Trans. Zool. Soc.*, 1871, plate 56, pp. 465–492; in this valuable paper the *powder-down patches* are also shown in *Podargus* and *Cacatua*.