

inter-orbital septum, and has grafted itself upon the cartilage of the pituitary ring, causing it also to ossify. On each side, behind these new bony patches, a free tongue of cartilage is seen. These tongues are the apices of the trabecular bars. They are better seen in the partial view (fig. 7). Underflooring the fore-half of the main skull base, close behind the pituitary ossifications, the thick mat of sub-mucous tissue is fast becoming bony. There is a right and left squarish patch, very large and elegant; in the grooved mid-line a few osseous points are also seen, ready to grow right and left into the two plates, and to make them one. These are the basi-temporals (*b.t.*) They soon coalesce with the ossifying basi-sphenoid above, and they represent the handle of the dagger-shaped parasphenoid of the Frog.¹ The super-occipital region (*s.o.*) is still soft, and the exoccipitals do not reach to the condyloid foramina (9). They begin at the hole for the *vagus*, and run to the selvage at the foramen magnum (8, *f.m.*) The kidney-shaped transverse condyle (*o.c.*) has in its substance the diminishing notochord (*n.c.*), which, however, is better seen in the partial upper view (fig. 7, *n.c.*) This figure shows that the notochord has tried, as it were, to break up into three fusiform segments. The hinder of these is enclosed in an ectosteal sheath, which will affect with bony growth the neighbouring cartilage, right and left, to form the basi-occipital. The fore-part is narrower, and lies in an open space, the counterpart of the membranous floor ("posterior basi-cranial fontanelle"—Rathke), which lies behind the pituitary space in the Snake's embryo. On each side of the middle notochordal spindle are seen the elegant mammillary elevations caused by the enclosed cochleæ (*cl.*). The internal carotids (*i.c.*) are seen creeping through the pituitary hole, and on each side the ossification has been set up, which forms the true endo-skeletal basi-sphenoid. On each side of the posterior pituitary or clinoid wall, the cartilage is pinched in to let the great trigeminal nerves pass over; but two parts of intensest interest are seen on each side of these shallow notches. These are the apices of the trabeculæ (*tr.*), free-ended, curved tongues of cartilage, with dark cells in their interior, and fixed to the out-turned anterior ends of the parachordal cartilages, just where the new bony matter is seen. The meaning of these parts that make the pituitary region was not seen at the time by the author of the paper we are quoting (Parker "On the Fowl's Skull"); further research was needed, and his figures are of much greater value than his descriptions.

Cranium of Fowl—Fourth Stage.—At the beginning of the third week of incubation the chondro-cranium is not only perfect as to form, but it has also so much increased its bony territories as to make it very useful for comparison with *chondrosteous* skulls of the lower types. When every investing bone has been removed, we get such a structure as is shown (from above) in fig. 9. Here the cranial basin has a short and fenestrate floor, and doubly-winged sides, which are gently scooped above, and form a pair of symmetrical ledges on which the widest part of the brain rests; whilst the floor dips much lower down, where the medulla oblongata and the pituitary body rest. The scooped fenestrate alisphenoids (*a.s.*) look inward, but fail to reach the median line by a great space, which space is filled in by no orbital wings, such as we should see in a Lizard, Turtle, or Mammal. The whole orbital region is, in the skull, a steep wall, having a retral crest on its fore-part, this crest being the rudiment of the large sheet of cartilage (*tegmen cranii*), which is thrown over the brain in the young Salmon.² This wall (*p.s.*), this crest, and the elegant cartilaginous awning in front of the crest, containing valves

¹ See article AMPHIBIA, vol. i p. 753, fig. 5, *p.s.*
² See "Salmon's Skull," *op. cit.*, plate 4, fig. 2, *l.c.*

and folded curtains of most cunning construction (see figs. 10 and 11)—all these have grown out of that inter-nasal

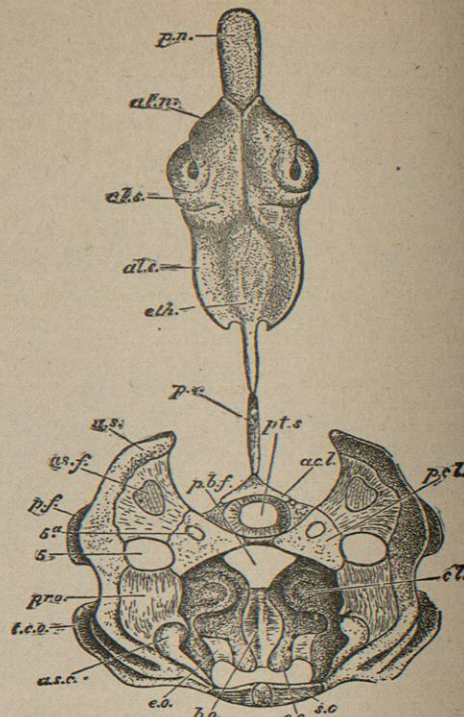


FIG. 9.—Skull of Chick, fourth stage, head nearly 1 1/2 inch long, beginning of third week, x 4 diameters. The additional letters are—*a.s.*, alisphenoid fenestra; *p.b.f.*, posterior basi-cranial fontanelle; *pro.*, prootic bone; *a.s.*, anterior semicircular canal; *t.c.o.*, tympanic wing of exoccipital; *b.o.*, basi-occipital; *8*, foramen rotundum; *5*, foramen ovale.

plate formed by the trabeculæ as their commissure (figs. 1 and 2, *tr.*)

Morphologically considered, these are added and distinct elements, but their differentiation from the trabeculæ cannot be seen well until now, and even now it is imperfect. The leafy coverings of cartilage are seen to dip down on each side of the prenasal spatula in front, and the cartilage at this part forms a coiled, valvular nose-lid—the "alinasal region." From this, in its inside, there hangs a curtain, all of cartilage (fig. 10, *n.tb.*), the "alinasal turbinal." It curves towards the septum, and then turns upwards below to become parallel to the inturred nasal wall (*l.n.w.*) Behind the alinasal comes the alisepal region (*al.s.*); and when cut across at the notch behind it and the hinder part of the roof, it shows a doubly coiled outgrowth, the "inferior turbinal" (fig. 11, *i.tb.*) The hinder region or "aliethmoid" is the true olfactory region; the roof suddenly turns inward, and is coiled upon itself, so as to form the bagpipe-shaped upper turbinals, whose swollen faces look inwards to the mesethmoid. Behind their inturred part they send down a cartilaginous curtain, the *pars plana*, or antorbital plate, the fore-face of which

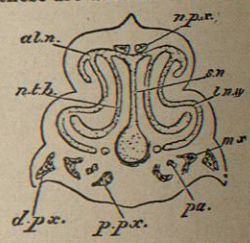


FIG. 10.—Skull of Chick, fourth stage, a transverse vertical section through the external nostrils, x 8 diameters. *s.n.*, septum nasi; *o.s.*, alinasal; *n.tb.*, alinasal turbinal; *l.n.w.*, lateral nasal wall; *n.p.*, nasal processes of premaxillaries; *d.p.*, dentary processes of the same; *p.p.x.*, palatine processes of the same; *pa.*, palatine; *ma.*, maxillary. On each side of the thick base of the septum the nasal nerves are seen.

does not develop any obvious "middle turbinal" as in Man.

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The differentiation of distinct morphological regions, which did not become obvious in the *membrano-cranium*, can now be seen to some extent in the well-developed cartilage. As in the *Ratite*, the orbito-nasal septum was, in the second stage, a continuous sheet of cartilage.¹

Looking upon the trabeculæ as the first facial arch correlated to and supplied by the orbito-nasal nerve, we see why there should be a segmentation of this uppermost and foremost part of the face into a suspensorium and a free arch, such as is seen next behind in the mandible.

This segmentation has commenced, and, oddly enough, that part of the trabecular commissure which will be absorbed has not lost its original flap-shape (see fig. 12, *p.e.*, *c.f.c.*, *s.v.l.*) The hour-glass-shaped window here formed by metamorphic action will become a notch in a day or two, and the flat region of the trabeculæ will be absorbed. Thus we get the Tinamine stage;² for in that intermediate form between the *Ratite* and *Carinate* types—the *Tinamou*—the metamorphic processes are stayed midway, and the bird is a native, so to speak, of the *Struthio-Gallinaceous* "marches." Beneath the retral ethmoidal spike is seen the olfactory groove (1.); whilst in front of the cranio-facial fenestra (*c.f.c.*), the orbito-nasal nerve (*n.n.*) grooves the septum, gets bridged over by it, and creeps down to its own proper facial bar—the trabeculæ. And the result of the metamorphosis in this *Carinate* bird is the formation of a pear-shaped fenestra (*i.o.f.*) between the eyeballs. This window was not cut out by Nature in a fit of economy (as the mere teleologists vainly speak), but is a fairly commenced separation of the common crest of the coalesced trabeculæ from the ethmoid forwards and the presphenoid behind (*p.e.*, *p.s.*)

The notch behind the cartilaginous frame of this window is formed by membrane into the optic foramen. A line drawn horizontally along the base of the fenestra, and another vertically to the upper margin of its narrow end, would mark out the starved presphenoid, without *alæ*, of this bird; for the mesethmoid and the basi-sphenoid (*p.e.*,

¹ See Parker "On Ostrich Skull," *Phil. Trans.*, 1866, plate 7, fig. 2, *p.e.*, and plate 8, fig. 10, *p.e.*
² "On Ostrich Skull," plate 15, fig. 8, *s.n.*, *p.e.*, *c.f.c.*

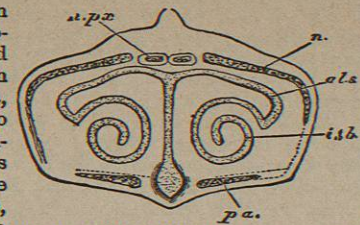


FIG. 11.—Another section from the same Chick, further back, x 8 diameters. *i.tb.*, inferior turbinal; *al.s.*, alisepal; *n.*, nasal bone.

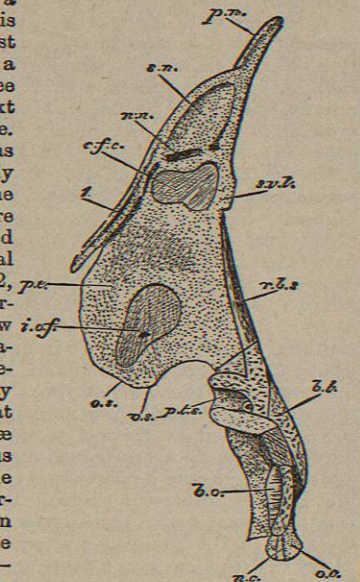


FIG. 12.—Axial part of the same skull, x 4 diameters. The new letters are *n.n.*, groove for nasal nerve; *c.f.c.*, cranio-facial cleft; *s.v.l.*, supe. vomerine lamina; *p.e.*, perpendicular ethmoid; *i.o.f.*, inter-orbital fenestra; *o.s.*, orbito-sphenoid.

b.s.) meet below the fenestra. Underneath the inter-orbital plate the parasphenoid bask (quite distinct) is seen, and underneath the basal bones the basi-temporal slab (*b.t.*) Turning again to the bird's-eye view (fig. 9.), we see that the notochord is now enclosed in a spearhead-shaped bone, the basi-occipital (*b.o.*) It is ridged above by the enclosed notochord, and, behind, the swelling halves of the condyle (*o.c.*) are seen. This basal bone is truncated in front, and forms the hinder margin of the wide rounded "posterior basi-cranial fontanelle" (*p.b.f.*) On each side are the exoccipitals (*e.o.*), and, above, the perfected occipital arch has a pair of super-occipitals (*s.o.*) as in man. The outer occipital region is grooved to receive the investing bones, and has tympanic wings to enlarge and protect that cavity. On each side of the fore-part of the basi-occipital is seen the cochlea (*cl.*); and in the ledge above the main periotic bone, the prootic (*pro.*) is largely spreading (the two lesser ossicles are appearing, but will be better shown in the next stage). The foramen ovale (5) is very large; it is bounded behind by the prootic, and in front by the alisphenoid (*a.s.*) This "great wing" has a large central fenestra, round which the bone has crept. In somewhat younger specimens this bony matter was in two patches, one above and another below the fenestra. The same thing may be seen in arboreal birds, as the Common Sparrow.

The stem of the alisphenoid almost meets its fellow-process over the posterior clinoid wall (*p.c.l.*) In the stem is seen a "foramen rotundum." Outside, the alisphenoid has a thick, secondary, post-frontal (*sphenotic*) wing (*p.f.*) The round pituitary space is walled in with bone. Its secondary parasphenoidal floor has been removed. We reserve a description of the fast-growing roof bones for the next stage, when they are most instructive for comparison with those of Fishes and Reptiles.

Cranium of Fowl—Fifth Stage.—In a day or two after

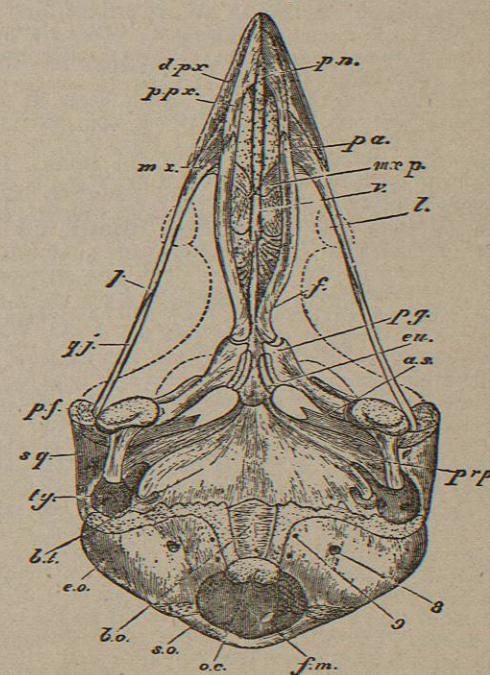


FIG. 13.—Ripe Chick's head, 1 1/2 inch long; lower view, x 3 diameters. The additional letters are *s.*, vomer; *l.*, lacrymal; *f.*, frontal; *cu.*, custachian opening; *p.p.x.*, posterior pterygoid processes; *sq.*, squamosal.

and the super-occipital behind. But the latter takes in all the breadth behind, whilst below the prootic are two, the upper the smaller; the lesser bone is the opisthotic, the larger, rounding the foramen magnum at its sides, is the exoccipital (*op.*, *e.o.*) These are infero-lateral elements. Below the whole are the basi-sphenoid and the basi-occipital, both of them underfloored by the basi-temporal (*b.t.*, *b.o.*) So much tilted backwards is the auditory mass that the crown of the anterior canal (*a.s.c.*) is imbedded in the super-occipital. In a Lizard, Snake, or Turtle that part would be first enclosed in a separate epiotic bone, which would be soon confluent with the super-occipital. But in these high *Sauropsida* the epiotic is a small, late centre, formed behind the commencement of the anterior canal in the front part of the recess in which the "flocculus" lies. Also the opisthotic is small, but is distinct for three or four months; it is a wedge of bone, flat-faced within, forming a straight suture with the hind edge of the prootic, and externally runs as a fine thread of bone between the two fenestræ of the labyrinth. We do not see this bone behind until afterwards, and it soon coalesces with the exoccipital, first with it and afterwards with the prootic, as in Lizards and Snakes.¹ After the elements of the chondrifying cranium have run into each other, the enclosed ear organs, by their copious growth, and also by their having many diverticula, such as the cochlea and canals, trespass on neighbouring territories, so that whilst the cochleæ burrow into the parachordal region, the semi-circular canals find room in the occipital arch.

In the Osseous Fish ("Salmon's Skull," *Phil. Trans.*, 1873, plate 5, fig. 8, *sp.o.*) there is a large bone called the "post-frontal" by Cuvier; in the Bird it often occurs, and looks like a secondary wing on the great sphenoidal wing (alisphenoid). In the Fish it covers the ampulla of the anterior canal; in the Bird it is in front of it and of the whole labyrinth. This bone, the "sphenotic," is ossified at the time of hatching.

The anterior sphenoidal region is all soft as yet (figs. 15 and 16, *p.s.*); and the great mesethmoidal wall (*p.e.*) covers only a third of its own proper territory. It now reaches to the notch; nearly to the roof also, but not to the parasphenoid. The cartilage it is ossifying is continued as an isthmus connecting the parts, behind and in front of the notch (cranio-facial hinge). Through this notch (fig. 16, *n.t.*) we see the swollen upper turbinal; and the nasal canal and bridge for the fore-part of the trabecular nerve is seen near the hind margin of the steep and well-formed septum nasi (*s.n.*), which has projecting from it the lessening rostrum (*p.n.*) Bridging over the notch, and let into the fore-edge of the frontal, are the never-coalesced nasal processes of the premaxillaries. Outside these, on each side (never in the middle in a Bird), are the nasals (fig. 15, *n.*) They are curious twisted bones, two-bladed in front to bind round the alinasal cartilages (*al.n.*) and outer nostril (*e.n.*); behind, they twist a little downwards the inner edge of their flat end. Tied by fibres to the side of the narrowed end of the frontal, and to that part of the nasal which is imbedded into it, is the lachrymal (fig. 15, *l.*) Its main part is the super-orbital, and this sends downwards a facial process, narrow and sigmoid. Within the lachrymal is the pars plana (*p.p.*), a subquadrate curtain, which is persistently cartilaginous in the Fowl, whose nasal labyrinth, unlike that of many birds, scarcely ossifies at

¹ The nomenclature of these parts is wrong in Mr Parker's paper on the "Fowl's Skull," *Phil. Trans.*, 1869; but he named their elements correctly in his former paper on the "Struthious Skull," *ibid.*, 1866. Researches into the growth of the Reptilian skull have helped to correct the error. He has found a true "pteric" in the Sparrow-Hawk (*Monthly Microsc. Jour.*, Feb. 1, 1873); that was the name given by him to the fowl's epiotic, whilst the latter name was applied to the posterior face of the opisthotic.

all, except the main dividing wall, the perpendicular ethmoid, which always early becomes solid.

The free mandibular bars are now continuous at their fore or lower end; the long and strong dentaries (figs. 15 and 16, *d.*) early coalesce. In front they cover the attenuating Meckel's cartilage (*mk.*); this, however, grows on behind, and its inner process (*i.a.p.*) is ossifying as the "articulare," the only endo-skeletal bone in the mandible. Behind, outside, and a little within, we see an upper and a lower splint, the surangular and the angular (*su.*, *a.*), and on the inner side, further forwards, the oblong splenial (*sp.*); but in this bird there has not been found a "coronoid," common in certain groups of Birds, besides Snakes, Lizards, and Crocodiles. In this and in other things the Fowl is often found wanting as to special elements.

The changes in the hyoid arch can be left until we come to the adult stage.

Cranium of Fowl—Sixth Stage.—This stage, which is

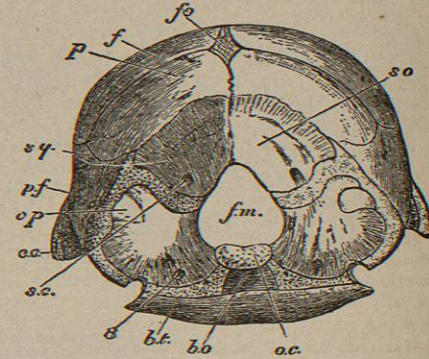


Fig. 17.—End view of skull of a Chick of three weeks old, sixth stage, X 3 diameters. Here the opisthotic bone appears in the occipital region, as in the adult Chelonian. Letters as above; *s.c.*, the opening of the sinus-canal.

that of chickens less than a month old, is introduced to show the occipital region from behind (fig. 17). This end view shows much that is ornithically characteristic. The subject was a somewhat starved chicken, whose retardation of growth caused a lingering of the ankylosis, which so soon removes all landmarks. Even now the great fontanelle, or membranous roof of the basin-like chondro-cranium, is barely covered by the still scant frontals and parietals (*f.*, *p.*); their flanking by the big squamosals (*sq.*), and the projection beyond these of the sphenotics, are well shown. A wholly cartilaginous epiotic region is still seen; it runs also inwards to the foramen magnum (*f.m.*), and still skirts the tympanic ala (*e.o.*) But on the upper and outer edge of the exoccipital a small plot is taken from the great exoccipital. This is the appearance through the cartilage of the opisthotic (*op.*); and this represents the permanent condition of the occipital arch in the *Chelonia*, which shows a free posterior face of the opisthotic above and outside the exoccipital. This view also shows how the skull is double-floored by the addition of the basi-temporal slab to the ossifying chondro-cranium (*b.t.*, *b.o.*)

Cranium of Fowl—Seventh Stage.—In chickens two months old, a section of the skull shows all the sutures except those lost by early fusion of the three parasphenoidal elements with the compound basi-sphenoidal ossifying cartilage. The periotic elements are all distinct, not only from each other, but also from their surroundings (*Phil. Trans.* 1869, plate 85, fig. 1.) The bony orbito-nasal wall (perpendicular ethmoid) has grown by metamorphosis of the cartilage up to, and somewhat over and under, the inter-orbital fenestra; thus half of this large septum is bony. There is no osseous presphenoid, but instead of the true orbito-sphenoids two osseous centres have appeared on

the post-orbital fontanelle, the foremost being the smaller bone; these help the orbital plate of the frontal to cover the eyeball with bone. In front of the doubly notched ethmoidal wall the face is connected with the skull by a narrow band of cartilage, which is never quite severed in this type. Thus the fore-face lifts on the skull in harmony with the depression of the mandible, by means of the elasticity of the parts, for, as we have seen, the firm splints above—nasals and nasal processes of the premaxillaries—are let into the frontal by their fibrous, lathy ends.

Cranium of Fowl—Eighth Stage—Chicks Three Months old.—Many sutures still remain at this stage, but those between the occipital and periotic elements are fast filling up (*Phil. Trans.*, 1869, plate 85, figs. 4-7, p. 794.) We must refer the reader to the work above cited for the details; no stage shows the exquisite architecture of the ornithic skull more lucidly than this. The synchondroses are reduced to fine lines or sutures, and the size of the object is of great importance, as tending to make a difficult study easy to the observer.

Cranium of Fowl—Ninth Stage.—In chickens of the first winter, eight or nine months old, nearly full-sized, but yet succulent even in their skeleton, many things are to be observed (*op. cit.*, plates 86, 87, figs. 1-3, p. 795.)

On the roof the sagittal suture is only obliterated in the parietal region, and the super-occipital still retains an upper notch. The occipital and auditory regions have entirely coalesced—the opisthotic with the exoccipital first, and then with the prootic; but the little epiotic seems to melt into the common mass of the ankylosing super-occipital and prootic, without any precedence either way. All the sutures across the cranio-facial hinge are still visible, namely, those made by the frontals, lachrymals, nasals, and nasal processes of the premaxillaries, in their relations. Where the frontals diverge by narrowness in front, behind the nasal processes of the premaxillaries, there the ethmoid is seen becoming fast bony from the substance of the perpendicular plate, and not by a separate upper bone, as in the *Struthionide*.¹ As to the facial bones, they yet retain much distinctness, and the prenasal and Meckelian rods still linger. The articular end of the latter rod is now ossifying fast, the two angular processes, so large in this type, are now bony. The fast coalescing roof and the coalesced floor are now of great thickness, and the diploë in this type is coarse (*op. cit.*, plate 86, fig. 14.) In all these growing stages, tracing bone by bone, as it appears, we have not yet met with the presphenoid, nor seen the behaviour of the great ethmoidal wall in relation to the hinder skull. In the most advanced winter chickens these things are to be seen (fig. 18, *p.s.*, *p.e.*, *b.s.*)

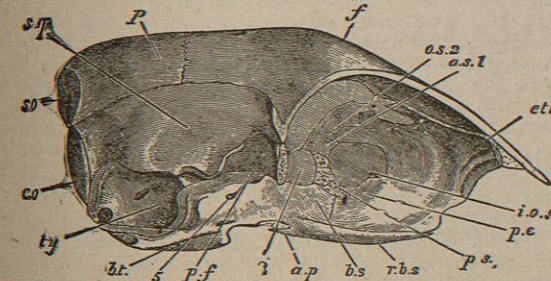


Fig. 18.—Skull of young Fowl of first winter, ninth stage, side view, X 1 1/2 diameters. *a.s. 1* and *a.s. 2*, the two small orbito-sphenoidal centres above the small presphenoid *p.s.*, which is only partially ossified at present. The sutures at this stage are very instructive. The fore-face has been removed, and the anterior edge of the perpendicular ethmoid (*p.e.*) is the posterior boundary of the cranio-facial cleft.

¹ *Phil. Trans.*, 1866, plate 8, fig. 10, *eth.*, *p.e.*

The presphenoidal region is merely that band of cartilage which lies partly above, but mainly behind, the fenestra (*i.o.f.*) A small ossicle has appeared in it close below the second orbito-sphenoid (*p.s.*, *a.s. 2*), the foremost orbito-sphenoid (*a.s. 1*) has coalesced with the perpendicular ethmoid.

From that bone the rostrum of the parasphenoid is still distinct (*r.b.s.*), but the perpendicular plate has now reached the basi-sphenoid (*p.e.*, *b.s.*), and between them, and below the still soft lower part of the presphenoid, there is a high vertical suture. This suture, and this steep bony wall beneath the presphenoid, are of the greatest interest to the morphologist. We saw that the basi-sphenoid was compound, having in it, besides the parasphenoidal elements as investing parts, both the parachordal ends and the trabecular apices. So it is, for the Bird's skull runs over, or rather is built upon, the marvellously metamorphosed first visceral arch—the arch formed by the primordial "trabeculæ cranii." Counting from the spine, we have three cranial sclerotomes in the osseous stage. The first is formed on a notochordal and parachordal foundation; this is the "basi-occipital." The next is formed on a foundation partly parachordal and partly facial—the basi-sphenoid. The third is the "presphenoid," and it is tilted up over the forth-growing trabecular arch, the elements of which early coalesce at the mid-line, and the common crest of which is not, for a long time, in any way actually separate from the approximating roofs of the nasal sacs.

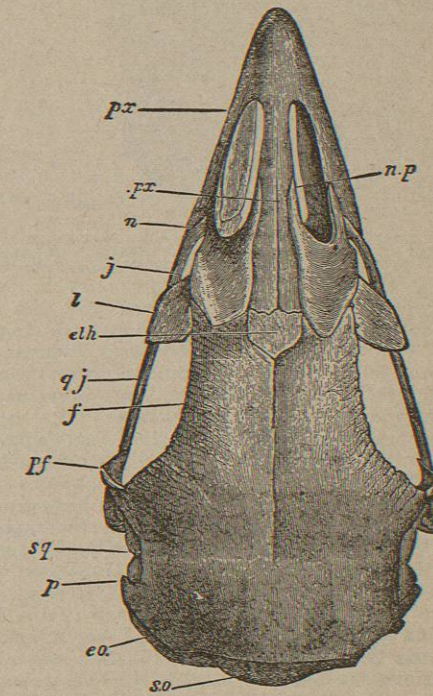


Fig. 19.—Skull of an old Fowl, tenth stage, X 1 1/2 diameters, upper view. Above the line from *n.* is seen the large two-spurred nasal, the processes of which—upper and lower—are marked *n.p.*, the cartilaginous structures of the nose are not figured.

Cranium of Fowl—Tenth Stage.—In old birds we find an intense degree of ankylosis, and yet certain sutures are persistent to old age, or at least show some chink or mark of their original separateness. In this the Fowl agrees with most birds, but, being at no great height above the