OBSERVATIONS UPON THE OSTEOLOGY OF THE ORDER TUBINARES AND STEGANOPODES.

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The order *Tubinares* has been made to include the Albatrosses, Fulmars, Shearwaters, and Petrels; the Albatrosses being carried in the family *Diomedeidæ*, and the remaining forms in the family *Procellariidæ*, with such divisions in each into subfamilies and genera as our present knowledge of their structure seems to warrant.

A splendid contribution to the anatomy and classification of the *Tubinares* was left us by my talented friend Mr. W. A. Forbes,* who so ably examined the material for this subject collected by the *Challenger* expedition.

As an introduction to his work, Mr. Forbes gives us a very excellent account of the "Previous Literature on the Anatomy and Classification of the Tubinares," which goes to show that the study of the structure of these birds has by no means been neglected.

My material at the present time is quite limited, although I have at my disposal everything the Smithsonian Institution collections contain. Under these circumstances I can hardly hope to add anything to the exhaustive researches of Forbes, who had at his command alcoholic specimens and skeletons of nearly all the genera known to us. His illustrations, however, are not many, so far as the skeletons of some of the types are concerned, and I am in hopes that this part of my labor will be acceptable to those who may take up the subject in future, and not have at hand, perhaps, some of the skeletons which I have figured to illustrate this memoir.

My remarks will be confined principally to the skull of the adult Albatross, the skeleton of the adult Fulmar, and the skeleton of the adult Gray Fork-tailed Petrel.

Representing the Shearwaters, I have nothing except one sternum of *Puffinus major*, collected by Mr. N. P. Scudder, and an imperfect skull of a Shearwater collected by Dall, which, from its measurements and the locality in which it was picked up (a beach specimen), I take to be *Puffinus tenuirostris*.

I am indebted to Dr. T. H. Bean, of the Smithsonian Institution, for the four fine alcoholic heads of *Diomedea albatrus*, collected by him in

* Report on the Scientific Results of the Voyage of H. M. S. *Challenger* during the years 1873–'76, under the command of Capt. George S. Nares, R. N., F. R. S., and Capt. Tourle Thomson, R. N. Prepared under the superintendence of the late Sir C. Wyville Thomson, Knt., F. R. S., etc., regius professor of natural history in the University of Edinburgh, director of the civilian staff on board, and now of John Murray, F. R. S. E., one of the naturalists of the expedition. Zoölogy, Vol. IV, pt. XI, pp. 1–64; Pls. I–VII (1882).

Alaska. They have been of the greatest service to me. This bird ranges over the Pacific Ocean at large.

Rodgers' Fulmar (*F. glacialis rodgersii*), the skeleton of which we will examine, is confined to the North Pacific. This is likewise the habitat of the Fork-tailed Petrel (*O. furcata*), four nearly perfect skeletons of which bird are found in our list for examination.

Specimens.	Locality.	Collector.	Smithsonian catalogue number.	Remarks.
Diomedea albatrus	Alaska	T. H. Bean	Writer's collection	Alcoholic head.
Diomedea albatrus, juv.	do	do	do	Do.
Do	do	do	do	Do.
Do	do	do	do	Do.
Puffinus major	Davis' Straits	N. P. Scudder	16976	Sternum, etc.
Fulmarus glacialis	do	do	16978	Do.
Do	do	do	16979	Do.
Do	do	do	16980	Do.
Do	do	do	16981	Do.
Do	North Atlantic	L. Kumlien	16987	Skeleton.
Diomedea albatrus	Cook's Inlet, Alaska	E. P. Herendeen	3333	Sternum.
Diomedea (sp. ?)	Oonalaska	Lieut. P. H. Ray	16738	Skull.
Fulmarus glacialis	Upernavick		16781	Skeleton.
Diomedea (sp. ?)	Tokio, Japan	P. L. Jouy	16948	Sternum.
Oceanodroma furcata		W. H. Dall	16990	Skeleton.
Do		do	16991	Do.
Do		do	16992	Do.
Do		do	16993	Do.

The skull of the doubtful species of Albatross, No. 16738, from Oonalaska, differs from those in my possession of *D. albatrus*, and probably is some other species, perhaps *D. nigripes* or *Phœbetria fuliginosa*.

The sternum of an Albatross bought by Mr. Jouy in the Tokio market appears to agree very well with specimens of the sternum of the Short-tailed Albatross.

Skeleton of Oceanodroma furcata (Fork-tailed Petrel.)

(Fig. 1.)

We find in the skull of this Petrel some very excellent characters, a number of which it holds in common with the Fulmars, and still fewer with the Albatrosses.

Regarding it from a lateral view, we observe the superior mandible to be powerfully hooked, with the culmen, transversely, very narrow between the longitudinally elliptical osseous nares.

The nasal assumes the holorhinal type, and a concavity appears above, over the region of the cranio-facial junction.

A lacrymal is a very peculiar bone in this bird, it, with a projecting part of the frontal at the superior externo-anterior angle of the orbit, having quite an extensive face that looks directly backward, thus forming a good share of the anterior wall of the orbital cavity. From this portion two processes are sent out; the one reaches directly forward to articulate by its extremity with the hinder free margin of the corresponding nasal. This process forms a wall for the upper part of the rhinal chamber, and may or may not leave a longitudinal, spindle-shaped foramen between its upper margin and the united free upper border of the nasal and frontal. (Fig. 1.)

The remaining process is the descending process of the lachrymal, and it is overlapped posteriorly at its middle by the pars-plana, but reaches the infraorbital bar by the latter being bent at a sharp angle upward to meet it.

This process has a circular foramen in front which leads into its internal cavity, but for which I fail to find an exit or recognize the use of to the bone unless it be a pneumatic opening.

The wing of the ethmoid completely fills in the remainder of the anterior wall for the orbit, being impervious in all its parts. It is separated from its fellow of the opposite side by a median superior area of bone, concave on its posterior aspect. This is the mesethmoid, and is perforated for the passage of the olfactory nerves, the entire wall of the brain-case being open opposite it. It is evident that this latter arrangement gives rise to a large subcircular foramen in each orbital wall at the upper postero superior aspect, through which we may see into the cavity of the brain-case. The optic foramen seems to be intact and perfect in all cases. Beyond it there is another circular foramen about the same size, which pierces the interorbital septum here—really a concavity between the sloping walls of the pars-plana on one hand and the lower portion of the anterior wall of the brain-case on the other.

The *quadrate* has a form much the same as in birds generally, but the mandibular facets at its foot are characteristic. The outer and oblong one is placed obliquely, its anterior end being forward; the inner and lower one, in addition to a facet which it has placed nearly in the horizontal plane, has another which looks almost directly forward. This latter one is transversely grooved for its entire length. Viewing this skull from above, we find it marked by a shallow, median groove, being deepest between the orbits.

The luniform, supraorbital, glandular depressions occupy the entire upper free margins of these cavities, extending between the lacrymals and upturned, pointed post-frontals. They are clean-cut and deep, being of about an equal width throughout.

Posteriorly the skull is smooth and rounded, in direct continuation of a similar character of surface of the parietal region. It lacks all those angular definitions of areas so prominent in the *Alcidæ* and *Urinatoridæ*.

The crotaphyte fossæ are lateral and very feebly pronounced. Seen upon its under side, we at once discover that the skull of this Petrel presents all the characters of a veritable Cecomorph, which it is. The arrangement of the bones of the hard palate is essentially the same as in the Loons, Auks, and Guillemots. We notice here, however, that in this Petrel the palatines each present a convexity toward each other opposite where they meet the maxillo-palatines. These latter are thin, firm plates of bone arranged as in the Auks or Gulls, with the exception that their median free margins seem to anchylos with the corresponding edges of the palatines over which they lay; consequently upon this view they are shut out of sight and do not appear in the interpalatine space.

The *vomer* is very long, being half a hollow cylinder behind, with its convex surface downward; the posterior end of this joins the palatines in the usual way. Below, it is longitudinally grooved in the median line. This groove is continued forward as a carination on the anterior portion, to terminate in a little spike in front. The concavity of the half cylinder and the anterior portion form together a long gutter for the rostrum of the sphenoid.

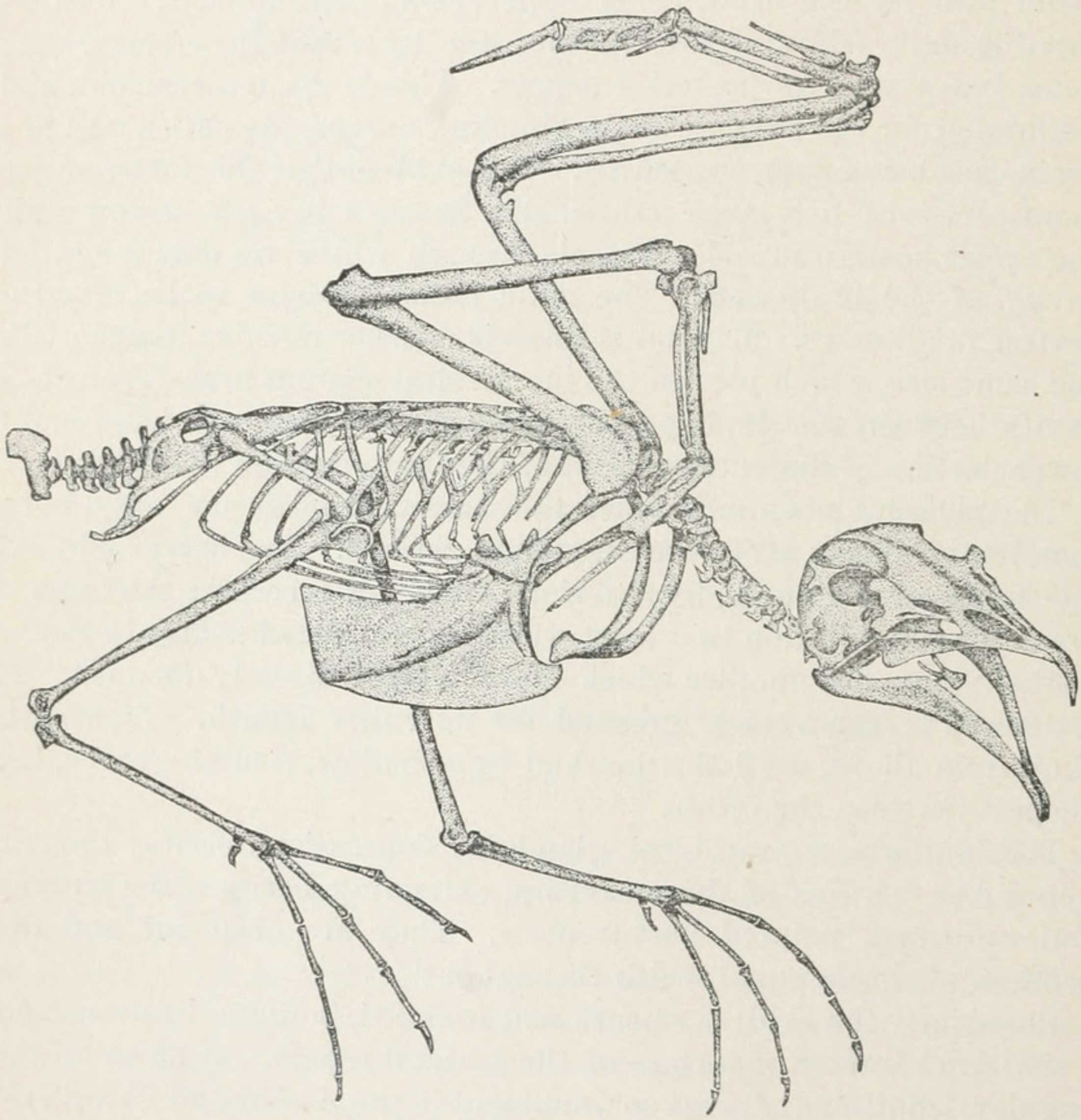

FIG. 1. Complete skeleton of *Oceanodroma furcata*. (Specimen 16990, Smithsonian collection.) Life size. By the author.

The *pterygoids* are slender, straight bones; their anterior heads meet each other and the heads of the palatines, the four forming a groove above for the under convex surface of the presphenoidal rostrum.

There is no sign whatever of the presence of basi pterygoid processes. Huxley mentions their occurrence in *Procellaria gigantea* in his Classification of Birds.

The Eustachian tubes seem to have a common aperture, and the external opening is nearly naked.

Behind this orifice the basi-temporal region is represented by a broad area, which, in common with the margins of the subcircular foramen magnum and the small hemispherical and sessile condyle, is in the horizontal plane.

An upper view of the mandible shows it to be perfectly V-shaped, with rather a short, longitudinally grooved symphysis. Its anterior apex is at the intersection of the lower ramal borders, which are straight lines, while the superior borders, forming as they do the sides of the symphysial groove above, become gently convex and approach each other to meet in this apex below. The anterior end of the mandible in an Albatross is shaped in much the same manner.

The side of each ramus is broad from above downward just beyond the feebly pronounced coronoid process. Beyond this the upper and lower borders are nearly parallel, and the space they include quite narrow.

A mandibular end is triangular in outline with the apex below, and the plane of its area making but a slight angle with the plane in which the inferior ramal borders are found.

The original elements of this lower jaw are completely united together, leaving scarcely any trace of their original margins or a ramal vacuity where it usually occurs in many birds.

For the rest the bone is pneumatic, the foramina being at their usual sites, upon the inturned processes of the articular ends.

Petrels have a broad first basi-branchial in their *hyoid arches*, which co-ossifies with a spine-like second basi-branchial.

The cerato-hyals and glosso-hyal never form in bone, while the second arches are exceedingly delicate osseous threads in *Oceanodroma*, curving up behind the occiput in the usual fashion of the class; these "greater cornua" being composed of the common elements and articulated in the common way.

Of the vertebral column, etc.—Usually in this Petrel the first free pair of tiny ribs occur upon the fourteenth vertebra of the column, but in one of these specimens they are liberated also on the thirteenth. In either event, however, there is a long, delicate free pair suspended from the fifteenth vertebra.

Neural spines occur upon the second to the sixth, inclusive, but are from thence onward suppressed until this feature makes its appearance again in the fourteenth vertebra. The hyapophysial canal is found in the sixth, seventh, and eighth, but thereafter a process is found all the way through the series to the sacrum. These hyapophysial processes are quite prominent in mid-dorsal region. Here, too, the neural spines are very intimately connected together, but nevertheless the vertebræ are all movable upon one another.

From the sixteenth to the twenty-first vertebra, inclusive, we find a

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series of true ribs occurring, connected to the sternum by costal ribs. They support anchylosed epipleural appendages, which may lap two ribs in the middle of the series.

A delicate pair of ribs also spring from beneath the ilia, but their hæmapophyses do not reach the costal borders of the sternum.

These dorsal vertebræ are almost entirely devoid of metapophyses or interlacing spiculæ above. Their articulations are heterocœlous, and they are non-pneumatic throughout the series.

In the *pelvis* the anterior ends of the ilia are truncate from before backward, and their inner margins do not usually meet the neural crest of the sacrum, leaving, in consequence, "ilio-neural grooves" at their sides. These bones are narrow, of nearly an equal width, and concave in both directions. They rise over the acetabula, on either side, to form small convex areas to the rear and above these cavities. Below this the remainder of each ilium, aided by the corresponding ischium, form the drooping sides of the pelvis so characteristic of the Petrels.

Each ischium has a posterior process, which, after forming the superior boundary to the obturator space, curves downward to become an expanded, foot-shaped end, which closes in the aforesaid space by having the lower margin of the foot applied to the upper margin of the post-pubis.

The ischiatic foramen is nearly circular and, in common with the acetabulum, rather small.

There is no pro-pubis in this Fork-tailed Petrel, and the obturator foramen and space, as a rule, form one vacuity.

Eight spreading caudal vertebræ, with a quadrilateral pygostyle, make up the skeleton of the tail. There appear to be many more of these segments, as the united uro-sacral vertebræ beyond them seem to continue the series so perfectly. This is still more striking in *Fulmarus*.

Of the sternum and pectoral arch.—The furcula is of the U-shaped variety, and curved backward toward the sternum, its quadrate hypocleidium having its lower border usually in contact with the upper border of the protruding carinal angle.

The clavicular limbs are about of an equal width throughout, the posterior tips of their heads becoming pointed, and in articulation meet the scapular heads at their inner angles. The outer aspect of each of these heads of the clavicular limbs are modeled so as to form an extensive concave facet for the head of the corresponding coracoid. This arrangement is not seen in the Albatrosses nor Fulmars.

A *coracoid* is principally notable for its greatly expanded sternal end, the outer angle of which is much produced.

Its shaft is subcylindrical and its head tuberous. The scapular process descends upon the inner side of the shaft, but, so far as I can see, is not pierced by any foramen, as it is in the Fulmars and *Diomedea*.

A *scapula* is dilated posteriorly and truncate after the manner most common to birds; its head is rather broad and compressed from above downward.

The entire pectoral arch is non-pneumatic, in keeping with the most of the rest of the skeleton.

The body of the sternum in *Oceanodroma* is of a square outline, with its postero-lateral angles slightly produced and its xiphoidal border entire. Above it is concave, being correspondingly convex upon its pectoral aspect. The carina is deep in front and gradually slopes to the mid-point of the hinder border of the sternal body. Its angle protrudes and its anterior margin is concave.

Each costal border has six articular facets upon it, and the costal processes are triangular in outline and quite prominent. The manubrium is wedge-shaped and small, and the coracoidal grooves nearly or quite meet at its base.

The chief pectoral muscular line starts from a point on the lower lip of a coracoidal groove half way between the manubrium and costal border, to be produced posteriorly and terminate at the junction of hinder and middle thirds of the line made by the carina where it joins the sternal body. This bone is non-pneumatic.

Of the appendicular skeleton.—When closed in a position of rest the bones of the antibrachium rather exceed in length the humerus, and both are long for the size of the bird.

The shaft of the latter bone is subcylindrical and nearly straight, viewed from any aspect. Curling, as it does, far over the pseudo-pneumatic fossa, the ulnar crest forms a prominent feature at the proximal end of the bone. Another and smaller fossa, protected somewhat in a similar manner by the overhanging humeral head, is separated from the former by a bony bridge.

The radial crest is short, but well pronounced, with its free border convex.

At the distal extremity of the humerus we notice a conspicuous ectocondyloid process, and to its inner side at the base of the shaft, beyond the trochlear tubercles, a deep pit.

The anconal aspect of this extremity is profoundly marked by a median tendinal groove. The bone is about 3.5 centimeters long.

After very careful search at the elbows of all four of these specimens of *Oceanodroma furcata* I fail to find the slightest trace of anything like a sesamoid bone, and the specimens are in a condition, too, that if they existed they would more than likely be there.

I am aware of the existence of Reinhardt's paper upon this subject, but it is not at the present writing available to me, and I can not say whether he claims to have found these sesamoids in *Oceanodroma* or not.

The shaft of *radius* is very straight and that of the *ulna* not much bowed, so we have a small interosseous space in this Petrel.

The skeleton of manus is long (4.5^{cm}), but does not call for special remark beyond the fact that pollex digit does not bear a claw, nor does the distal phalanx of index in the specimens, although the latter under the microscope seems to have a facet there for that purpose.

The expanded phalanx above this one is not perforated (Fig. 1), as it so often is in the *Laridæ*. The limbs of this skeleton are non-pneumatic.

In the pelvic extremity the *femur* is comparatively short, its average length being 1.5^{cm}, the tibio-tarsus measuring 3.8^{cm}, and the tarso-metatarsus 2.5^{cm}. The femoral shaft is cylindrical and slightly arched forward. Its trochanterian ridge is suppressed, being on a level with the summit of the bone, while its head is quite sessile and excavated for the round ligament. Distally its condyles are proportionately developed, the outer one being rather the lower of the two.

Tibio-tarsus also has quite a straight and smooth shaft, presenting all the characters as commonly seen in the majority of the class. Its own special character, however, which its owner seems to hold in common with the family, consists in a marked prominence of the procnemial ridge over the nearly aborted ectocnemial ridge. Neither of these extend for any distance down the shaft, but are, on the contrary, directed equally upward and forward in rather a striking manner.

I have failed to discover the presence of a *patella* in this Petrel, but from the fact that this sesamoid occurs among the Fulmars—birds with a tibia very much like our present subject—I think we are justified in believing that perhaps a very minute one is to be found in the tendon. This latter has been scraped away in every instance by the preparator, whereas the tendons at the elbow were allowed to remain.

The *fibula* is extremely short and delicately constructed, extending but a very short distance below its ridge on the side of the other leg-bone.

Hypotarsus of the next segment of this extremity seems to have but a single median groove at its posterior aspect for the guidance of tendons. This is continued for the entire length of the shaft behind, becoming more faintly marked as we descend the bone, while anteriorly this longitudinal groove is strongly marked.

The first metatarsal is a diminutive bone, attached to the side of the main shaft at its usual site by ligament. It has articulating with it the ungual joint, the basal one never appearing in these birds. Of the distal trochleæ the inner one is the most elevated and at the same time most posterior.

The podal joints of the anterior toes are extremely long and delicate, but otherwise arranged upon the plan most common to the avian foot.

BRIEF SUMMARY OF THE OSTEOLOGICAL CHARACTERS OF OCEANODROMA FURCATA.

(1) Superior osseous mandible powerfully hooked; culmen convex; nasal holorhinal; lacrymal with long, anterior process, which extends forward to the nasal; maxillo-jugal bar bent at an angle upward to meet descending process of lacrymal.

(2) Ethmoid peculiarly bulky and pierced by the olfactories. Crotaphyte fossæ lateral; maxillo-palatines do not encroach upon the interpalatine space. As negative characters: Basipterygoid processes not present; angle of mandible truncate (no processes); no ramal vacuity.

(3) Sternal end of coracoid much produced laterally and externally. Hypocleidium of furcula in contact when articulated with anterior margin of carina of the sternum.

(4) Xiphoidal end of sternum a transverse straight line, neither fenestrated nor notched; carina deep in front, occupies entire length of sternal body.

(5) Humerus possesses an ectocondyloid process, and is shorter than the skeleton of antibrachium.

(6) Accessory metatarsal is free and articulates with ungual joint of hallux, the basal one not appearing.

THE SKELETON IN THE FULMARS (FULMARUS GLACIALIS RODGERSII).

There are but a few unimportant differences between the skeleton of Rodgers' Fulmar and *F. glacialis*, and I prefer to confine myself to the discussion of the former bird in my description of the osteological characters of those well-known representatives of the order *Tubinares*. Moreover, as they possess not a few characters in common with *Oceanodroma*, I feel at liberty to make this description rather a comparative one than otherwise, as my account of the osteological characters of the latter form is quite full; thus my labor will be lessened, and I know the result will be of more value and greater use.

The superior mandible in the skull of Rodgers' Fulmar is large and massive; its posterior two-thirds is convex, while a smaller median convexity is engrafted upon its anterior end, which is produced downward in a powerful hook.

The margins are likewise gently convex and cultrate. Each narial aperture is spindle-formed and the nasal is of the holorhinal type, its two processes being wide and thoroughly incorporated with the surrounding bones.

We find the lacrymal constructed upon the same principle as in the Fork-tailed Petrel, though the upper margin of the anterior process unites with the frontal and nasal above it. Then the pars plana and the body of the bone have also merged into each other, leaving us in doubt as to the exact locality of the suture. The arrangement of the parts at the inner aspect of the orbital cavity is as in *Oceanodroma*, but we observe that foramina occurs over the ethmoidal wings, while the perforation is comparatively larger and, in fact, absorbs all that part of the bone entitled to such a name. The maxillo-jugal bar is not bent up to meet the lacrymal, and the quadrate is the same as in the Petrels.

Jutting out prominently from the sides each sphenotic process is of a quadrilateral outline, and a ridge upon their posterior aspects divide either supraorbital glandular depression from the corresponding crotaphyte fossa.

Regarding this skull from above, we are to note how profoundly it is impressed by the glandular pits; that they do not meet in the median line, and, further, that their position agrees precisely with what we found in *Oceanodroma*. A shallow, median groove here marks the skull, the remainder of which is smooth and globular. Viewed from behind, the peculiar form and position of the deep crotaphyte fossæ forces itself upon us, and the jutting sphenotic processes come directly into view. Underneath, the skull presents us with many points of interest.

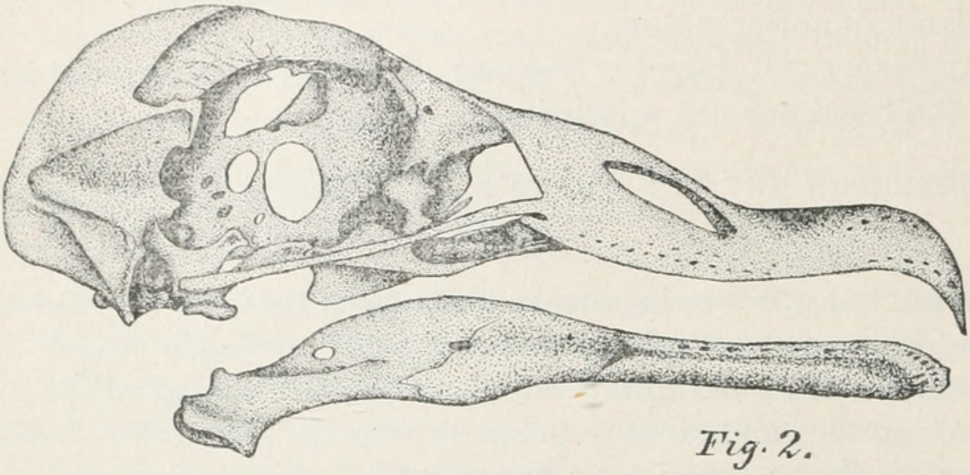

Fig. 2.

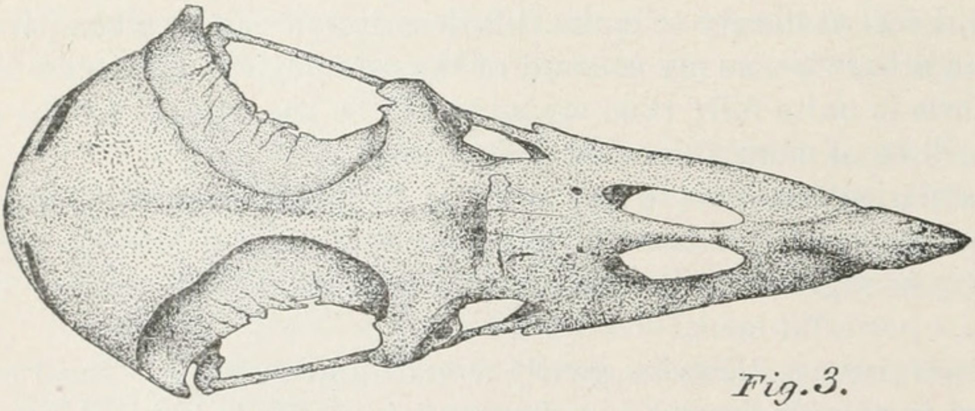

Fig. 3.

Fig. 2. Right lateral view of the skull of *Fulmarus glacialis rodgersii*, ♂.

Fig. 3. Same form above, mandible removed. Both figures drawn by the author from specimen 12613 of the Smithsonian collection. Life size.

The superior mandible is canoe-shaped, with its prow to the front, and its deep concavity extending to the rear.

The maxillo-palatines are elliptical disks tilted up as in the *Laridæ*, and encroaching for their entire inner margins upon the interpalatine space, where they are well separated from and parallel to each other.

Of extraordinary size, the *vomer* (Fig. 6) in this Fulmar is of an elongated, cordate form, nearly flat, being slightly concave above; carinated in the median line beneath, with its anterior tip somewhat depressed; and, finally, meeting the palatines behind as usual, these latter bones have to curl to one side to clear it laterally, for this vomer forms a very complete floor to the rhinal chamber without coming in contact with its neighbors.

Well over this vomer, in the median line, the rostrum is extended as a long spiculiform process. The anterior ethmoidal margin is sharp, but becomes broad as the bone abuts against the region of the cranio-facial hinge. Beyond this it is sometimes extended as a semiosseous median supero-rhinal septum.

The palatines are also unusually broad, their postero-external angles being well rounded off. Laterally they are quite horizontal, but each inner margin, just beyond the palatine heads, is turned down for a short distance as a prominent inner carination.

Thoroughly developed *basi-pterygoid* processes meet to articulate with others coming from the pterygoid bones themselves. Huxley found those present also in the Giant Fulmar, and I have reason to suspect their presence in the Shearwaters (*Puffinus*).

In Rodgers' Fulmar the occipital condyle is hemispherical in form, and the outline of the foramen magnum subcircular.

I regret to say that I can offer nothing upon the *hyoid arches* of this Fulmar, as that part of the skeleton has been lost in all the specimens.

In the *mandible* the symphysis is short and sunken between the convex ramal walls. It protrudes slightly in front as a blunt process.

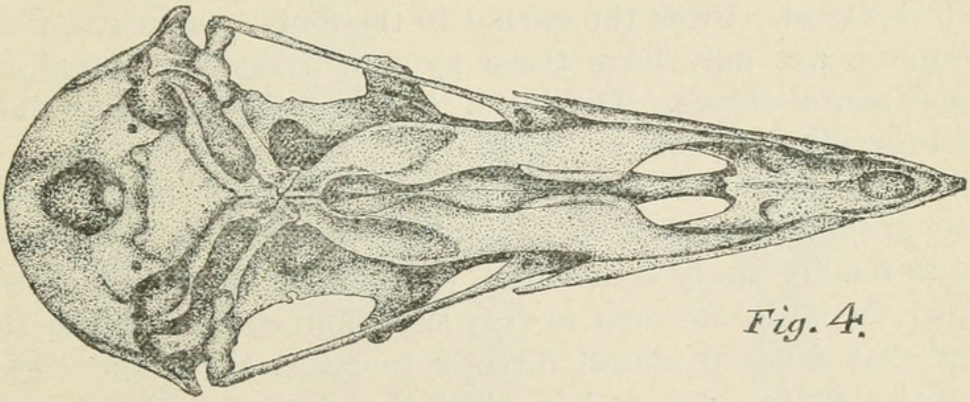

Fig. 4.

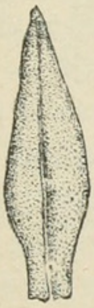

Fig. 6.

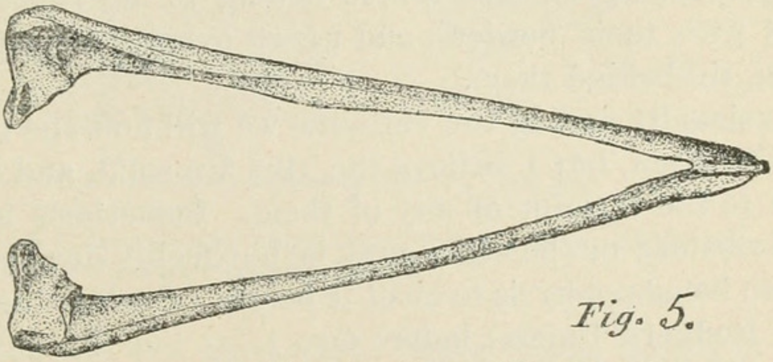

Fig. 5.

FIG. 4. Basal view of the skull of *Fulmarus glacialis rodgersii*; mandible removed.
FIG. 5. Mandible of the same specimen, viewed from above.
FIG. 6. The vomer of the same, from above. All these figures are life size, and drawn by the author from specimen 12613 of the Smithsonian collection.

Both superior and inferior borders of the bone are rounded and the coronoid processes very feebly developed.

Each surangular is pierced by an elliptical foramen, but the true ramal vacuity is covered over by the extended growth of the mandibular elements.

The angles are truncate, slightly produced below, and the articular cups show on their upper sides at the usual sites the large pneumatic foramen on either one. Much of the skull proper is likewise permeated by air.

Of the vertebral column and the rest of axial skeleton.—What I have said of the vertebral column of *Oceanodroma* applies almost exactly to the column in this Fulmar; the twenty first vertebra, however, in both the common *Fulmarus* and *F. rodgersii* anchyloses as the anterior one of that series which goes to form the sacrum between the pelvic bones. Its ribs in consequence meet a pair of costal ribs below, that in their turn articulate with the sternum.

Rodgers' Fulmar has the hyapophysial canal of the cervical series passing through the sixth to the tenth vertebra, inclusive.

Moreover, in the dorsal region we find this bird differs from the Petrel in having fully developed metapophyses linking the outer ends of the transverse processes together.

The eleventh, twelfth, and thirteenth vertebræ all have a large, single hypapophysis. This is not so long, and has lateral, basic processes in the next two, while through the dorsal series it becomes gradually longer, then shortens again, to appear for the last time as a minute point on the first sacral. From the second to the fourth, inclusive, the cervical vertebræ not only have these hypapophyses, but equally well-developed neural spines. The latter gradually disappear in the next two, and the arterial canal supplants the former.

The skeleton of the trunk of *Fulmarus glacialis*, from the specimen collected in the North Atlantic by Ludwig Kumlien in 1877, has been allowed to remain nicely articulated, with all the bones in their normal positions. In it the sternum is very short and concave, while the six vertebral ribs descend almost directly to reach the costal ones, and other particulars are observed in which it agrees with *F. rodgersii.*

Epipleural appendages which belong to the ribs of this Fulmar anchylos with their borders, and never overlap more than the next succeeding rib behind them.

Occasionally among the vertebræ we will find one that shows a pneumatic foramen, but I believe the ribs are solid, and air does not gain access to the interior of any of them. Sometimes in the last pair of sacral ribs one or the other may be but feebly developed and not have any free hæmapophysis to meet it below. Such is the case in the skeleton of Rodgers' Fulmar before me.

Kinship with the Albatross unmistakably crops out in the *sternum* of this bird. A glance at the figures is enough to satisfy one of this fact.

In outline the bone is quite square, and although in some specimens the xiphoidal border is, like in the one I figure, jagged to an extent that leads us to believe it to be without any regular pattern, I have, nevertheless, sufficient material before me to prove that the tendency of the bone is to become doubly notched.

Above, it is very concave, accompanied of course by a corresponding convexity of the pectoral aspect. It is upon this latter that we notice that the muscular line meets the base of the keel at junction of middle and *anterior* third, differing considerably from *Oceanodroma* in this respect.

The carina is deep in front and gradually slopes away to the posterior margin. Its anterior border is broad and straight, being deeply grooved from above downward. The angle stands out quite prominently and

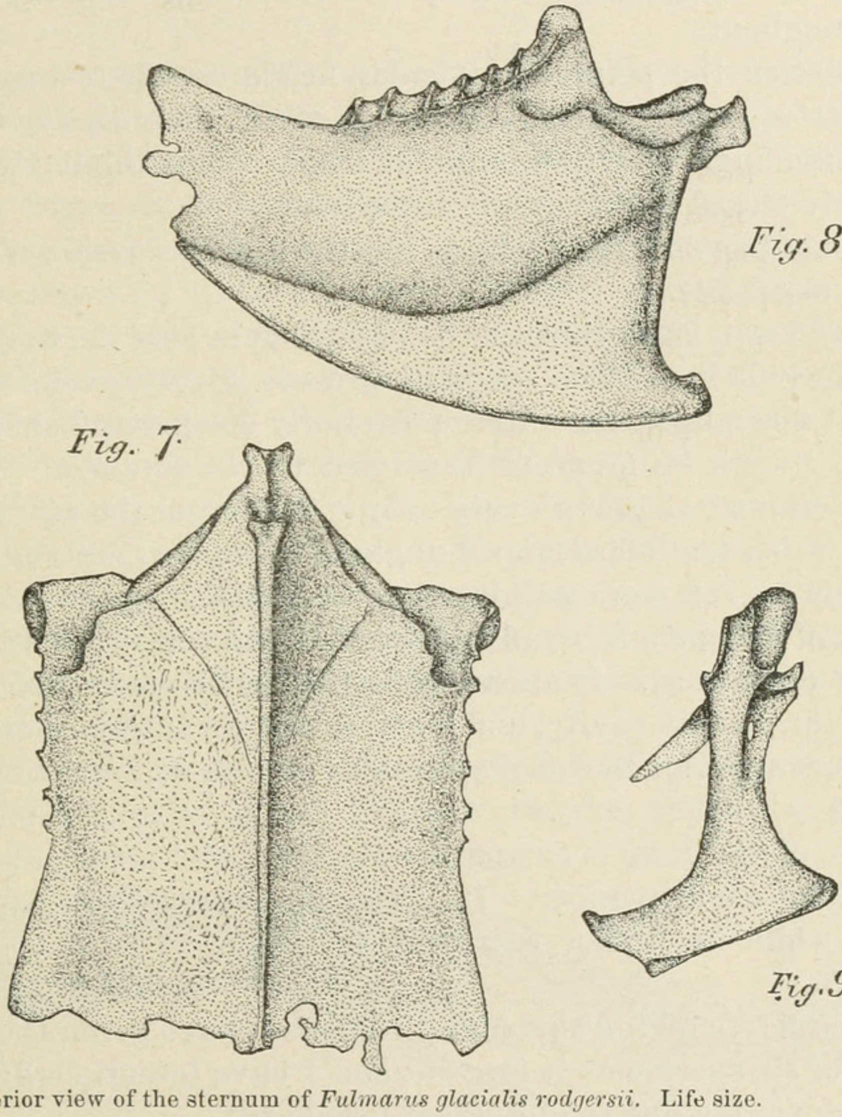

Fig. 8.

Fig. 7

Fig. 9.

FIG. 7. Inferior view of the sternum of *Fulmarus glacialis rodgersii*. Life size.

FIG. 8. The same bone; right lateral view.

FIG. 9. Direct anterior aspect of right coracoid and scapula. Same specimen. All life size. Drawn by the author from specimen 12613 of the Smithsonian collection.

may have its end truncate and thickened. Each costal border is very wide from side to side, and supports the six prominent, regularly arranged facets for the costal ribs.

There are no pneumatic foramina to be seen among them. Indeed, this is one of the differences between this bone and the sternum of an Albatross, which is thoroughly permeated by air cavities. The anterior border, between the rather lofty costal processes, is bent forward at an angle, the apex of which supports below the trihedral manubrium.

The coracoidal grooves are long and shallow, meeting mesiad at the manubrial base and having a lip of bone at their externo-inferior borders to hold each coracoid in position when articulated.

As in the sternum just described, the elements of the *pectoral arch* or shoulder-girdle are non-pneumatic, and, in consequence, proportionately heavy.

The *furcula* when articulated differs from that of the Petrel in not reaching the anterior border of the sternum. Viewed from in front we find it to be of the U-shaped style, with the limbs of nearly uniform caliber throughout.

In articulation the pointed clavicular heads merely rest against the inner aspect of each coracoidal summit, while their tips overlap the antero-median angle of either scapular head. Thus the tendinal canal is completely closed in among the three bones.

This furcula has no hypocleidium, but the arch is considerably thickened at its usual site.

A *coracoid* has a large tuberous head, which is bent forward and toward the median line. The scapular process is very extensive, being carried well down upon the antero-posteriorly compressed shaft. I believe it will always be found to be pierced by the foramen. The coracoid of this Fulmar acquires a very unique form from the extraordinary manner in which the infero lateral angle of its sternal extremity is produced. This is even more striking than we found it in the Petrel.

The head of a *scapula* is broad transversely and somewhat compressed from above downward. It offers about the usual amount of articular surface for the glenoid cavity, and when *in situ* its anterior border occupies the entire superior line of the scapular process of the corresponding coracoid.

The blade of the bone is comparatively short and gently arches over the ribs in the usual manner. Its anterior two-thirds is narrow and thickened, while its hinder extremity is slightly dilated and its tip rounded off.

These characters of the shoulder-girdle, as I have given them, agree in the five or six specimens before me, and I have intentionally omitted any slight deviation due to individual peculiarity.

Of the pelvis and caudal vertebræ.—As already mentioned above, the anterior vertebra of the pelvic sacrum extends beyond the iliac bones (Figs. 10 and 11), and its neural spine is indistinguishably anchylosed with that of the next one behind it, and so on to a point opposite the acetabulæ, where this neural crest is suppressed, and the rim that surmounts it for its entire length merges into the flattened neural arches of the next three or four vertebræ. Both at this point, and still more so behind, these sacral vertebræ are unusually well individualized, so that the skeleton of the tail seems to really begin between the cotyloid cavities. Usually, however, eleven or twelve are anchylosed in the "sacrum" and eight or nine are free and constitute the tail, in addition to the terminal pygostyle.

As a rule the anterior portion of each ilium is depressed below the neural crest of the united sacral vertebræ, having "ilio-neural" canals to their inner sides. Each anterior iliac border is truncate, thin, faintly emarginated, and sometimes unevenly serrated, while the blade of the bone is concave from before backward, as well as from side to side, and contracts slightly before reaching the cotyloid cavity.

Upon the under sides six vertebræ throw out their processes against them, and both pairs of sacral ribs may become anchylosed, though usually the anterior pair remain free, connecting with the sternum by costal ribs.

The seventh vertebra of the sacrum is the only one where the lateral apophyses are reduced. It is immediately opposite the acetabula.

From the eighth, inclusive, and on, however, the pleur- and par-apophyses regularly graduate into the form they assume in the true caudals, their processes being very nearly of an equal length and their extremities abutting against the free inner margins of the ilia.

So really, from an under view, the sacral and caudal series of vertebræ have all the appearance of a gradually modified chain of bones from the last dorsal; in short, a tail with the pelvic bones simply pressed against its sides to become anchylosed there.

The post-acetabular area of either ilium is very narrow and gradually becomes reduced to a point behind, the surfaces turning toward each other as we proceed in that direction, being bounded externally by a raised border. This latter extends between the apex of each antitrochanter to the aforesaid point behind, where the ilia terminate posteriorly on either side.

From this line and downward the sides of the pelvis are formed behind by the remainder of each ilium, an ischium and a post-pubis.

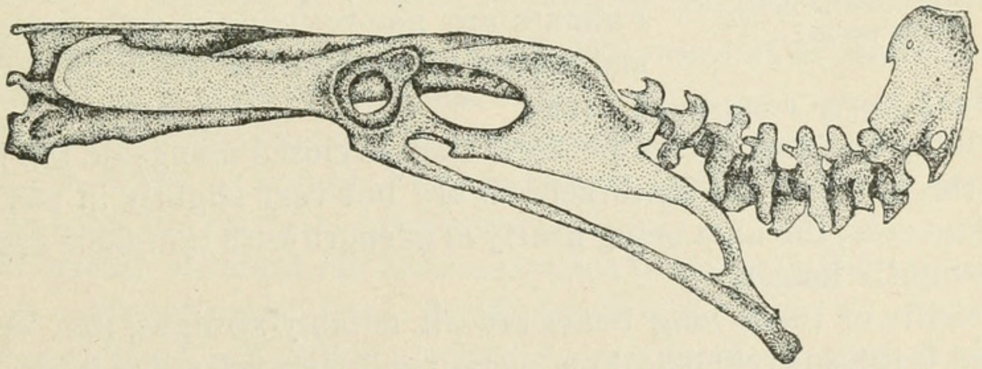

FIG. 10. Left lateral view of the pelvis and coccygeal vertebræ of *Fulmarus glacialis rodgersii*, ♂. Life size. By the author. (Specimen 12613, Smithsonian collection.)

These surfaces look almost directly outward and only slightly upward. Each presents for our inspection the large subelliptical ischiatic foramen, the cotyloid cavity, and antitrochanter; and the obturator foramen, which here has almost entirely merged into the extensive and long, oval obturator space, closed in behind, as in the Petrels, by the peculiarly formed foot-like process of the hinder end of the ischium.

Just the faintest trace of a pro-pubis is seen in the pelvis of this Fulmar, while the post-pubis is narrow, nearly straight, slightly expanded behind where its upper edge meets the aforesaid process of the ischium, beyond which it soon terminates in a square-cut end that in life is produced in a cartilage of an equal width for a short distance farther.

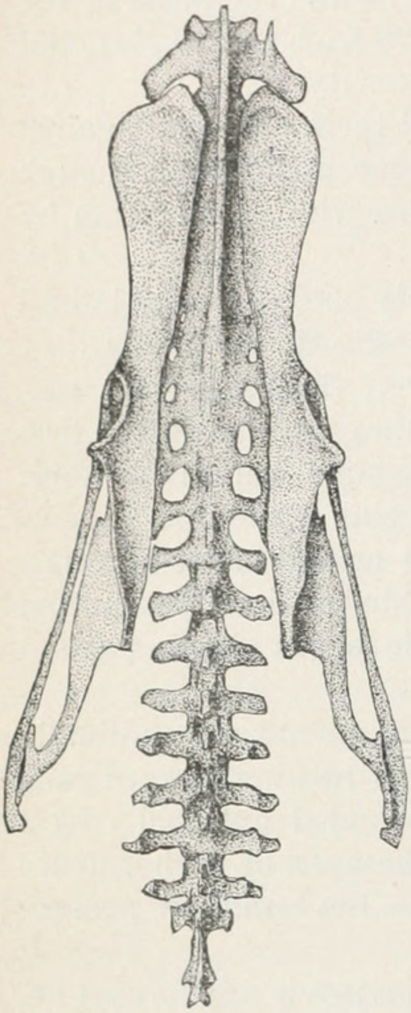

FIG. 11. The pelvis of *Fulmarus glacialis rodgersii*, seen from above. Same specimen as shown in Fig. 10. Life size. By the author.

The *caudal vertebræ* are all supplied with chevron bones, except the first two or three anterior ones. They become progressively larger from before backward, and are all bifid, being profoundly cleft in an antero-posterior direction. This is continued to the lower angle of the pygostyle, where it is represented in most specimens by a notch.

These chevron bones are anchylosed to the vertebræ over which they stand, and their bases are produced in front so as to encroach slightly upon the segment next in front of them, when the series is articulated *in situ*.

The pygostyle is a large quadrate bone, with sharpened anterior border, but thickened behind. A clean, circular foramen is generally to be found at its infero-posterior angle, indicating the point of union of the two anterior vertebræ that compose this compound bone, it being a vacuity between their chevron bones.

Of the appendicular skeleton.—We find that both the pectoral and pelvic limbs in the Fulmars are non-pneumatic, and much animal matter is contained in the large cavities of the long bones composing them.

When the skeleton of the pectoral limb is closed alongside the body *in situ* the bones of the antibrachium are but very slightly in advance of the humerus, the ulna being nearly of a length with that bone and the radius slightly longer.

The shafts of these long bones are all notably straight, that of the humerus being subcylindrical on section and showing scarcely any curvature viewed from either aspect.

The head of the *humerus* is fashioned as we found it in the Petrels, but the radial crest is more prominent and of a triangular form. Its distal extremity supports a large ectocondyloid process, between which and the opposite border, on the palmar aspect, a conspicuous concavity exists, as described for *Oceanodroma*.

Rodgers' Fulmar, as far as I can learn from the excellent material before me, is devoid of any such thing as sesamoids about the elbow-joint, and this of course applies to the common Fulmar, of which there is an excellent ligamentous skeleton at hand.

The shaft of the *ulna* shows faintly the row of osseous papillæ for the quill-butts of the secondaries. So straight is the shaft of the *radius* that scarcely any interosseous space occurs between these antibrachial bones; such as it is, however, is long and narrow, extending between the shafts for their full length.

Carpus is composed of the two usual segments, and *carpo-metacarpus* is formed much as we find it in the *Laridæ*. Pollex phalanx and the distal phalanx of the index are slender and subtrihedral and both strikingly long.

The expanded portion of the proximal joint of index digit is not perforated, as in many Gulls, and the small joint next to it is about half as long.

Excepting the great difference in size the pelvic limb of this Fulmar nearly agrees with the pelvic limb of *Oceanodroma*. We observe that the head of the femur is very much scooped out for the ligamentuum teres and that the muscular lines mark its shaft pretty well. The patella and oddly-shaped head of tibio-tarsus I have already figured elsewhere. (Proc. U. S. Nat. Mus., 1883, Vol. VI, p. 329, Fig. 5.) I know of no bird where the suppression of the ectocnemial ridge at the proximal end of the bone and the high development of the procnemial ridge is better shown.

The *fibula* is almost thread-like below its middle articulation with the greater leg-bone, and its lower extremity anchyloses with its shaft.

In the *tarso-metatarsus* the hypotarsus is doubly grooved behind, but otherwise the arrangement of the accessory metatarsal and podal digits is essentially the same as described for the Petrels.

OSTEOLOGICAL POINTS WHEREIN OCEANODROMA FURCATA AND FULMARUS GLACIALIS RODGERSII DIFFER.

1. *Oceanodroma.*—Maxillo-jugal bar bent upward at an angle to meet the descending process of lacrymal.

1. *Fulmarus.*—Maxillo-jugal bar nearly straight.

2. *Oceanodroma.*—Crotaphyte fossæ lateral, feebly impressed, not produced to meet the occipital prominence behind.

2. *Fulmarus.*—Crotaphyte fossæ extended to the posterior aspect and upon the occipital prominence; deeply impressed.

3. *Oceanodroma.*—Maxillo-palatines do not encroach upon the interpalatine space. Vomer long and narrow, hinder half concave above, correspondingly convex below and longitudinally grooved; anterior half carinated below, pointed in front and its concavity above continuous with that of the posterior half.

3. *Fulmarus.*—Maxillo-palatines do encroach upon the interpalatine space. Vomer very large, nearly flat, broad, and general outline elongo-cordate.

4. *Oceanodroma.*—Basi-pterygoid processes entirely absent.

4. *Fulmarus.*—Basi-pterygoid processes present and thoroughly developed, articulating with pterygoids.

5. *Oceanodroma.*—Anterior tip of mandibular symphysis at the intersection of the right lines forming the inferior ramal borders. Surangular entire.

5. *Fulmarus.*—Anterior tip of mandibular symphysis produced directly with its protruding process squarely cut across. Surangular pierced by a foramen.

6. *Oceanodroma.*—Twenty-first vertebra of the spinal column free. Xiphoidal extremity of sternum entire, its hinder border a transverse, straight line.

6. *Fulmarus.*—Twenty-first vertebra of the spinal column anchyloses with the pelvic sacrum. Xiphoidal end of sternum not entire, its hinder border jagged with an evident predisposition to become two-notched.

NOTES UPON SPECIMEN NO. 3618, SUPPOSED TO BE A SKULL OF PUFFINUS TENUIROSTRIS, AND OTHER MATERIAL.

It will be impossible for me to state positively as to what manner of bird the skull No. 3618 of the tabulated list of material belonged, but there is some reason to believe it to be that of a Shearwater. It is evidently a specimen that has been picked up on the beach, and was collected by Professor Dall at Oonalaska. Its basal points have been much broken and all the small free bones lost. As I have already said, my measurements of the specimen lead me to think that it is the skull of *P. tenuirostris* and from an adult bird.

The superior mandible is upon the same type as *Fulmarus*, though much modified. The supraorbital glandular depressions meet for a short distance in the median line.

The base of the orbit and surrounding parts are much as we find them in the Petrels and Fulmars, but the optic foramen and the foramen in the interorbital septum have run into one. *Basi-pterygoidal facets are present at the base of the rostrum.*

The crotaphyte fossæ are broad and deep, and meet the sides of the supraoccipital prominence, to be produced to some extent from either side upon its dome.

The foramen magnum is unusually large.

In *Puffinus major* the pectoral arch and sternum has the general form of the like parts in *Fulmarus rodgersii*, but differs from them in having the furcula meet the carina of the sternum when articulated in life; in having the sternum a pneumatic bone, as in the Albatrosses; in the sternal body being comparatively longer; and in having its xiphoidal border two-notched and convex forward.

OBSERVATIONS UPON THE OSTEOLOGY OF DIOMEDEA ALBATRUS.

Although made largely upon the characters presented by the osseous parts of the roof of their mouths, Huxley's remark, in his Classification of Birds, that the *Procellariidæ* were aberrant forms and inclined to

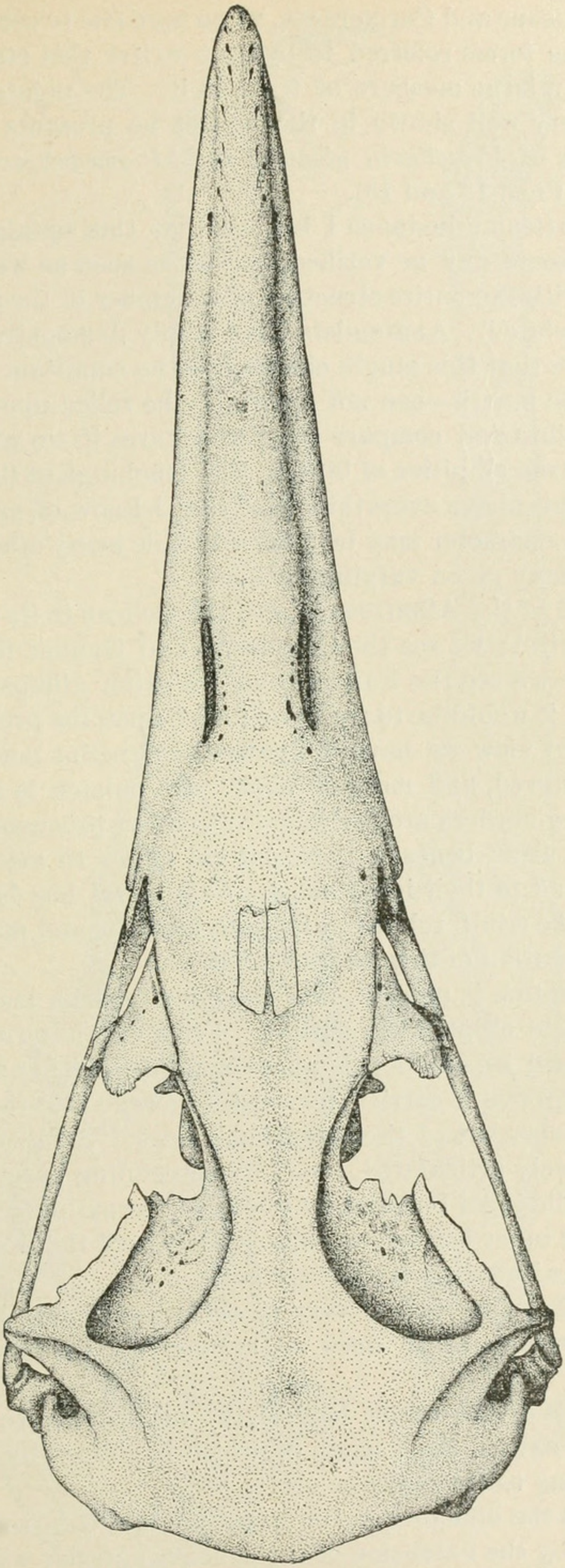

FIG. 12. Skull of *Diomedea albatrus*, viewed from above, with mandible removed. Drawn by the author from an Alaskan specimen presented him by Dr. T. H. Bean. Slightly reduced.

ward the Pelicans and Cormorants, when we come to compare the skulls of the various forms referred to by that writer this statement will be seen to have a large measure of truth in it. The points he calls attention to are very well shown in the figures he presents us in his well-known paper of *Procellaria gigantea* and *Diomedea exulans* (P. Z. S., 1867, p. 431, Figs. 12 and 13).

In this particular instance I believe that this opinion of Professor Huxley will some day be verified, or just so soon as we become better acquainted with the entire structure of a number of the forms now supposed to be related. Anatomists have amply demonstrated during the past few years that this single character—the condition of the bones at the roof of the mouth—can not invariably be relied upon, and we must always look into and compare other structures if we wish to correctly judge of the true affinities of birds. The teachings of the law of evolution call for this above everything else that I know of, as we there learn how one such character may be retained while many others in the same organization may go on varying for ages.

In the skull of the Albatross we see the Pelican in its posterior view; we see the Petrel; we see the Cormorant and Gannet foreshadowed in its palatines; we see the Fulmar, and we catch glimpses of the Gull; yet how hard it would be to put your finger upon the predominant type.

Upon lateral view we have the powerful superior mandible, with its terminal, decurved, and massive hook. Its culmen is roundly convex and its dentary borders are cultrate, the dentary processes behind being thrown down from beneath these lateral edges to meet the palatines below them and to their inner sides. Each nasal has been thoroughly absorbed in the adult, robbed of its individuality, and made to fulfill its part in the creation of this form of skull.

No nasal septum is present, and the bony nostrils are comparatively small and quite elliptical in outline. From the anterior arc of each, upon the lateral aspect of this upper mandible, either side, a shallow, longitudinal groove is carried forward, to merge into the dentary edge at the commencement of the mandibular hook. A *lacrymal* is a highly pneumatic, freely articulated, bone, its descending process meeting the straight maxillo-jugal bar, and its postero-external process above being rounded. Its inner border articulates with both the frontal and nasal, here indistinguishably merged together.

An ethmoidal wing is not very powerfully developed and does not meet the lacrymal, as it does so extensively in the Fulmars and Petrels.

All the walls of the upper half of the orbit conspire to render it a hemiglobular cavity, the bottom of which is pierced by a considerable foramen leading to the opposite orbit.

The tract of the olfactory nerve is nearly, quite in some specimens, bridged over by the extension of the concave anterior wall of the brain-case. The optic foramen is small, circular, and usually distinct.

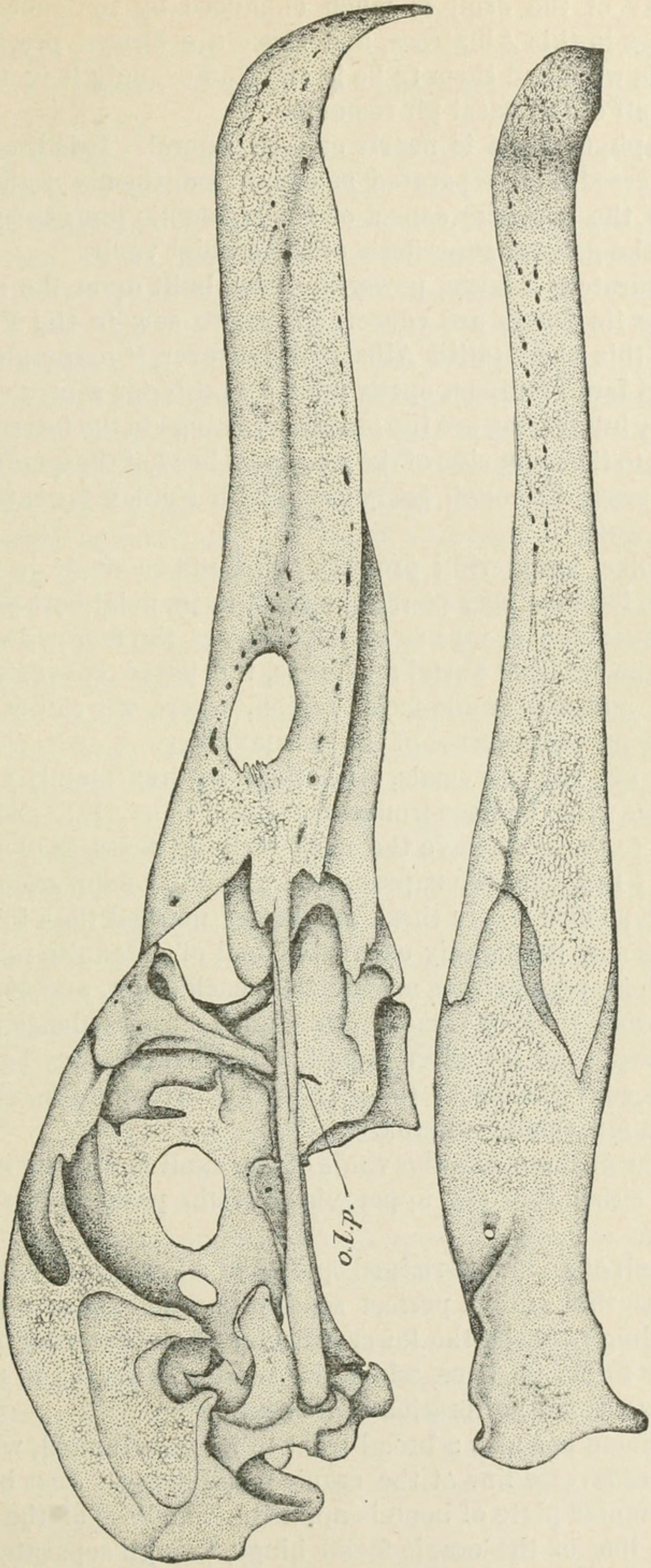

FIG. 13. Right lateral view of the skull of *Diomedea albatrus*. Drawn by the author from the same specimen shown in Fig. 12. Amount of reduction the same. The letters *o. l. p.* show the position of the "*ossiculum lacrymo-palatinum*" *in situ* from this aspect.

Profundity of the orbit is much enhanced by the enormous post-frontal wings in this Albatross, and these are formed precisely in the same way as we found them to be in the Puffins, only here the base of the latter half of the nasal pit remains.

The crotaphyte fossa is nearly entirely lateral. It is broad, though feebly impressed, and separated as usual from the nasal glandular depression on the posterior aspect of the sphenotic process by a narrow isthmus of the general superficies of the cranial vault.

Each quadrate is a large, powerful bone, built upon the same plan, in so far as its facets are concerned, as we saw in the Fulmar and Petrel. In this Short-tailed Albatross, however, it is completely pneumatic, and a large foramen opens upon its posterior aspect.

Extremely interesting are the osseous openings to the internal ear, and the deep pit to the inner side of the mastoidal head of the quadrate, which would well repay thorough comparison with similar formations in the skull of the *Sula*.

A triangular, bony wing protects the foramen ovale in front, and a pneumatic foramen may pierce the skull in its neighborhood.

Viewed from above, we are enabled to see the furrows leading forward from the external narial apertures, the broad convexity between these latter and the cranio-facial region, where we can still see the traces of the nasal processes of the premaxillary.

Laterally are the lacrymals, with their sutures plainly visible connecting them with the naso-frontal margins.

Posterior to these we have the most striking features of this aspect of the skull; these are the supraorbital glandular depressions.

I know of no bird where these are better marked than in this Albatross, they being profoundly excavated and of a definite reniform outline. Their convex surfaces are opposite each other, and separated by a fronto-median tract of some width. Each base is deficient in bone for a little less than its anterior half, while behind they bear the impress of the convolutions of the glands they lodge in life, and are perforated by a few small foramina.

To the rear of these pits the vault of the skull is broadly convex and presents at either side the upper views of the post-frontals and crotaphyte fossæ.

In the skull of an undetermined species of Albatross (No. 16738 of the List) I notice that quite a perfect septum narium exists; a platform of bone extending between the lower margins of the external openings of the nostrils forms its base, while the septum is reared in the median line and has a small perforation in its center.

This specimen has also a broad front to its mesethmoid, which terminates in a transverse line at the cranio-facial hinge. Just beyond this a thin, triangular plate of bone is applied. The base of the triangle is also in the line of the cranio-facial hinge, though separated from the mesethmoid. Anteriorly its apex is produced to merge into the septum narium in the median plane. This arrangement is exactly what we found in some of the Auks, though, of course, modeled to accommodate itself to the differently proportioned parts, and the nasal septum is also absent in the latter.

The cranio-facial hinge, then, in the Albatross is a very free one, though not so much so as we find it in *Sula*.

A direct basal view (Fig. 14) of the skull of *Diomedea albatrus* presents us from before backward the following points for examination: (1) The anterior half of the superior mandible is canoe-shaped, the prominent hook taking the place of the prow. (2) The largely developed palatines are considerably below the maxillo-jugal bars; anteriorly they are carried forward as prominent and parallel ridges within the dentary borders of the premaxillary to subside on the inner sides of the canoe-shaped portion beyond. (3) The postero-external angles of the palatines are rounded, the "external laminæ" being sharp, while the "internal laminæ" are thickened and rather conspicuous carinations. (4) Between these latter an oval interspace occurs, which is carried forward as a deep median cleft as far as, or rather farther than, the point where the anterior ridges of the palatines described above subside upon the sides of the premaxillary. (5) At about the middle point in this cleft a small oval plate of bone makes its appearance; this is the foot of the anterior end of the large decurved vomer of this Albatross. (6) A short distance posterior to this appear two slit-like marks, one on either side, their free ends being behind and close to the palatine bones; these are the inferior arcs of the maxillo-palatines. (7) The pterygoids are strong, straight bones, their lower aspects being rounded, their upper ones longitudinally sharp-crested; their heads and the palatine heads all meet to form upon their upper side a deep groove for the rostrum. (8) A considerable portion of this latter may be seen between this articulation and the basi-temporal region in the median line. (9) The Eustachian tubes are open, naked grooves. (10) The basi-temporal triangular area is quite as much contracted as we find it in *Sula* or *Pelecanus*. (11) The condyle is rather elevated and transversely elliptical. (12) The foramen magnum is large, broadly elliptical, with its major axis, like *Pelecanus* and *Sula*, in the median line. It is at the base of a notable convexity which occupies all the area posterior to the basi-temporal region and extending from side to side between the mastoidal prominence.

The periphery of the foramen magnum lies in a plane which makes an angle of 45 degrees with the plane of the basis cranii.

In addition to these principal characters, we must also notice that the inner facets on the mandibular feet of the quadrates are the lower, and are about in the same plane with the lower margins of the internal laminæ of the palatines.

Returning for the moment to these latter bones, we find that their "ascending processes" are lofty and handsomely curled about the an-

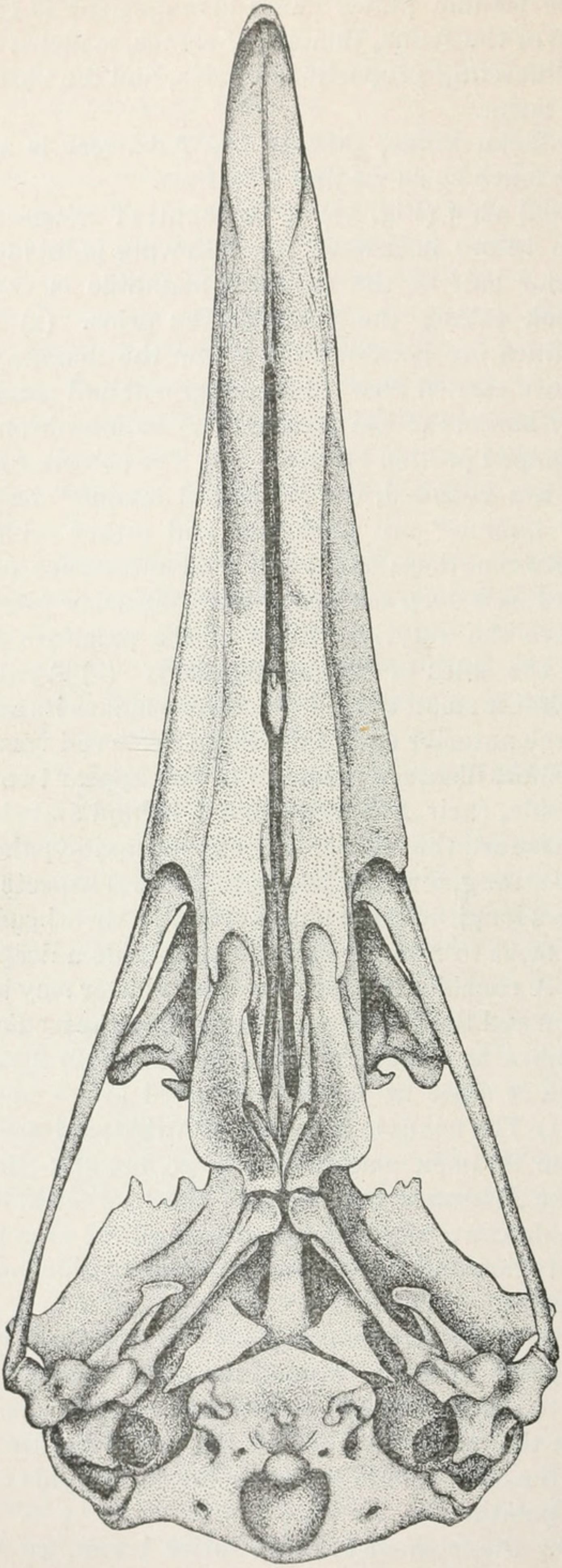

FIG. 14. Basal view of the skull of *Diomedea albatrus;* mandible removed. By the author from the same specimen as shown in Figs. 12 and 13; reduction the same.

terior portion of the united mesethmoid and rostrum. Their inner laminæ are produced forward to anchylose with the limbs of the *vomer*.

This latter bone is quite an extraordinary structure in an Albatross, and differs not a little in the various species. To get at its exact shape and relations to the surrounding structures I found that I was obliged to cut away certain portions of a spare skull and remove it, together with the pterygoids and mutilated parts of the palatines. From this specimen I made the drawings presented in Figs. 16 and 17.

Viewing this from above, we find that all three bones contribute certain of their parts to form a deeply excavated, longitudinal groove that extends the entire length of the structure. During life the spear-shaped rostrum rides in this, occupying, however, but the hinder two-thirds of the channel. Seen from the side, we find that the vomerine portion of this rostral bed is continued downward and forward as a median carination, which anteriorly curves down between the maxillo-palatines, to have its apex finished off in a little foot-like process which appears, as above described, in the interpalatine cleft.

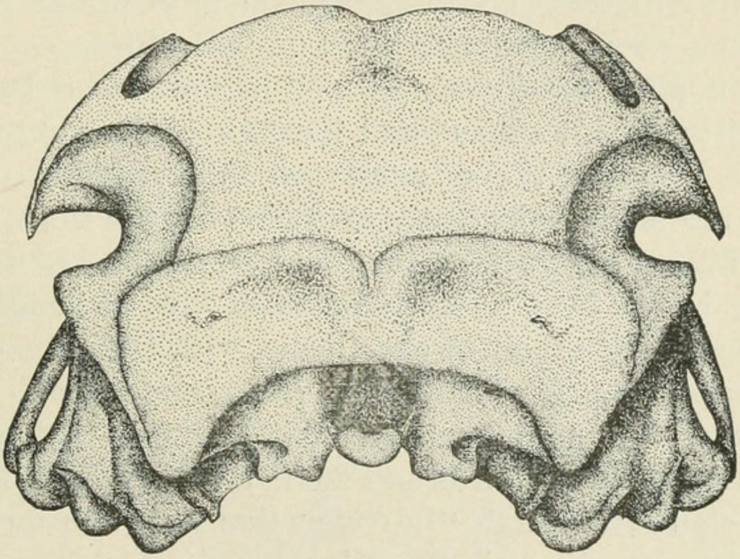

FIG. 15. Posterior view of the skull of *Diomedea brachyura;* mandible removed; life size. By the author from same specimen as Figs. 12 *et seq.*

In the undiagnosed skull of an Albatross (No. 16738) the pterygoids and palatines behave in the same way as in the Short-tailed variety, but the vomer shows no mid-channel beyond the end of the sphenoidal rostrum, is fully double the width of the other, and rather reminds us of the extraordinary vomer of Rodgers' Fulmar. Anteriorly, however, its tip is carried down to appear in the inter-palatine cleft, as in *D. albatrus.* Forbes figures a vomer similar to this for *D. exulans* in his *Challenger* memoir.

The *maxillo-palatines* are large, compact, elliptical plates. They stand but a few degrees removed from the vertical plane, each facing outward and slightly downward. Upon a lateral view the mandibular side nearly shuts this bone out of sight, and it is only in certain positions that we can secure a good look at it. The surface next the median plane is smooth and but slightly convex, while the outer aspect has a rather spongy interlacement of bony trabeculæ thrown up against it, developed on the part of the maxillary, premaxillary, and nasal, which most effectively act as its main supports.

In two of my specimens I find a small, delicate rod of bone attached by ligament to the upper aspect of the palatine body immediately beneath the ethmoidal wing. These ligaments hold it in an upright position, and its superior and stouter end is bent toward the median plane; from this extremity, also, ligaments are attached which pass to the inferior border of the pars-plana and perhaps across to the descending process of the lacrymal. This little bone I take to be the os uncinatum of other anatomists, and said by them to occur both in the Albatrosses and Gulls. It seems to play no other part in the bird's economy other than to afford additional support to the membranous wall that forms the lower half of the partition between the orbital cavity and the rhinal chamber.

As I have elsewhere stated, I have found this bone in but few other birds than this Albatross, one of the specimens of which, *Diomedea albatrus*, has it in a very perfect condition on both sides.

It has been my misfortune, too, not to have seen Professor Reinhardt's paper upon this subject and his figures showing its position in other birds. Whether the *os uncinatum* is a constant ossification or not my material is not sufficiently extensive for me to say.

Professor Parker also states that he has discovered its presence in the Gull, but I have been unable to confirm this, although I have carefully examined many excellent specimens, with their ligaments still intact, of *Larus glaucus*, *L. philadelphia*, *Rissa*, and others. This is what makes me think that perhaps it may not be a constant ossification, or perhaps occurs only in old birds and not in immature specimens. Forbes says of this ossification that, "in connection with the descending limb of the lacrymal bone, there is often developed a peculiar ossicle, named by Brandt, who was the first to describe its existence, in *Diomedea brachyura* [*albatrus*] and *Puffinus major*, the 'ossiculum lachrymo-palatinum,' from its connection with those two bones.

"Its nature and relations in the group have subsequently been more extensively investigated by Reinhardt, who calls it the 'os crochu.'

"When best developed, as in the Albatrosses, the ossiculum lacrymo-palatinum is a small styliform ossicle of nearly cylindrical (as in *Thalassiarche culminata* [Coll. Scientif. Mem., Pl. XXI, Fig. 7]) or somewhat lamellar (*Phœbetria fuliginosa* [Coll. Scientif. Mem., Pl. XXI, Fig. 8]) shape, attached above by an articulation to the inner face of the descending limb of the lachrymal bone, and below connected by a ligament to the upper surface of the palatine bone. Seen from the side, in the dried skull [his Pl. XXII, Fig. 1], the bone is visible below the malar arch. It lies, in the recent state, in a cavity between the nose and the roof of the mouth, in an oblique position, pointing downward and inward. This bone is present in all the genera and species of Albatrosses examined by me, as well as in *Thalassiarche chlororhyncha*, as mentioned by Reinhardt. In the *Oceanitidæ*, in *Procellaria*, and *Cymochorea*, as well as *Daption* and *Pagodroma*, its place is taken by a narrow ligament, with a small, more or less ossified nodule of bone lying in it, only connected by connective tissue with the surrounding bones. In *Acipetes*, *Prion*, *Puffinus*, *Majaqueus*, *Adamastor*, and *Œstrelata* it is small and delicate, articulating with the lacrymal above and ending freely (in the cleaned skull) below.

"It is interesting to observe that a very similar bone, both as regards shape and position, occurs in the genus *Fregata*, as already pointed out by Reinhardt, whose observation I have been able to verify. But it also occurs in forms so different from these, as the *Musophagidæ*, many *Cuculidæ*, *Chunga*, and *Cariama*, as well as in some *Laridæ* and *Alcidæ*, so that its presence is obviously of no particular taxonomic value. Professor Parker informs me that its precise morphological significance is at present rather uncertain." (Coll. Scientif. Mem., p. 415.)

So prominent and jutting are the bony chambers which contain the organ of hearing upon the internal lateral aspects of the cranial cavity that the oval fossa, which harbors the hind brain in life, is far deeper than we would have any reason to suspect from an inspection of the posterior external view of the skull alone. This applies almost with equal truth to the fossæ lodging the other lobes.

The usual arterial and nervous foramina open here in nearly the same positions as we find them in birds generally.

Fig. 16.

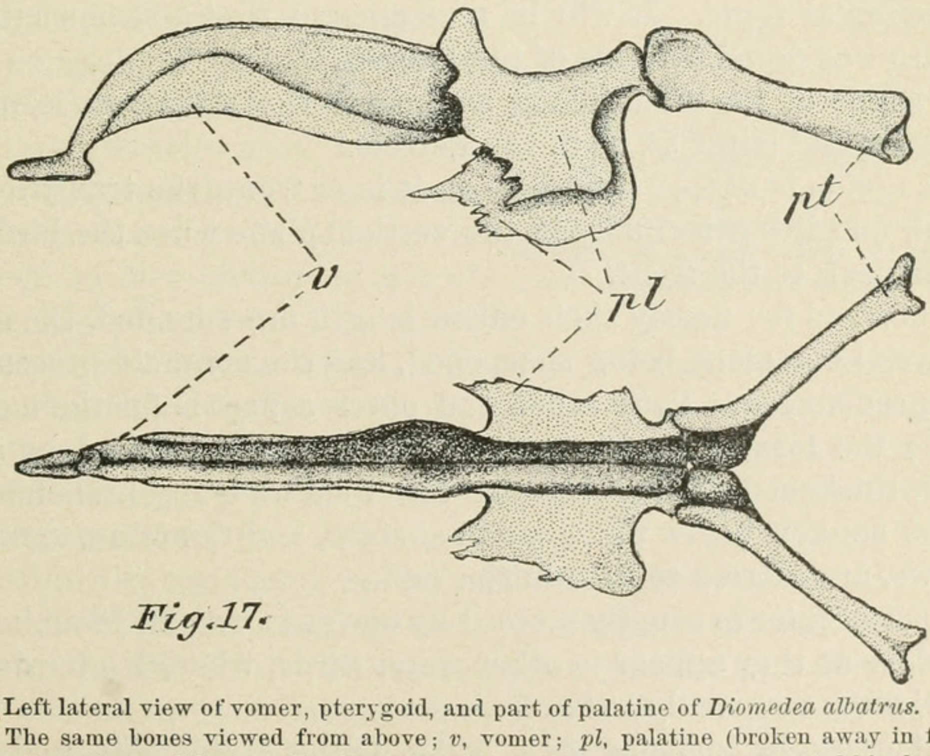

Fig. 17.

FIG. 16. Left lateral view of vomer, pterygoid, and part of palatine of *Diomedea albatrus*.

FIG. 17. The same bones viewed from above; *v*, vomer; *pl*, palatine (broken away in front); *pt*, pterygoid. Both figures life size. By the author, from another specimen presented him by Dr. T. H. Bean. The little foot on the anterior end of the vomer makes its appearance in the median cleft just beyond the maxillo-palatines, as seen in Fig. 14.

The pituitary fossa is deep and its posterior wall entire. There seems to be two carotid openings at its base, but they are very close together, and I would not be surprised to find them united in one in some specimens. The floor of this cranial cavity is a circular convexity, bounded on the sides by the bony wall of the middle ear, in front by the broad posterior wall of the pituitary fossa, while behind, after a low descent, it opens out upon the flat upper surface of the occipital condyle. In front of the pituitary pit we find a considerable of a partition separating the two distinct and circular optic foramina, each opening into an orbital cavity. Above these there is a nearly horizontal shelf, which supports the rhinencephalon, and at its anterior apex the hinder edge of the median ethmoid is visible, which guides each olfactory into its covered passage beyond. Considerable diplöic tissue is found between the tables of the vault of the cranium in this Albatross, and the skull as a whole seems to be pretty well permeated by air.

The sclerotals of an eyeball are comparatively small plates, with irregularly serrated margins. They differ somewhat in their general outline, and there seems to be no fixed plan as to the method in which they shall overlap each other.

The symphysial extremity of the *mandible* (Fig. 19) is formed very much as it is in the Petrel, and evidently constructed upon the same plan. Its symphysis proper is exceedingly short and the superior excavation deep.

Old Albatrosses have a median process co-ossified upon the under side of this with the bone. It is ensheathed in the horny integument of the bill, receiving a separate piece to cover it in that situation. The process itself is sometimes long and sharp, directed backward in the anterior ramal angle. It will be remembered that a somewhat similar structure was found in some of the Herons.

The shape of the mandible as a whole in this Albatross is precisely like the capital letter V, as in the Petrels.

Each ramus is deeper behind than it is in front, the transition being gradual, and lies principally in the vertical plane when the bird stands with his beak to the front.

The borders for nearly their entire length are rounded, the superior symphysial one alone being sharpened, and the coronoid process is but feebly pronounced. Both inner and outer aspect is for the most part smooth; the former for its anterior two-thirds is marked by a longitudinal, thickened ridge, while the latter shows many branching ramifications sunken below the general surface, and foramina, arranged in two rows, are carried to its anterior end.

The surangular is usually pierced by one or two small foramina in the same place as they appear in other water birds, where I have described them, though commonly only one is seen.

Albatrosses, in common with Auks, Gulls, Guillemots, and others, have a fan-shaped process developed by the surangular, which remains more or less distinct throughout life. It is seen reaching forward on the inner aspect of the bone, and seems to be principally designed to hold the splenial element in place, which latter in *Diomedea* may or may not completely occlude the true ramal vacuity. Quite a fossa is sometimes found posterior to the blade of this fan-shaped process in birds where its handle is more or less individualized.

These mandibular elements, for flat bones, interlock and cross each other in the most remarkable way in the neighborhood of this foramen, and their study in all birds is a very interesting one.

The articular cups are very deep at their centers above, culminating in pneumatic pits; the usual circular foramen is also found near the end of the stumpy inner process of this part.

The facets and their arrangement are well shown in Fig. 18 and should be compared with others presented, as *Sula*, *Pelecanus*, and the Gulls.

Posteriorly the hind end of either mandibular limb presents a vertical face, and the angle is drawn down below in a somewhat tuberous, trihedral process.

Only about the proximal third of either ramus seems to be pneumatic; the rest of the bone is dense and solid.

Of the hyoid arches.—It will be seen from Fig. 20 that these do not very thoroughly develop in an Albatross. The glossohyal and ceratohyals never develop in bone, but are represented in cartilage even in very old birds (*D. albatrus*), and always remain so.

A strong antero-median process is developed on the inferior aspect of the first basibranchial, which offers upon its anterior face the articular facet for the cartilaginous glossohyal.

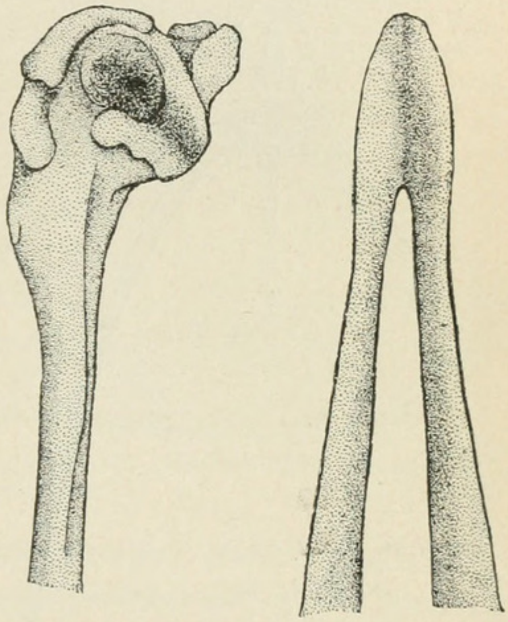

Fig. 18. *Fig. 19.*

FIG. 18. Articular extremity of right ramus of mandible of *Diomedea albatrus*; viewed from above.

FIG. 19. Anterior portion of mandible, from above; same specimen. Both life size. By the author, from the same specimen shown in Fig. 13.

The body of this basibranchial is subcircular in outline, thick through and through, and co-ossifies with the median spine-like second basibranchial behind. This latter, like the epibranchial, is finished off by a cartilaginous tip.

Articular pits are found, one on either side of the first basibranchial for the heads of the long, slender, rod-like ceratobranchials. These articulate directly with the short epibranchials, and these are but slightly curved upward behind, as we find them in so many other birds.

Of the sternum and pectoral arch.—It would be impossible to convey any idea, by means of a drawing alone, of the extreme lightness of this bone in an Albatross. Indeed, from the figures (21 and 22) I think one would be rather led to believe that this sternum was a thick and heavy one, so massive and ponderous appear all its anterior parts. But not only these, but all its walls, wherever they will admit of it, are absolutely honey-combed with pneumatic cavities. All that bulging promontory in front of the bone is in exactly the same condition.

The foramina leading to these cavities from without are very numerous, and occur in groups in several localities. Chief among these is a long, irregular, scattered row of them adown the entire median furrow of the visceral aspect of the sternal body. Collections of others are found up on the sides of the body on the same surface; some of these latter may even perforate the bone.

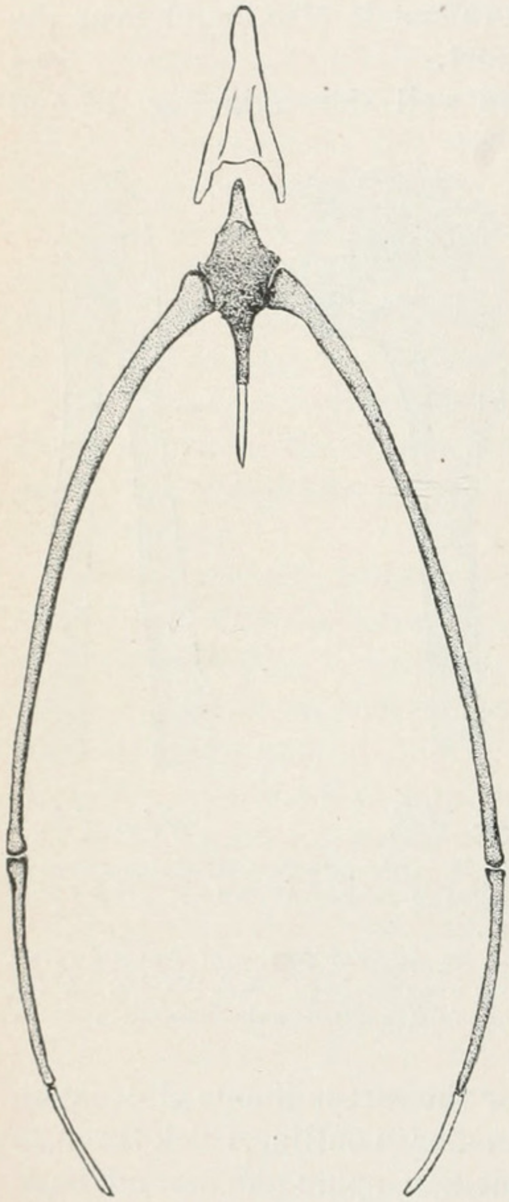

FIG. 20. Hyoid arches of *Diomedea albatrus;* viewed from above; life size. From the same specimen as Fig. 13.

The principal entrances to the sides, however, are through the collections of apertures found at the bases of the inter-articular fossæ upon the costal borders. Sometimes these are so large that we may obtain a view of the inside and plainly see the osseous trabeculæ thrown across in various directions to support the pectoral and visceral sternal walls.

Viewing this sternum from in front, we notice a deep and broad median notch, which is concave from side to side, and whose lateral walls on their outer aspects are devoted to the upper portions of the articular facets for the coracoids. This notch is shut out of sight from either a direct lateral view or a view from above. Lower down and at the sides we find the remainders of the coracoidal facets. These nearly meet behind the small manubrium; then slope downward and outward. They are concave in the vertical direction, but nearly straight the other way, and they connect with the others spoken of above at the upper sides of their inner ends.

Another facet is devoted to the coracoid upon the sternum of *Diomedea.* This is far removed from the first one, being concealed behind a lip of bone at the outer aspect and at the base of either costal process. This articular notch retains the end of the outer angle of the sternal end of the coracoid in place when the arch is articulated as in life.

These shielding lips of bone are well seen upon the pectoral view of the sternum shown in Fig. 20.

A lateral view (Fig. 21) shows the spreading costal process; the wide costal border below it, with the foramina between the hæmapophysial facets; the smooth and convex sternal body, and the thick and fairly well-developed carina.

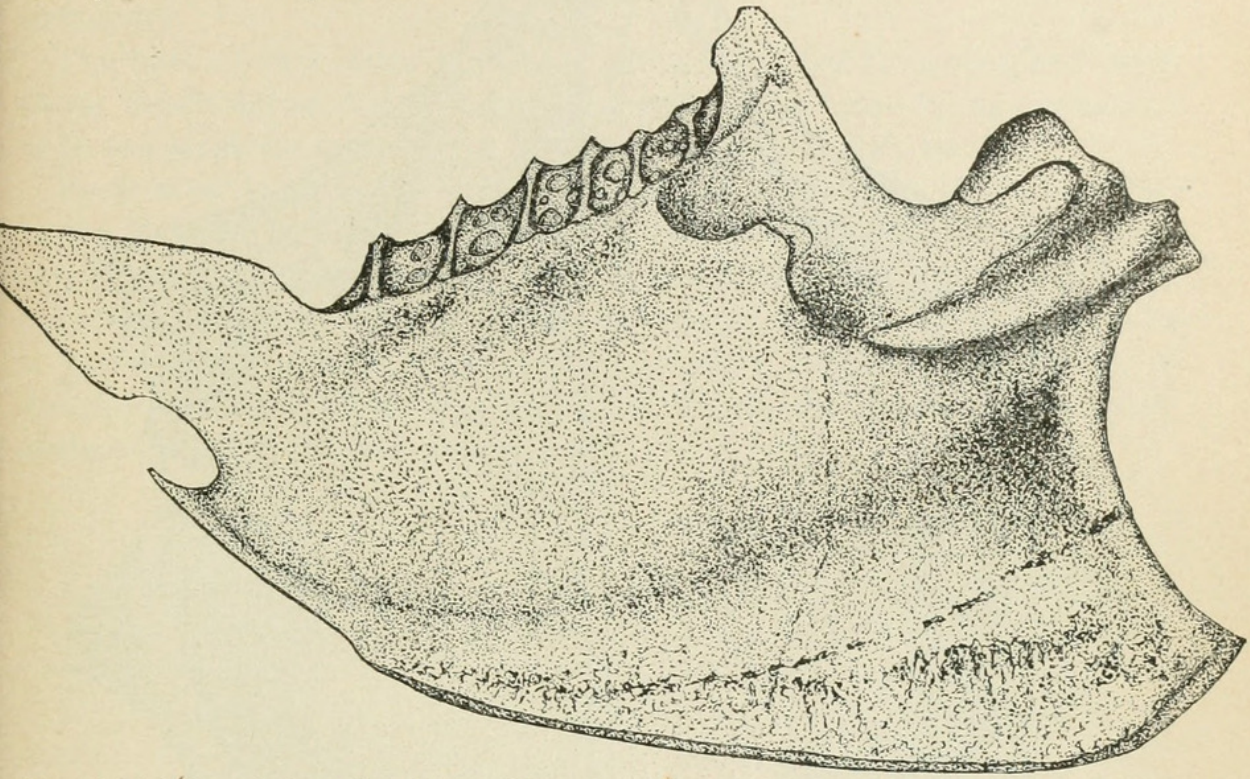

FIG. 21. Right lateral view of sternum of *Diomedea albatrus*; life size. By the author, from specimen 3333 of the Smithsonian collection.

The anterior border of this latter is concave forward, while its inferior one is nearly straight and stops short of the xiphoidal end of the body. The carinal angle juts out quite prominently and is thick through and through, the inferior border being produced and expanded upon it.

Regarding it from a pectoral aspect, we find the general outline of the bone to be nearly square, with its hinder margin exhibiting one deep notch, with the convex side forward and the postero-lateral angles rounded. Analyzing this, however, we see that each postero-lateral portion is made up of one large subcordate process, due to the great median notch above alluded to, and shallow concave notches, which occur, one on either side, just behind the costal borders, and a median xiphoidal pair, one on either side of the produced middle part of the bone.

This sternum of the Albatross differs principally from the sternum in Rodgers' Fulmar in its being pneumatic, its method of articulation with the coracoids, and the form assumed by its xiphoidal border. *Puffinus* differs from both of them in having its xiphoidal border distinctly and profoundly two-notched, agreeing in this respect with most of the Jaegers and Gulls.

The *shoulder-girdle* (Fig. 23), due to the spreading furcula, is very wide from side to side, and, due to the short coracoids, is rather squatty in appearance. The furcula is one of the broadest among living birds,

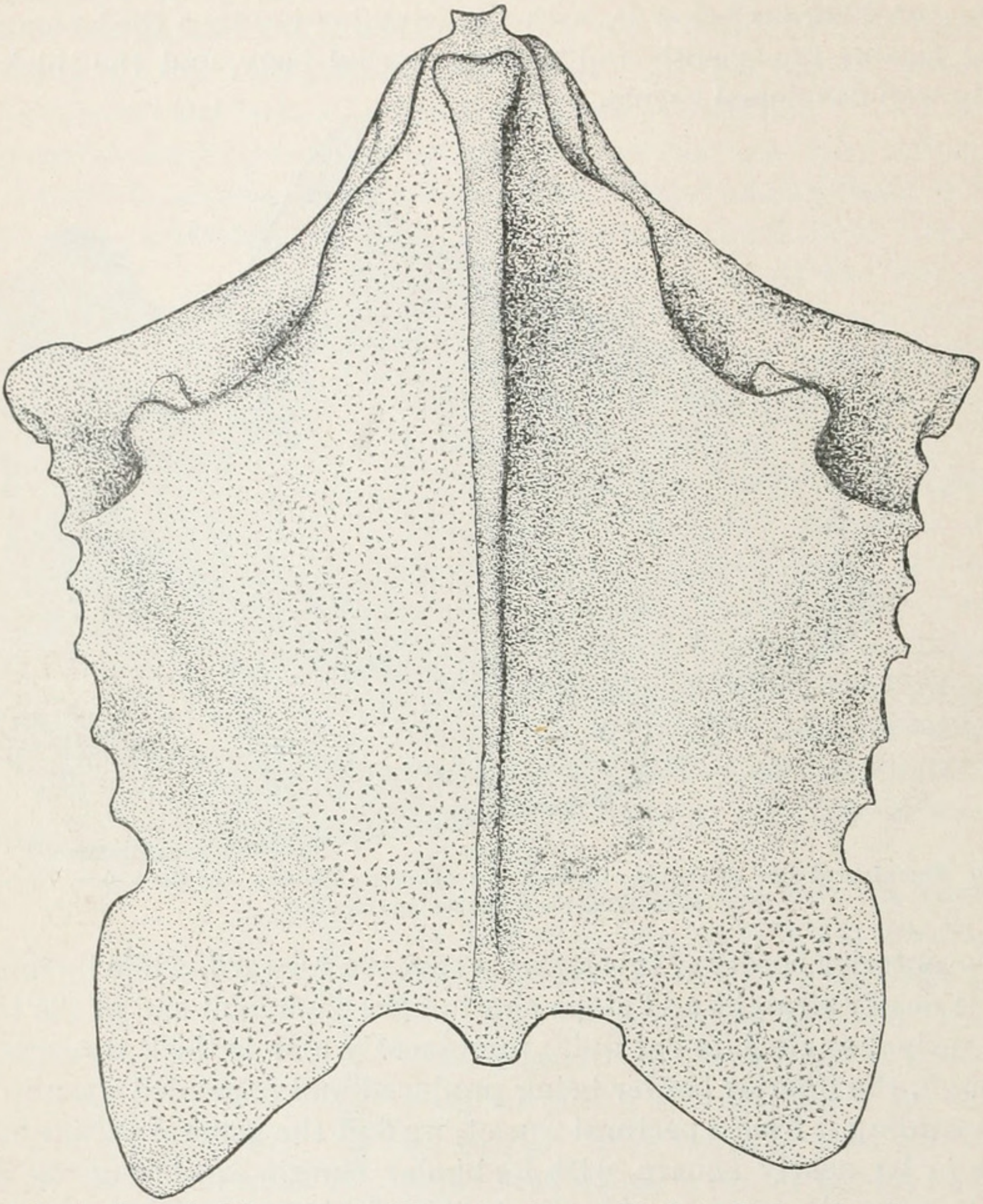

FIG. 22. Pectoral aspect of the sternum of *Diomedea albatrus;* life size. By the author, from specimen 3333, Smithsonian collection.

the shallowness of its U almost equaling that of the extinct *Hesperornis.* Each clavicular limb is, compared with the other elements of the arch, slender, and of nearly uniform caliber throughout. The heads gradually taper out to a point posteriorly, and articulate with the coracoids and scapulæ as they do in Rodgers' Fulmar, described above.

The middle of this arch below is thickened, being concave in front and somewhat produced behind, but bearing no proper hypocleidium, the modifications being apparently intended to give a greater surface for ligamentous attachment to the carinal angle of the sternum.

In some specimens, when the girdle is articulated *in situ,* this part of the furcula may rest against the apex of the angle of the carina, being thoroughly strapped to it during life by ligamentous bands.

It will be remembered, that anchylosis takes place at this point in old Cormorants, and direct and extensive articulation in *Sula*, and, if my memory serves me right, something of the kind takes place in *Pelecanus* and *Tachypetes*.

The *coracoid*, though short, is extremely stout and massive in structure. The antero-posteriorly compressed shaft amounts to little more than a constriction between the head and wonderfully expanded sternal extremity.

The base of this latter possesses articular facets to correspond with those described on the sternum; the outer small one being connected with the large inner one by a gently concave and thin border.

Each externo-lateral angle of the base of a coracoid is produced as in the Fulmars and Petrels; it is here, however, a broad, quadrate process, instead of being carried out to a point, as in the latter birds. A coracoidal head is much flattened at its summit and smooth, while as a whole this tuberous extremity is directed forward and inward to develop a shallow facet upon its mesial aspect for the furcula to articulate with, as described above.

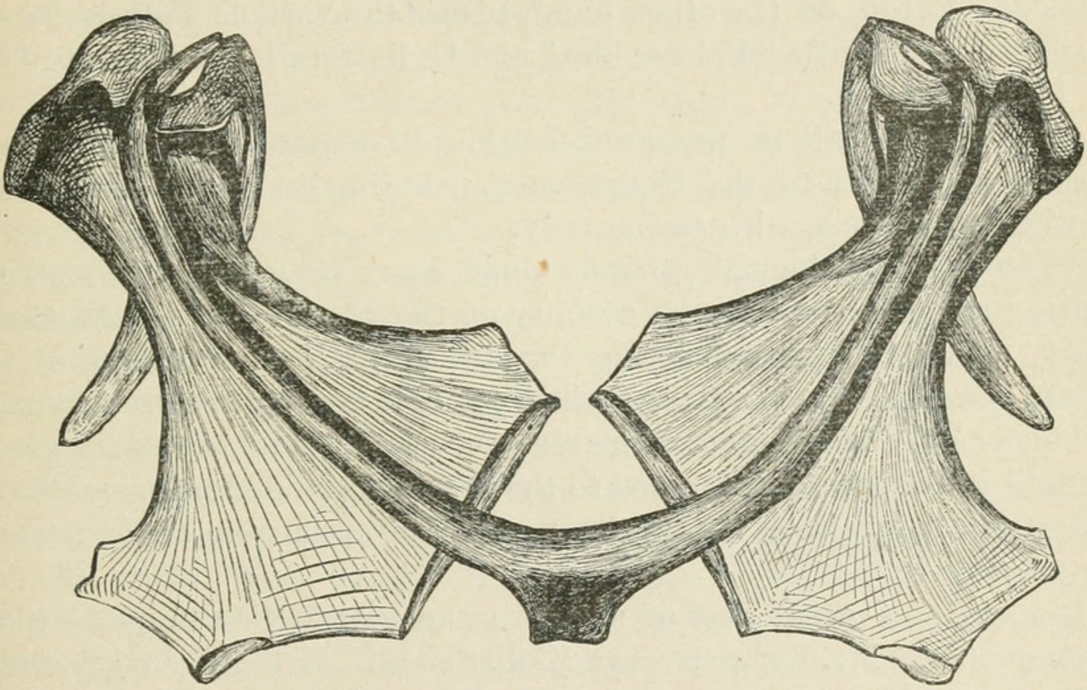

FIG. 23. The shoulder-girdle of *Diomedea albatrus;* anterior view; life size. By the author, from specimen 3333, Smithsonian collection. Collected by E. Herendeen at Cook's Inlet, Alaska.

Its scapular process is situate rather high upon the shaft, being concave from side to side in front, and rather flattened behind. Usually it is pierced by the foramen found in so many other of the water birds, and here quite close to the coracoidal shaft.

The glenoid cavity is comparatively small, so far as it is formed in bone, and no doubt in life its proper size is attained through the assistance of other structures. Coracoid and scapula offer each about the same proportional amount of surface to it as commonly seen among birds. A *scapula* is not much decurved along its blade, and this part of the bone is thickened, being nearly of an equal width throughout its length, though somewhat dilated at its hinder extremity, terminating in a rounded apex. Its head articulates with the entire width of the scapular process of the coracoid on the transverse facet which occupies its superior margin.

The mesial angle of this head is tilted up to meet the posterior apex of the clavicle, when *in situ*, as naturally articulated. The furcula and scapulæ of this shoulder-girdle are both non-pneumatic, but the coracoids have air admitted to their internal cavities through a few foramina, which are situated on their posterior aspects in the broad concavity which is formed at each sternal extremity.

This condition of the coracoids in the Albatrosses disagrees with what we found in the Fulmars, these bones in *F. rodgersii* being completely non-pneumatic.

So far as the Tubinares are concerned, this completes the description of all the material I have at present at my command. Mr Forbes says that L'Herminier, A. Milne-Edwards, and Huxley have all, in describing various points in the osteology of the Tubinares, pointed out similarities of various kinds between their osseous structure and that of various forms of Steganopodes, though they still kept them close to the Laridæ. Eyton, on the other hand, places the various Petrels he describes in the family "Pelecanidæ," and Gulls forming a separate family by themselves.

"But no one will be prepared, I think, to dispute that the Steganopodes are allied to the Herodiones, including under that name the Storks and Herons, with *Scopus* only.

"Thus, on osteological grounds alone, there is sufficient ground for placing the Tubinares in the vicinity of the Steganopodes and Herodines. And, in fact, neglecting the desmognathous structure of the palate—the taxonomic value of which *per se* is becoming more and more dubious as our knowledge of the structure of birds increases—there is little in the characters assigned to the groups Pelargomorphæ and Dysporomorphæ by Professor Huxley that is not applicable to the general Petrel type."

It gives me a great deal of pleasure and satisfaction to quote these passages from Mr. Forbes's work (Coll. Scientif. Mem., p. 434), because of all the various schemes of classification and relationships proposed for the Tubinares that I have read none so well meet my own views in the premises as these.

OBSERVATIONS UPON SEVERAL OF THE AMERICAN REPRESENTATIVES OF THE ORDER STEGANOPODES.

This group is represented in the fauna of this country by six very well-distinguished families, viz:

1. The Phaëthontidæ,	The Tropic Birds.
2. The Sulidæ,	The Gannets.
3. The Anhingidæ,	The Darters.
4. The Phalacrocoracidæ,	The Cormorants.
5. The Pelecanidæ,	The Pelicans.
6. The Fregatidæ,	The Man-o'-War Birds.

At different times anatomists have devoted considerable attention to the structure of these birds, and every year, I think, we are becoming more unanimous upon the affinities they hold with other groups. On the present occasion I can contribute but little to this subject, although a good skeleton of *Sula bassana*—No. 16643 of the Smithsonian collection, and kindly loaned me by that institution—will permit me to illustrate the osteology of that representative of the *Sulidæ*. Then I will have something to add about the skeleton in the Cormorants and a word or two about the craniology of *Pelecanus*.

OSTEOLOGY OF SULA BASSANA.

Some of the smaller bones in my specimen are missing, such as the major portion of the hyoid arches, a few ribs, and joints of the toes, but in the main it is in excellent condition, and from it no doubt I can present a very fair review of the skeleton of this type.

Sula is noted for the high pneumatic condition enjoyed by almost its entire skeleton. We find this property extended throughout the axial portion of it, with the exception of the ribs and free caudal vertebræ. The pectoral limb is completely so, but in the pelvic extremity the femur is the only bone that appears to be pneumatic.

Of the skull.—In form the superior osseous mandible is flat upon its under side with cultrate tomium, while superiorly it is convex from side to side, and tapers from base to apex gradually to a point, being a little decurved near the extremity. Sometimes we find it pierced by a foramen on this upper side, which leads to its hollow interior, but *Sula* is without nostrils, though their probable position, did they exist, is perhaps indicated by the posterior end of the longitudinal furrow that marks the mandible upon its lateral aspect (Fig. 24).

An osseous, thoroughly adherent crust overlies the greater part of this superior surface, the only smooth place being a small area in front of the cranio-facial hinge. This envelope is very thin; nevertheless when compared with the smooth portion found above it its thickness is easily appreciated. Its entire surface is marked all over by an exquisite anastomosing venation, the ramifications starting, in some instances, from minute foramina in its substance.

A *lacrymal* is a free bone, articulating with a roughened facet of some extent beneath the antero-external angle of the frontal above, and by a smooth, gliding facet on the upper side of the maxillary, which latter bone is thickened in a perpendicular direction and otherwise enlarged in order to offer it the proper amount of surface. As for the bone itself, it is of rather a columnar form, with the exception of its extended anterior margin, which is roundly notched and shows on its inner side the large pneumatic opening leading to its hollow interior.

In Gannets there exists, projecting horizontally from the outer margin of the frontal bone, on either side, from its "prefrontal process," a few millimetres posterior to the fronto lacrymal suture, a small rounded

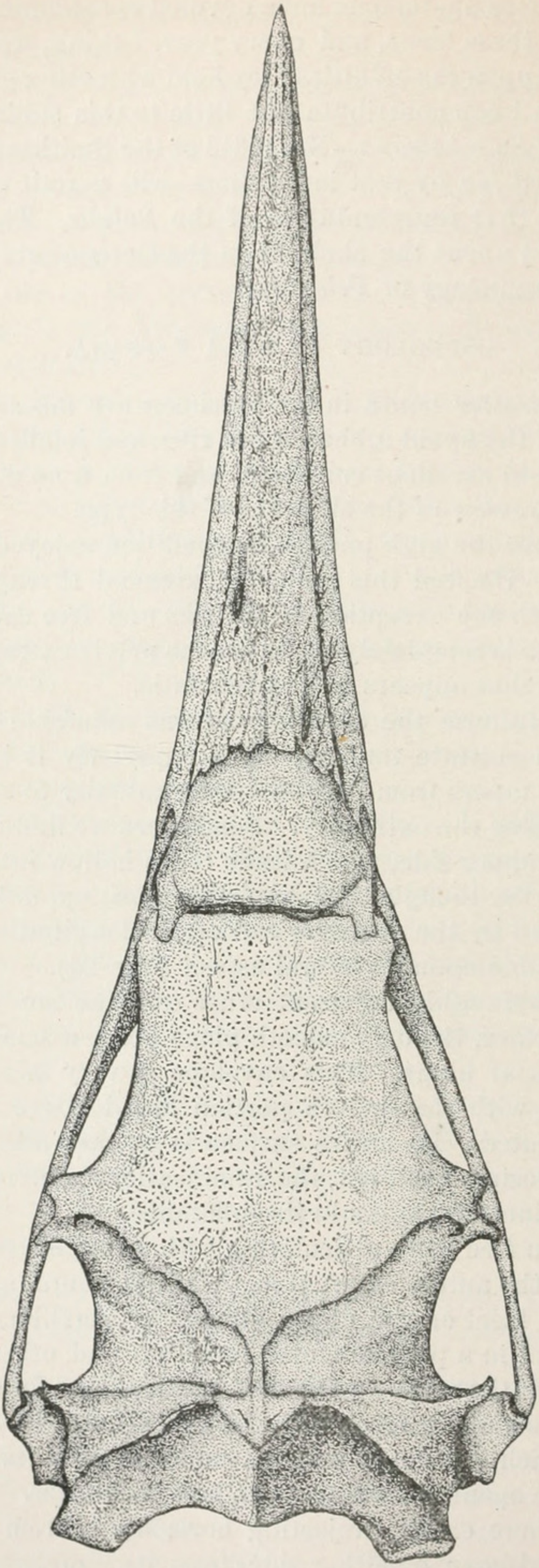

FIG. 24. Skull of *Sula bassana;* viewed from above; mandible removed; life size. By the author, from a specimen in the Smithsonian collection.

ledge of membrano-cartilage, which reminds one of the horizontal portion of the true lacrymal bone in certain gallinaceous birds, as the *Perdicinæ*, for example. This feature has been studied by me in *Sula brewsteri* and *S. gossi*, specimens of which I am indebted to Mr. E. J. Reed of Guaymas, Mexico, who kindly collected them for me. This membrano-cartilaginous process probably never ossifies in the *Sulidæ*.

In the adult bird it is impossible to distinguish the exact position, or any of the borders, of the nasal bone.

The maxillo-jugal bar shows very plainly the suture between the jugal and quadrato-jugal; the latter is much smaller than the other portion, and shows a strong peg-like process upon the inner aspect of its posterior end, which is at right angles to the axis of the bone. It fits in the deep conical socket on the side of the quadrate. Beyond its enlargement for the lacrymal the maxillary is a thin, horizontal plate of bone, anchylosed in the usual way at its anterior end. Here it really enters into the apparatus of the cranio-facial hinge. A process pointing backward and apparently coming from the premaxillary is seen over this horizontal plate of the maxillary on either side. Professor Parker found this condition present also in another species of *Sula*, and this eminent anatomist also describes a "post-maxillary" for these birds which heightens the zygoma, overlying, as it does, its commencement.

In this specimen the interorbital septum, which is a thin, smooth plate, shows considerable of a fenestra near its middle, and a few such openings of a very much smaller size pierce its posterior wall.

The circular optic foramen is entire, is of a size apparently three or four times the caliber of the nerve it passes, and it seems to include the smaller foramen to its outer side.

The orbital cavity itself in this Gannet is very deep, the eaves of its roof almost overhanging the jugal bar beneath. Its superior periphery is smooth and rounded. All in front of the rhinal chamber is filled in by the spongy mass formed by the united maxillo-palatines. The hinder portions of these bones are, however, still distinct, and they have all the appearance of these elements as they are found in birds which possess them as concavo-convex plates facing outward.

The rostrum of the sphenoid is a hollow subcylindrical tube, united above with the interorbital septum. As we proceed anteriorly it becomes more flattened from side to side, and gradually rises upward. At a point about half way between the palatines and cranio-facial hinge it terminates in a process directed forward; above this is the sharpened ethmoidal margin, nearly perpendicular to the long axis of the skull. Osseous wings to the ethmoid never develop in *Sula*, not even rudimentary traces of them being seen at their customary sites.

The cranio-facial hinge is exceedingly perfect in its construction, being composed of a thin plate of bone occupying the full width of the skull; the bones both above and below are separated from each other by a small interval for the entire length of the transverse line constituting the hinge.

The part played in the mechanism by the maxillaries has already been described above.

We find the sphenotic process to be bifid and jutting directly out from the side of the skull; on the other hand, the mastoidal process is a crest of bone curling forward. Between these two the very wide crotaphyte valley is seen.

The quadrate is a large, massive bone, with its mastoidal head composed of two prominent ellipsoidal trochleæ, separated from each other by an intervening notch. Below these the shaft is seen to be rather compressed in an antero-posterior direction, and supports in front at its lower half an unusually formed orbital process. This is a thin, triangular plate of bone placed in the vertical plane, and with its apex directed forward. The pneumatic foramen of the quadrate usually occurs on the posterior aspect of the shaft in most birds, but here it is situated to the inner and lower side of this orbital process.

The pit for the quadrato-jugal is cylindrical and deep, and a perforation at its bottom may lead into the hollow of the bone. On the posterior aspect of the quadrate we find an irregular facet for the mandible; it looks directly to the rear and stands at the head of a longitudinal and deep groove which is found between two similarly placed facets on the foot of the bone.

Each pterygoid is a trihedral and compressed bone with prominent borders.

Regarding this skull from a superior view (Fig. 24), we see in it a foramen in the superior mandible near the site of the narial opening of the majority of other birds. From this aspect we also have a good view of the wonderfully perfect cranio-facial hinge of the Gannet.

Posterior to this is a broad, smooth area, very slightly convex, and showing only at its hinder half the barest trace of a longitudinal furrow. This surface extends from the cranio-facial hinge to the anterior border of the crotaphyte fossæ, while laterally it is bounded by the margins of the orbits.

This view also shows the extent and form of these crotaphyte fossæ and how they are separated from each other in the median line simply by an extension backward of a very narrow strip of the general surface that lies beyond them. They are bounded behind by conspicuous and sharpened crests that curl slightly forward, and are best marked laterally, becoming very low as they near the upper part of the supra-occipital prominence.

The under view of the skull reveals a number of interesting points. We find that the anterior portions of the palatines are parallel to each other, separated by a median cleft of a width equal to either one of them, and which becomes pointed behind.

Their anterior ends do not merge into the premaxillary beyond until they are well past the points where the maxillaries are inserted. These anterior portions are thin, horizontal plates, being directly continuous

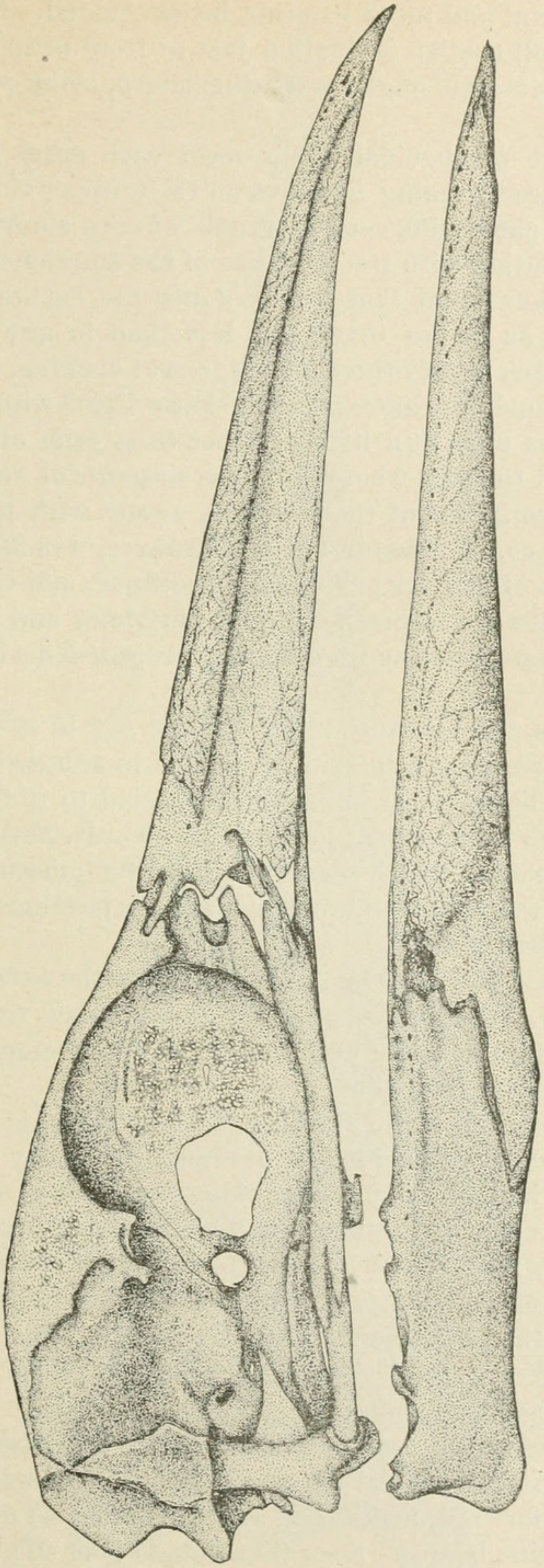

FIG. 25. Skull of *Sula bassana;* right lateral view; life size. By the author, from the specimen shown in Fig. 24.

with the horizontal and fused palatine bodies behind. This latter portion shows a small median carination just in front of the united heads, and the postero external angles are rather sharp, being pointed directly backward.

Anteriorly, the pterygoidal heads meet each other and the fused palatines, the three forming a groove on their upper sides for the rostrum. At their outer ends each pterygoid offers a shallow cup to form the usual articulation with the quadrate of the corresponding side.

Professor Parker found that "in *Sula alba* the basi-temporals are as little developed as in the *Dromæidæ*, less than in any other carinate bird. Behind each moiety there is a large oval opening, not far in front of the occipital condyle; this exposes the loose diploë within. The small Eustachian tubes open at a little distance from each other, in a wide, shallow fossa, on the part where the three elements of the parasphenoid meet." The description of these details agrees with the skull of the specimen before us. Professor Parker, however, was fortunate in having the skeleton of the ear parts in his specimen, and of them he says that "in *Sula alba* the columella auris is very long and bent. It has a small, cartilaginous, extra supra-stapedial process and a long attenuated stylohyal."

On either side, the entrance to the middle ear in this Gannet, as in others of the same genus, is shallow, and it is situated quite internal to the quadrate bone, while immediately mesiad to it there is a pit of great depth, with its aperture looking downwards, and its base in the vault of the cranium, which seems designed for muscular lodgement; the positions of the usual foramina about it are peculiar, and extremely interesting in these birds.

The bony wings that shield the entrance to the ears are large and tilted up behind. Each one shows the double facet for the mastoidal head of quadrate, the outer one having its inner margin encroached upon by the pit described above.

The postero-internal angle of either of these wings is connected with the side of the elevated basi-temporal region by a bony bar. This condition can best be seen from a posterior view. When speaking of the orbital cavity I neglected to mention that the upper part of the septum is longitudinally marked, as in most birds, by an open, single groove for the passage of the olfactory nerve to the rhinal space beyond. The exit for it from the brain-case is very small, indeed, and on one side the bone spreads over it, rendering the nerve track, for a fraction of the initial part of its course, tubular.

The brain-box itself is capacious and notable for its great width over its compression in the vertical direction. Its anterior wall looks directly downward and forward, making an angle of about 45 degrees with the horizontal palatine bodies. Seen from behind (Fig. 27), the skull shows above the extent to which the crotaphyte fossæ approach each other in the median line and the crest that divides them from the occipital area,

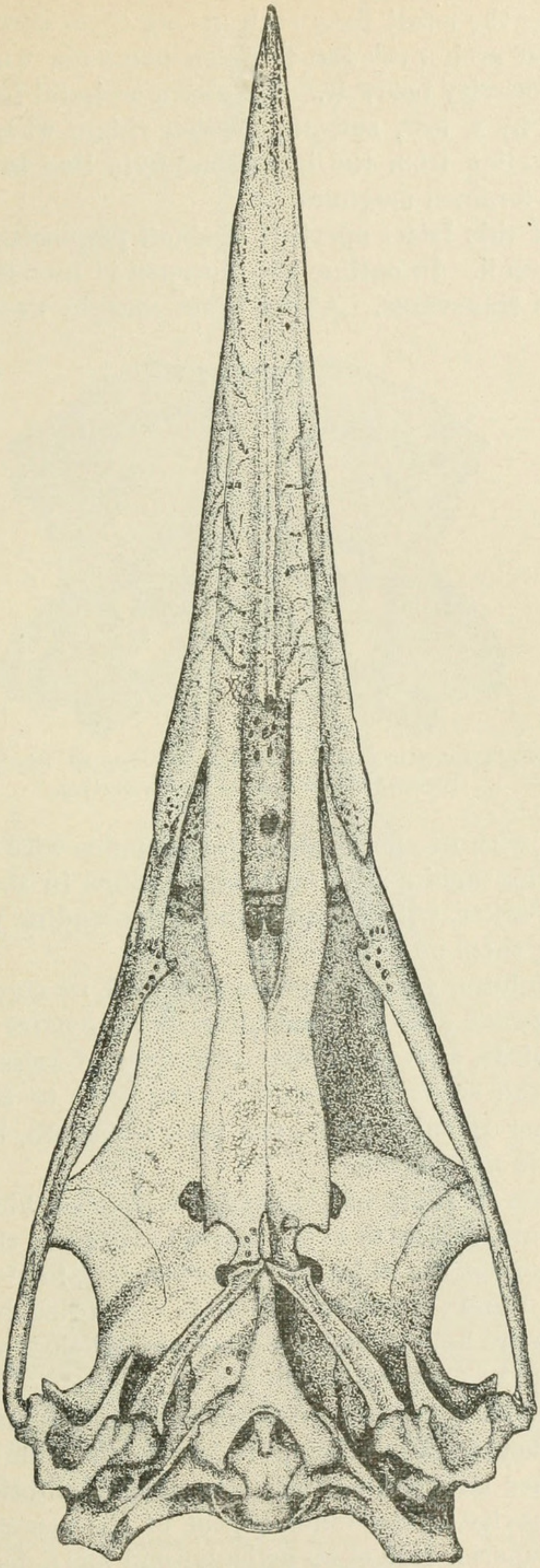

FIG. 26. Skull of *Sula bassana;* basal view; mandible removed; life size. By the author, from the saem specimen shown in Figs. 24 and 25.

This latter has the usual form seen among these cormorant like birds, constituting an arch over the foramen magnum, which occupies the center of a concavity below it. The supra-occipital prominence is here distinguished by a low, smooth, median ridge, which traverses this dome-like elevation from the intercrotaphyte line to the superior periphery of the foramen magnum.

The plane of this latter aperture is about perpendicular to the plane of the basis cranii. In outline the foramen is broadly elliptical, with the short axis transverse. At its lower margin we see a large ellip-

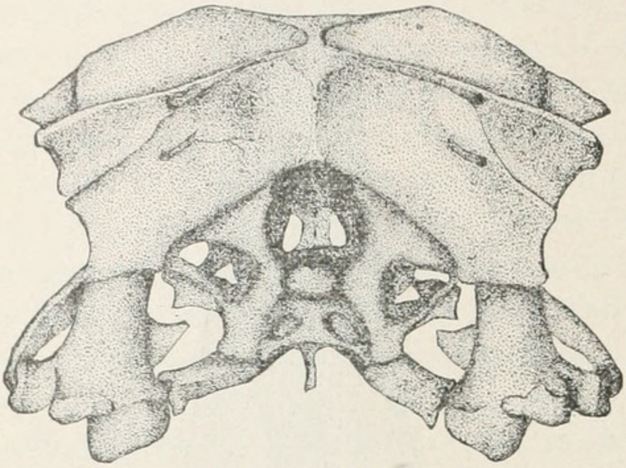

FIG. 27. Posterior view of the skull of *Sula bassana;* mandible removed; life size. By the author, from the same specimen shown in Figs. 24 *et seq.*

soidal condyle, with its short axis at right angles with that of the foramen. Below this again are the oval openings in the basi-temporal, spoken of by Parker, with the prominent descending processes of this region flanking them on either side.

In form the inferior *mandible* is spear-shaped, its sides tapering gradually to a sharpened apex. These latter, for the outer aspects of their anterior two thirds, show the same character of venated surface as I described for the superior mandible. Posterior to this, however, as well as the inner ramal aspects, the bone is smooth, having the same appearance as in most birds.

The symphysis is short and develops a spine behind, which points directly backward and is in every respect similar to the process in the same place, between the sides of the lower jaw, in Herons and Albatrosses. Each ramus of this mandible is very thick from side to side, but these parts are hollow, and the bone as a whole is very light, owing to the high state of pneumaticity it enjoys.

The foramina for the entrance of air to its interior are four in number, two on either limb, one being to the mesial side of the articular cup, and another larger, longitudinally placed, elliptical one just beyond this concavity on the inner aspect of the ramus near its upper border. The superior side of an articular end has a deep excavation at its center upon which the facets for the quadrate do not encroach, so that, when the jaw is articulated, this pit comes opposite the notch be-

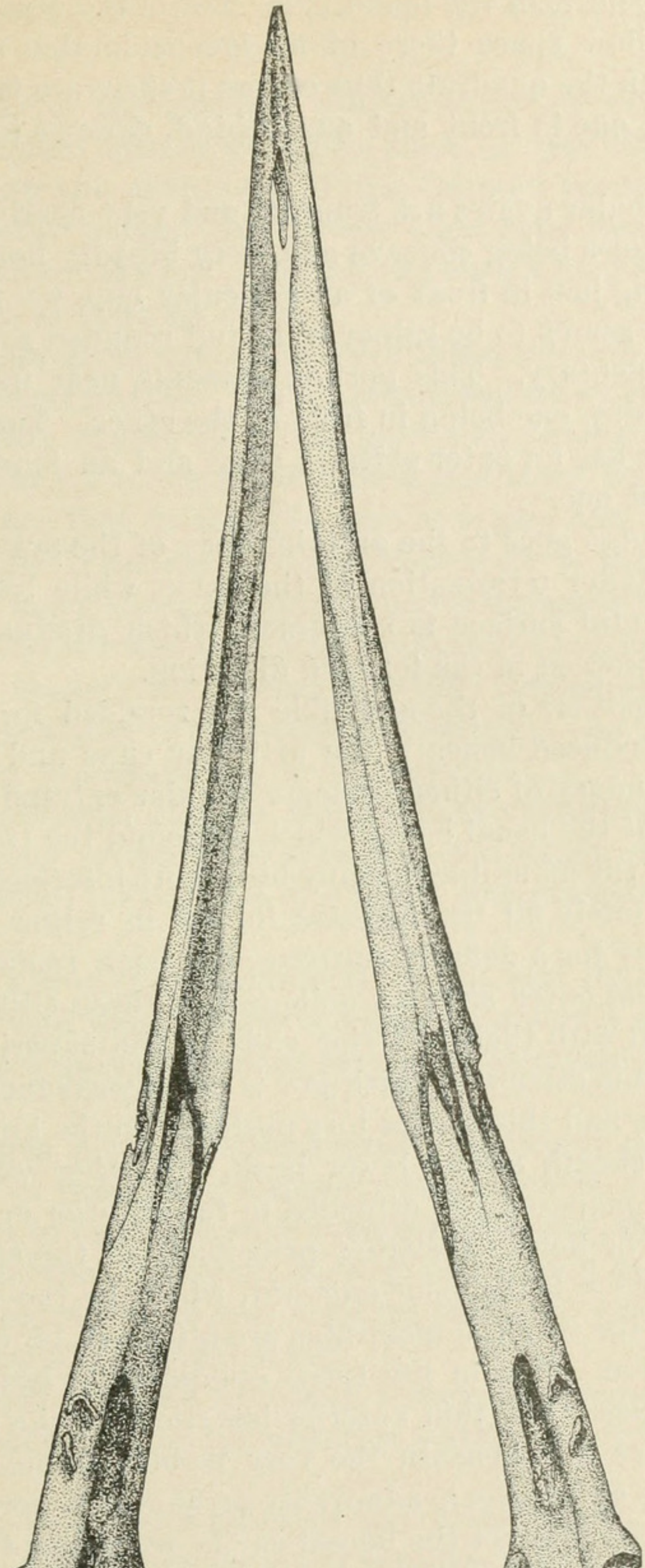

FIG. 28. Inferior mandible of *Sula bassana;* seen from above; life size. By the author, from the same specimen figured in 24 *et seq*.

tween the trochleæ of the mandibular foot of the quadrate, creating an irregular hollow space there of no inconsiderable size between the bones. When the quadrate thus covers it there are two entrances that are left open, one in front and one behind, close to the pneumatic foramen.

The mandibular angles are truncate and very nearly perpendicularly so, their surfaces being concave and very broadly luniform in outline.

Commencing just in front of an articular cup, we find the superior border of the ramus to be rather wide and rounded as far as the meeting with the dentary. This portion presents near its middle a double coranoid process, one being in front of the other. The dentary portion of this border has an outer cultrate edge and an inner and somewhat lower rounded one.

The outer edge goes to the anterior apex of the symphysis, the inner one to the hinder termination of the same, while between the two a nearly horizontal surface is contained, which gradually becomes narrower as we proceed in the forward direction.

The lower borders of the mandible are rounded for their entire extent, being produced beneath the articular cups and continuous with the inner boundary of either truncate angular extremity.

We find that the usual bones which surround the true ramal vacuity on the side of the mandible in many birds here interlock with each other so as to completely fill the fenestra in, but in rather an unusual way and apparently for a definite purpose; for each ramus presents, both on its inner and outer side, an oblique slit, these slits being opposite each other and with their anterior ends in the superior border. It is evident that this otherwise thick jaw is much weakened at these points in each ramus, and this occurs just posterior to the hinder termination of the horny sheath of the lower beak. In other words, the hinder moities of the mandible are attached to the anterior or dentary portion by thin plates of bone, consisting principally of the splenial elements, and are capable of being bent outward, which in the recent specimen can, owing to the way the quadrates are attached, be effected to a considerable degree. Now in life these oblique slits have their anterior ends come opposite the thin anterior insertions of the maxillaries, and these latter are just beneath the very mobile cranio-facial hinge, so that the whole apparatus is admirably arranged to permit an increase in size of the fore part of the buccal cavity when this Gannet swallows the fish that constitutes its food, and which its beak is so well fitted otherwise to capture. Moreover, this possible increase in caliber takes place in that portion of the digestive tract where it is most needed, or where the bony walls of the mouth would prevent the admission of a very large morsel unless some such mechanism existed—at the very entrance of the buccal cavity and just posterior to the more horny thecæ of the beak. In Gannets, however, this mobility is to an extent restricted by the integumental sheath of the beak.

OF THE REMAINDER OF THE SKELETON OF THE TRUNK IN SULA BASSANA.

In this specimen of the common Gannet there are twenty-one free vertebræ in the spinal column before we meet the one that first anchyloses to form, with the assistance of the thirteen succeeding ones, a sacrum for the pelvic bones. Then follow eight more free ones devoted to the movable part of the tail. Finally, we have a long pygostyle that probably contains at least six more.

They are all completely pneumatic save those ulterior free segments in the tail and the pygostyle. The sixteenth and seventeenth vertebræ support each a pair of free ribs; the next four belong to the dorsal series, and all have true vertebral ribs articulating with costal ribs from the sternum. This is also the case with the first two pair that spring from the pelvic sacrum. Behind these there is still another pair of ribs that very much resemble the post-pubic elements in form, whose hæmapophyses do not reach the costal borders of the sternum.

In mid-series these ribs support movable epipleural appendages, attached in the usual way to their posterior borders. As I have already stated above, they are completely non-pneumatic.

The neural canal is notable for being nearly cylindrical throughout the first twenty-one vertebræ; it is only at the region of the enlargement for the brachial plexus that it is rather compressed in the vertical direction.

The atlas has a minute perforation in its cup, and its neural arch is strikingly broad and deep. Axis vertebra possesses a stumpy neural spine, and its hypapophysis, directed somewhat backward, is very prominent.

The odontoid peg is comparatively small and nearly sessile with the centrum, the latter presenting a concave face below it.

From the third to the fourteenth vertebra, inclusive, the neural spine is a very inconspicuous character, while from this on it gradually makes its appearance, increasing in size until we have the usually quadrate, longitudinal plate of the dorsal series.

Third and fourth vertebræ have each a prominent hypapophysis like the one in the axis, but in the fifth this feature nearly entirely disappears.

Sixth vertebra is faintly marked by the carotid canal; this gradually becomes more and more tubular in the seventh, eighth, and ninth, while in the tenth to the thirteenth, inclusive, it is a closed cylindrical canal of a caliber somewhat less than the neural canal above it. It disappears entirely from the fourteenth vertebra.

The lateral canals extend from the third vertebra to the fifteenth, inclusive; they are short in any of the segments, and their posterior apertures are far larger than their anterior ones.

At the commencement of the cervical series the parial parapophyses are short and not particularly well developed. They project backward from the inferior walls of the lateral canals, but as the carotid canal begins to develop these processes withdraw from the former positions, move gradually lower down beneath the centrum, at the same time increase in length and importance, so that in those vertebræ where the carotid canal exists they project from its postero-inferior border directly backward as parallel and not far-separated spines.

The post-zygapophyses do not appear as divergent limbs until we find them so in the eighth vertebra; in all the cervical segments anterior to this one the facets are situate on the inferior aspect of the tuberous hinder end of the neural arch at its lateral angles.

Metapophyses are seen on the ninth vertebra, but gradually disappear, to be entirely absent in the fourteenth or fifteenth.

The transverse processes in the dorsal region are broad, flat, and horizontal, being directed more and more to the rear as we approach the pelvis. The plates of the neural spines above do not meet each other when the column is articulated, and there is an entire absence of all interlacing, ossified tendons or metapophyses in this region. In fact, all the vertebræ have a very clean-cut, non-angular appearance, with the majority of projecting borders rounded.

The articular ends of the centra are constructed upon the "heterocœlous" type; the anterior faces in the ultimate cervicals and leading dorsals being notably wide and shallow, and often riddled with foramina.

Pygostyle and the free caudal vertebræ will be spoken of after the pelvis has been described; in the mean time we will turn our attention for a few moments to the description of the sternum and pectoral arch.

The sternum (Figs. 29 and 30).—This bone in a Gannet has the most unique form possible. A pectoral aspect of the bone shows that the body has an oblong figure or outline, with the average width nearly equal to half the length. Beyond this parallelogramic part the anterior portion projects as a massive-promontory, and a large part of the carina is beyond this again.

The anterior moiety of the bone is convex on this side, and correspondingly concave on the thoracic aspect. Behind, the body is so flattened out as to be nearly horizontal. The costal borders look outward and slightly upward, and each possesses six moderately well-developed facets for the costal ribs. There are no pneumatic foramina in the elongated and shallow intervals.

The principal orifices of this character consist in a diffuse group on the superior aspect of the anterior projecting part, within the general concavity of the bone.

Either costal process gracefully rises from its base as a laminated and prominent horn, curving in the anterior direction.

The posterior moieties of the lateral borders are somewhat rounded and extend almost directly backward over the lateral processes behind.

These postero-external xiphoidal processes are very long and wide, being rounded off at their extremities and directed a little outward.

They are created by this hinder portion of the bone being so profoundly one-notched that a general concave margin has resulted, with simply a median papilliform process remaining (Fig. 29).

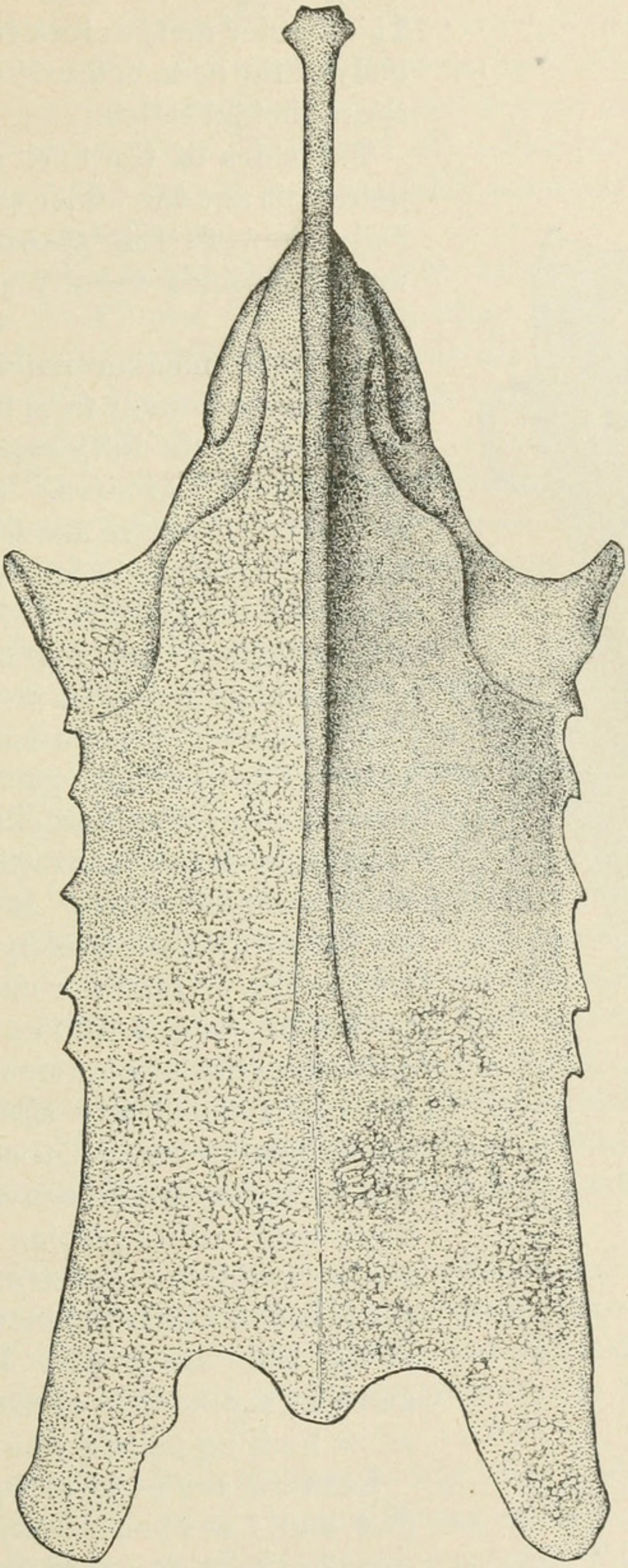

FIG. 29. Sternum of *Sula bassana;* pectoral aspect; life size. By the author, from the same specimen shown in Figs. 24 *et seq.*

The carina juts out very prominently in front of the bone; its anterior angle showing a large facet, concave from above downward, for the furcula, which in life articulates with it. Above this the border is again concave and sharp, while above this, again, there is a compressed process that represents the manubrium.

The lower border of the keel is straight and in the horizontal plane, being capped off with a spreading rim. This border merges into the surface of the body of the bone before it half way reaches the xiphoidal notch.

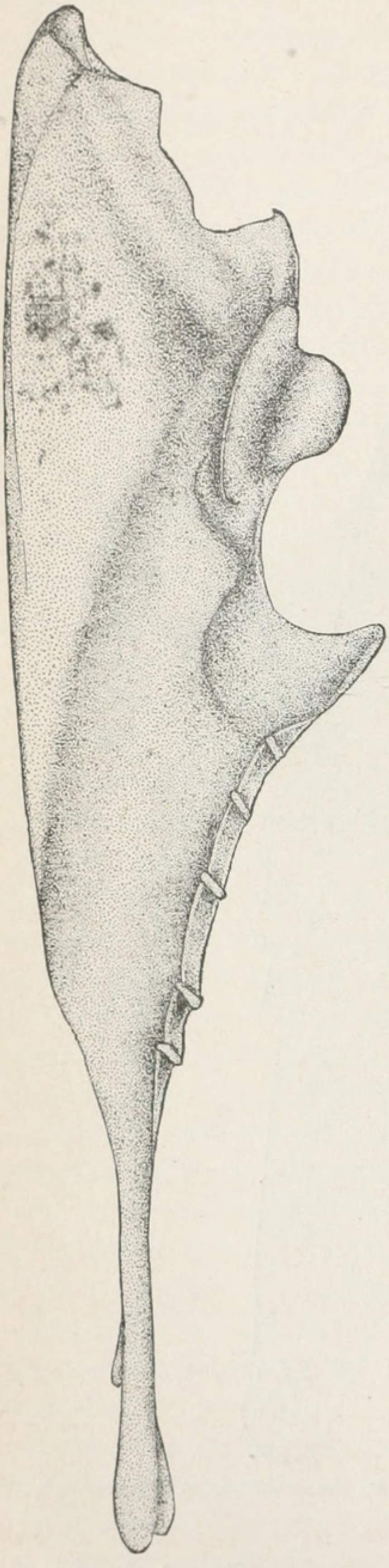

Fig. 30. Sternum of *Sula bassana*; left lateral view; life size. By the author, from the same specimen as shown in Figs. 24 *et seq.*

The sides of the keel are smooth, and neither it nor the under side of the sternal body show, in this specimen, any of the muscular lines usually present in most birds.

A broad median notch, concave from side to side, convex from before backward, lies between the lofty superior portions of the coracoidal grooves. These latter meet in front of it at the manubrial base, while behind its surface becomes directly continuous with the general surface of the upper side of the body, and right where the group of pneumatic foramina are found.

A coracoidal groove looks forward and outward for its upper portion, directly upward for its lower, and extends about half way between the base of the costal process and the manubrium. It consists of two portions which are directly continuous with each other. The lower one is a shelf-like projection, with a convex border forward and its articular surface in the horizontal plane. Immediately above this rises a much broader surface, though not so long, which is decidedly convex from above downward. This portion of the facet for the coracoid is considerably higher than the plane in which the borders of the body of the bone are found. It faces forward and outward, and has one regular convexity as its limiting margin above.

Between the point of its outer termination and the apex of the corresponding costal process the border is one sweeping concavity.

This form of sternum seems to be peculiar to the *Sulidæ*, and it differs in a number of points both from the Cormorants and from the Pelicans. Nor do we see anything in it to remind us of birds of more distant kinship, as the Albatrosses. In other respects, however, it presents characters common to all of these, and not a few resemblances with the last-named group. When this sternum is articulated with the shoulder-girdle its fantastic shape is by no means diminished, for the forms of the various bones which compose the latter, and now to be described, are equally curious and decided departures from the more common style of these elements.

Of the shoulder-girdle (Figs. 33, 34, and 35).—This part of the skeleton is, like so much of the rest of it, thoroughly pneumatic, the foramina occurring at their usual sites.

The clavicles form a broad U-shaped arch, and are completely united below, where, at their under side at the median point, they support an extensive facet for articulation with the carinal angle of the sternum. This does away with any such a thing as a hypocleidium proper, still the bone projects slightly over this facet.

The clavicular limbs are compressed from side to side, broader above than below, with the anterior and posterior borders rounded off.

A clavicular head is also compressed in the same manner as its shaft, and tapers off as a pointed process.

The most striking feature about this part of the bone is, however, the extraordinary facet it supports to articulate with the coracoid.

Either one of these is situate at the outer aspect of a head, upon a promontory of bone there found of a proper form to receive it. The facet is of an elliptical outline, placed vertically, and facing directly backward. Something of a notch is found between it and the clavicular head, in which occurs a number of the principal pneumatic foramina of the furcula. On the anterior surface, just below the summit of a *coracoid*, we find a distinct elliptical facet for articulation with a similar one just described for the fourchette. Between this and the ear-shaped glenoid facet considerable of a valley is found. On the opposite side of the coracoidal head we find a group of pneumatic foramina and below these a peculiarly formed scapular process, a spine-like apophysis, which rather gracefully curls upward and then toward the shaft of the bone.

This latter portion of the bone is subcylindrical and smooth, dilating below into a transverse fan-shaped sternal extremity.

A *scapula* offers but a very small portion of the articular surface for the glenoid cavity; not more than an eighth of it in the present specimen.

The head of the bone then reaches forward and inward, but only the outer two-thirds of this makes an indifferent articulation with the narrow and roughened border of the scapular process of the coracoid.

The shaft of the bone is quite stout behind this and somewhat compressed in the vertical direction, while posteriorly it flattens out into a broad paddle-shaped extremity that finally tapers to a point behind. (Fig. 35.)

Of the pelvis and caudal vertebræ.—The first vertebra that anchyloses with the pelvic sacrum projects entirely beyond the iliac bones (Figs. 31 and 32). Its centrum, in common with the next three that follow it, is much compressed from side to side, and its neural spine is continuous with the common neural ridge above of the succeeding segments.

The first five vertebræ that lie beneath the ilia throw out their apophyses in the usual way for their support; the last two of this series meet the iliac margins. Here the neural canal and centra are large, so as to afford room for the increase in size of the cord where the sacral plexus is thrown off.

Twenty-eighth and twenty-ninth vertebræ have their processes thrown directly upward, so that they are not visible upon direct ventral aspect.

In the thirtieth vertebra they are powerfully developed and extend directly across the basin to abut by anchylosis against the pelvic walls immediately behind the cotyloid cavity on either side. From this point the centra of the uro sacral segments taper quite rapidly in size to an enlarged facet on the posterior aspect of the last one, intended for the first free caudal.

The extremities of their diapophyses anchylos in a very thorough manner with the inner iliac margins, and a lateral view shows their sides to be riddled with pneumatic foramina between these processes.

Viewing this pelvis from above, we notice that the entire inner margins of the iliac bones have merged into and completely anchylosed with the sacrum.

This converts the ilio-neural grooves into ilio-neural canals and gives the bone a very compact appearance.

The anterior margins of the ilia are rounded and are set off with rather a deep and raised emargination.

Post- and pre-acetabular surfaces are about equal in the extent of their superficial areas.

The anterior iliac surfaces are concave on either side, and each faces upward and outward to about an equal degree.

Elevated above these anterior iliac concavities we find the post-acetabular area to be nearly horizontal. Large elliptical foramina are found between the apophyses of the last three or four uro-sacrals, and these latter, likewise, develop quite a prominent neural crest.

Upon lateral aspect of this pelvis we find a very large cotyloid ring, the inner margin of which is fully equal in size to the outer. A moderately sized antitrochanter occupies its usual site, with its articular surface directed downward, forward, and outward.

Behind this occurs an enormous elliptical ischiac foramen, that occupies nearly all of this post-acetabular lateral aspect. Through the fenestra thus formed we are enabled to get a good lateral view of the uro-sacral vertebræ and the extensive pneumatic condition they enjoy (Fig. 31).

The lower margin of the ilium is sharp and convex; it forms the superior boundary to a long, narrow, obturator space, which opens freely into the rather small obturator foramen.

A pro-pubis does not develop in this Gannet, while the post-pubis is for the most of its extent fragile and slender. It begins to increase in

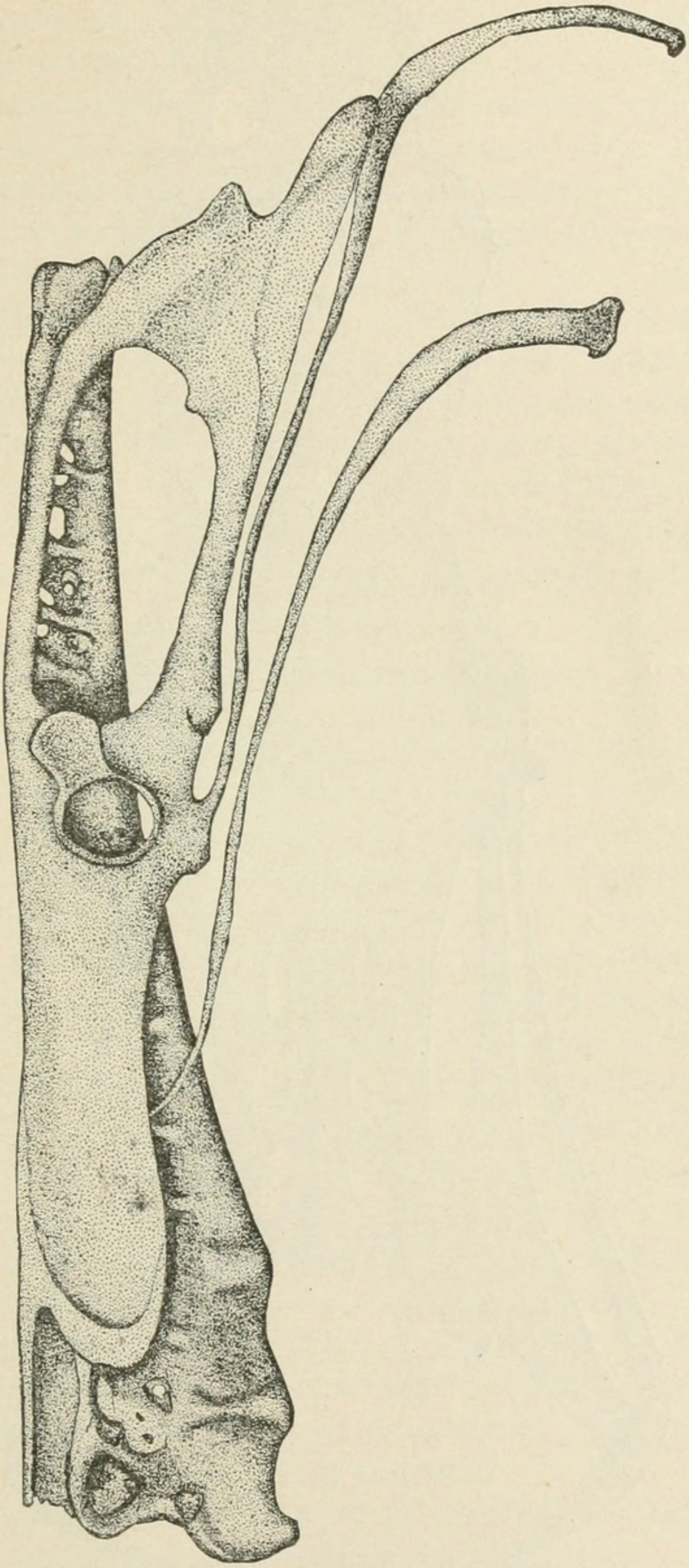

FIG. 31. Pelvis of *Sula bassana*, with sacral rib; left lateral view; life size. By the author, from the same specimen as shown in Fig. 24 *et seq.*

size just before arriving at a point opposite the end of the ischium. At this point it offers a small facet on its upper margin for the ischiac. postero-inferior angle, and the two bones are in contact during life

The post-pubis then, retaining its increase in size, curves inward toward the fellow of the opposite side, to terminate in a cartilaginous tip.

The posterior border of this lateral aspect shows a well-marked ilio-

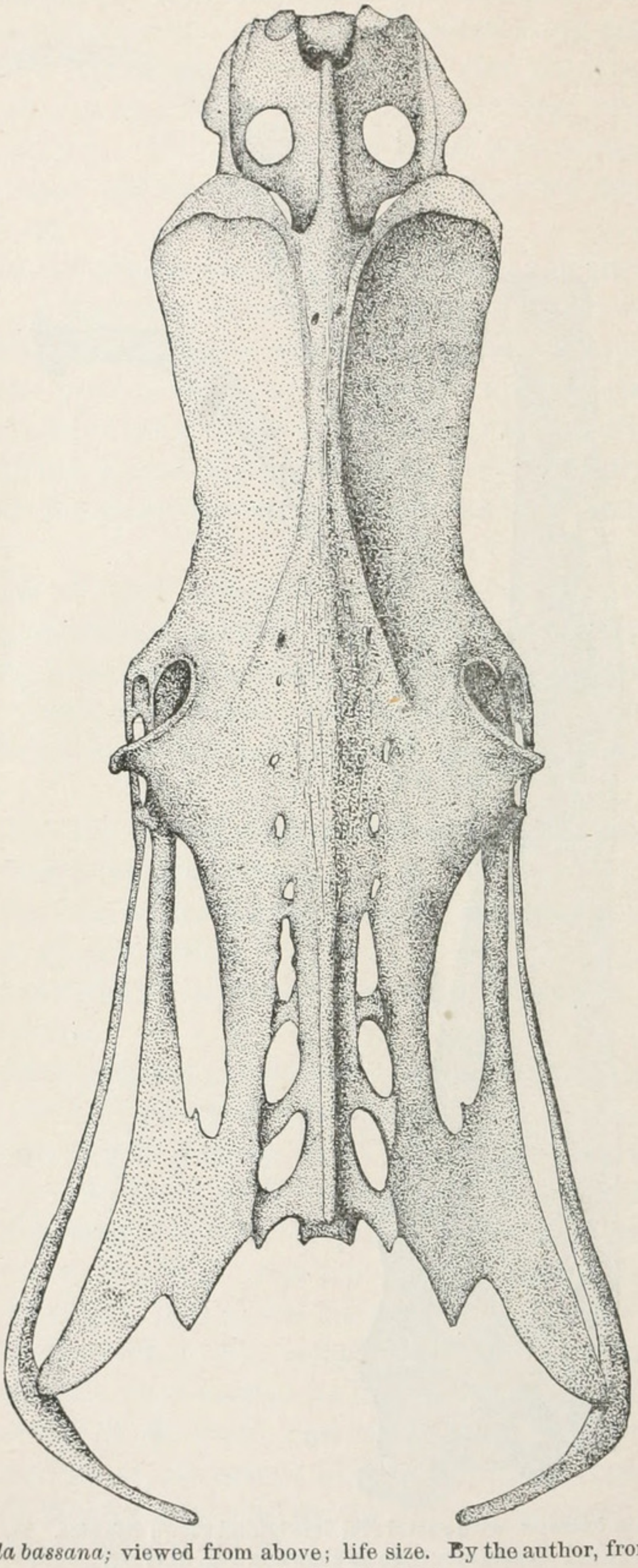

FIG. 32. Pelvis of *Sula bassana;* viewed from above; life size. By the author, from the same specimen seen in Fig. 24 *et seq.*

ischiac notch at about the middle of its extent. The outer side of the bone between it and the ischiac foramen is directed upward as well as outward.

As already mentioned above, there are eight free vertebræ in the tail, and a large pygostyle. The neural spines of these vertebræ are short and stumpy; some of them are bifid anteriorly; the neural arches beneath them close over the spinal canal for the entire length of the series, and it is seen to perforate, for a short distance, the pygostyle. The transverse processes are unusually thick and strong, being generally depressed, and in those segments where chevron bones occur they are anchylosed to the centra and hook forward over the preceding vertebra, after a fashion of many other birds wherein they are found.

On either end of any of the centra the facets show but little concavity or convexity.

The *pygostyle* (Fig. 37) appears to be composed of about six vertebræ, of which the three anterior ones can be quite easily made out. It has a very unusual form in this bird, being very long and subconical, with sharp superior border and rather decurved apex. Below, it is broad and somewhat convex. Viewing it from in front we notice that it has all the elements present, though in a very rudimentary state, of one of the caudal vertebræ, including a large, prominent, and anchylosed chevron bone.

OF THE APPENDICULAR SKELETON.

The pectoral limb.—We find the bone of the brachium to be somewhat longer than the radius and ulna in this limb, but the material before me will not permit me to say whether or no this holds true with Cormorants and Pelicans. In it the ulnar crest is prominent and projecting, though rather inclined to retreat from the elongated and shallow pneumatic fossa than arch over it, as in many other water birds. The radial crest is reduced to a long, low, inconspicuous ridge, and, in fact, this proximal end of the humerus, as a whole, merges into the shaft so gradually from both sides, and its being so narrow withal, that we are rather impressed with its lack of strength and an absence of a certain robustness so characteristic of other birds of equal size that lead a similar life. This in no way applies, however, to the shaft itself, for this subcylindrical and hollow bony tube, with its double sigmoidal curve, carries with it the very elements of strength and power.

Its distal extremity lacks but little of being as wide as the widest part of the head of the bone. It is without an ecto-condyloid process, has the trochleæ very prominent, and presents for examination a deep fossa to the anconal side of the ulnar tubercle.

The shaft of *radius* for so long a one is unusually straight, and only a slight curve is noticed in the proximal moiety of *ulna*.

In its continuity the former bone is subtrihedral in its form, with its pneumatic foramina situated beneath the transversely expanded portion of the distal end. Muscular lines mark this radial shaft along its inferior aspect.

For its distal moiety the shaft of ulna is nearly cylindrical in form,

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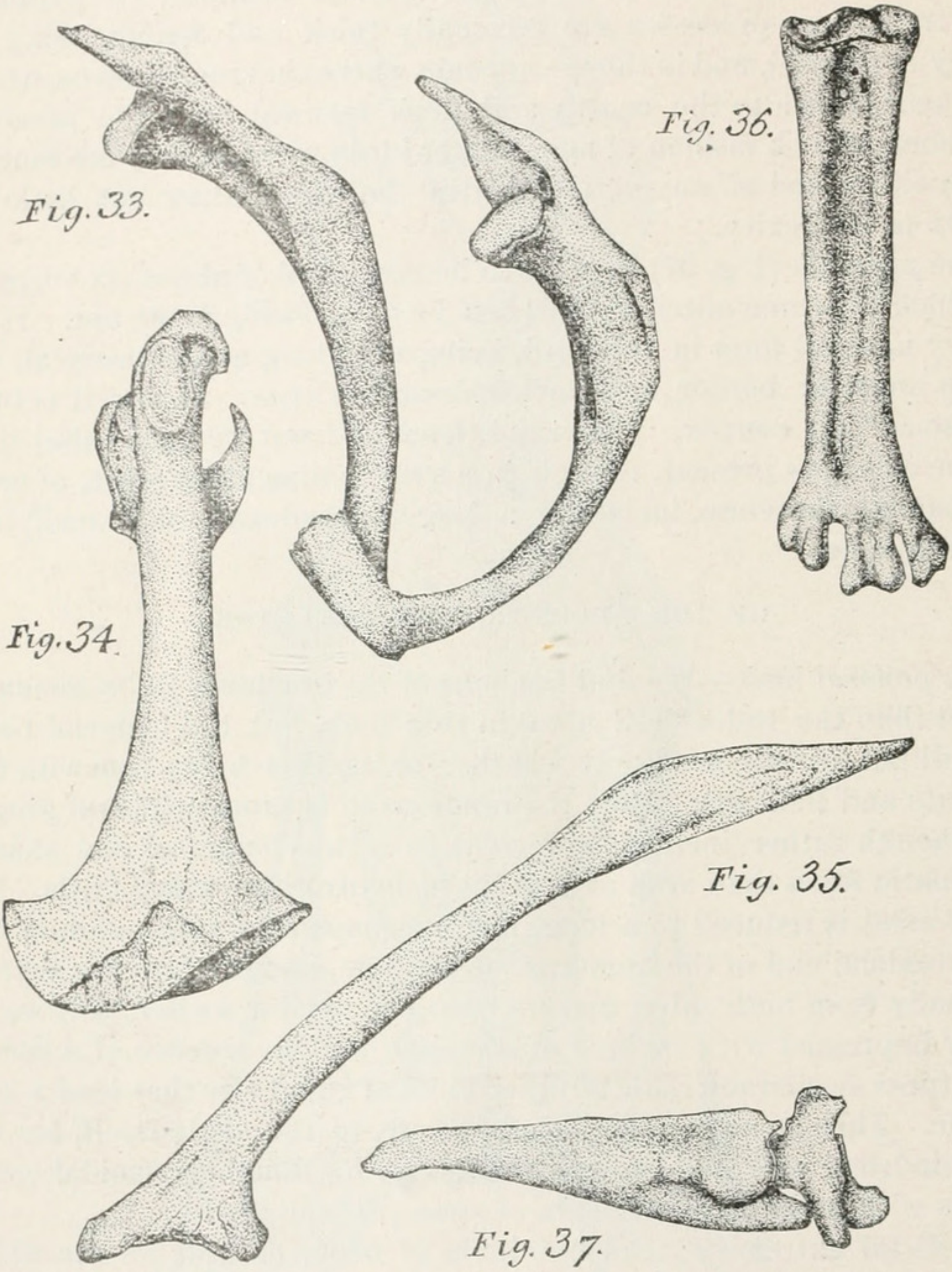
but this is gradually exchanged for the subtrihedral as we pass over the proximal half of the bone.

It presents for examination a double row of feebly marked papillæ for the quill-butts of the secondary feathers.



Various bones of *Sula bassana*, from the same specimen as shown in Figs. 24 *et seq.*; all life size. By the author.

FIG. 33. The furcula, rotated outward, so as to show facets of articulation for heads of coracoids.
FIG. 34. Right coracoid, anterior aspect.
FIG. 35. Right scapula, outer aspect.
FIG. 36. Anterior aspect of right tarso-metatarsal bone.
FIG. 37. Right lateral view of pygostyle, together with last coccygeal vertebra.

A long, shallow, though notable, fossa is seen at the proximal and anconal side of the shaft, which terminates just beyond the prominent cup-shaped articulation for the ulnar tubercle of humerus in a single pneumatic foramen. This fossa has all the appearance of being intended to lodge an air-sac, but the lack of fresh material prevents me from speaking positively upon this point.

Other pneumatic holes occur at the distal end of ulna upon all sides, except the outer one. The olecranon, though large and rather tuberous, would not particularly attract our attention.

A distinct canal upon the outer aspect of the distal end of the shaft for the passage of the tendons characterizes this bone. The articular surface shows nothing of special interest.

As usual, the carpal segments are but two in number—a *radiale* and an *ulnare.* They present the forms and facets common to these bones generally. Both are pneumatic and have large apertures for the admission of air to their hollow interiors.

The *carpo metacarpus* also presents a number of these foramina at either of its extremities; the principal one, however, is found just below the trochlear surface formed by os magnum upon the anconal side of the bone. A notable process occurs immediately below it, and another group of these air-holes to its outer aspect near the short and inconspicuous first metacarpal.

The main shaft is straight and of good caliber; it is longitudinally grooved nearly its entire length on the palmar side for a tendon going to the fingers. This is best marked upon the distal moiety of the bone. The metacarpal of middle digit is also straight for the major extent of its continuity; its extremities becoming enlarged in order to allow it to make the usual connections with index metacarpal. It is rather slender and develops no special processes, as it sometimes does in other representatives of the class.

The expanded portion of the proximal joint of index digit is not perforated, not even by the numerous pneumatic foramina which are irregularly scattered over its surface. Below it is produced as a notable

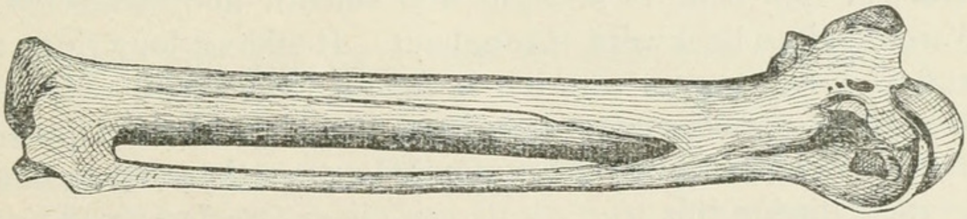


FIG. 38. Right metacarpus of *Sula bassana;* anconal aspect; life size. By the author, from the same specimen as shown in Fig. 24.

process, and a process that is seen in some of the extinct birds, as in *Ichthyornis*, for instance. The shaft of this phalanx is broad and flat anteriorly, and perfectly straight from above downward.

Equal to half the length of carpo-metacarpus, the distal phalanx of index digit is of a trihedral form, with an extensive excavation at the posterior aspect of its proximal end, which is continued in a lesser degree the entire length of the bone. It bears no claw below, but is finished off by a distinct little process.

Pollex phalanx has very much the same form as the one just described, but it lacks the longitudinal excavation down its posterior aspect. Both of the bones are pneumatic. Lastly, we have the smallest phalanx of all belonging to the middle finger. This, as usual, is behind the broad proximal joint of index, and not quite equal to half its hinder border in length.

Of the pelvic limb.—In comparison with the general size of the Gannet this lower extremity is very short, though the bones composing its skeleton are none the less strong in consequence. In the *femur* we find the axis of the head and neck making an angle with the longitudinal axis of the shaft. The head is quite distinct, globular, and excavated as usual on top. Its surface is continuous with the broad articular surface which occupies the entire summit of the bone. No trochanterian ridge rises above this latter, and, indeed, this character of the femur is but poorly developed.

A pneumatic foramen is always seen at its most common site, on the anterior aspect, just below the superior articular surface.

The shaft is cylindrical, roughened in some places by lines and diffuse tuberosities for muscular attachment, bent slightly to the front and somewhat to the inner side. At its distal extremity the condyles are fashioned after the usual pattern among birds, but all their characters in *Sula* present sort of a lack of strong development. The fibular cleft is but faintly marked, the intercondyloid notch or fossa is shallow, and the ridges in front much rounded and inconspicuous.

Something of the same condition is extended to the proximal end of *tibio-tarsus* of the leg, though not to such a marked degree, I think. Here the cnemial process rises but slightly above the articular summit of the bone, and the pro- and ecto-cnemial ridges which descend below it soon merge into the shaft, and are, at the best, but indifferently developed.

The shaft of this bone is straight and smooth and somewhat compressed from before backward throughout. It offers a long ridge to the fibula and is broad across where it is found. The distal extremity of the bone evinces more character than the upper one. An oblique bridge to confine the extensor tendons is extended across the deep groove that contains them during life.

Nearly parallel with each other, the condyles are wide apart, prominent and convex in front, to become suppressed and low thin-crested behind.

The fibula has the usual form seen in birds, but is here particularly interesting from the fact that it does not anchylose with the shaft of the leg-bone until it arrives at the middle of its lower third, and even from this low point the remainder of the bone, including an oval "external malleolus," stands out quite prominently. This rare condition of things was pointed out also for *Urinator lumme.*

Sula bassana has a long oval *patella*, obliquely marked across its anterior surface by a groove for the tendon of the ambiens muscle. This bone I have already figured in another connection. (Proc. U. S. Nat. Mus., Vol. VII, p. 327, P of Fig. E.)

Tarso-metatarsus in *Sula* is strikingly large in its proportions when compared with the other bones of the limb. In length it is a little more than half as long as tibio-tarsus, but being wider and broader it appears much more massive. (Fig. 36.)

Its hypo-tarsus presents three short, longitudinal elevations of unequal sizes. These inclose two tubular passages for tendons, and are grooved themselves besides. The back of the shaft is flat, but in front it is much scooped out above, where it shows two antero-posterior perforations.

At the distal extremity three large trochlear projections present themselves. They are separated from one another by wide clefts of about an equal depth. These trochleæ are placed nearly side by side, the middle one being the lowest down, the inner next, and the outer one the most elevated. Their median grooves are best marked behind, but in addition the internal trochlea presents a deep, vertical notch upon its outer aspect.

The usual arterial perforation pierces the bone above the cleft found between the outer and middle projections, a groove leading in to it from above.

Accessory metatarsal is rather an elongated bone, swung to the lower part of the shaft in the usual way by ligament.

The basal joint of hallux, which it supports, is comparatively more slender for its length than the other joints of the foot.

These latter are in number and arrangement for the three anterior toes the same as in the vast majority of the class. They present all the characters usually attributed to the phalanges of the podal digits in birds, and are well proportioned, both as regard their relative calibers and lengths.

NOTES UPON THE SKELETON OF PHALACROCORAX URILE.

Three or four years ago I published in "Science" an account of the osteology of this Cormorant, then called *P. bicristatus*. Professor Coues, in his "Key" to North American Birds, second edition, did me the honor to reproduce my figures from "Science," and I further added to them in an article on the patella of birds, which appeared in the Proceedings of the U. S. National Museum (Vol. VII, p. 325). Here I pointed out the unusual characters of the patella as they were to be found in the Cormorants, and gave a front view of this sesamoid in *P. urile*.

Cormorants are further noted for possessing, in common with *Plotus*, an osseous nuchal style (Fig. 39, *st. o.*), occupying a position corresponding to the ligamentum nuchæ of most mammals.

As in *Plotus*, from either side of this freely articulated style of the occiput the temporal muscles also arise. This little bone has been remarked upon by Owen, Brandt, Eyton, Garrod, and other eminent ornithotomists. Garrod's paper on the "Anatomy of *Plotus anhinga*" is especially worthy of mention in this connection, and contains a great deal of matter of value relating to the structure of the Darters and Cormorants. (P. Z. S., 1876, pp. 335–345.)

The Cormorants have a median groove in the superior aspect of their fused palatines for the rostrum of the sphenoid. Upon Parker's authority, too, we find that in the "Cormorants an oblong ossicle lies on the commencement of the zygoma. It is large in *P. carbo* and small in *P. graculus*."

For additional points in the skeleton of the *Phalacrocoracidæ* I must refer the reader to my article in "Science" referred to above (Vol. II, No. 41, p. 640), where figures of the sternum, shoulder-girdle, and other parts of the skeleton may be seen.

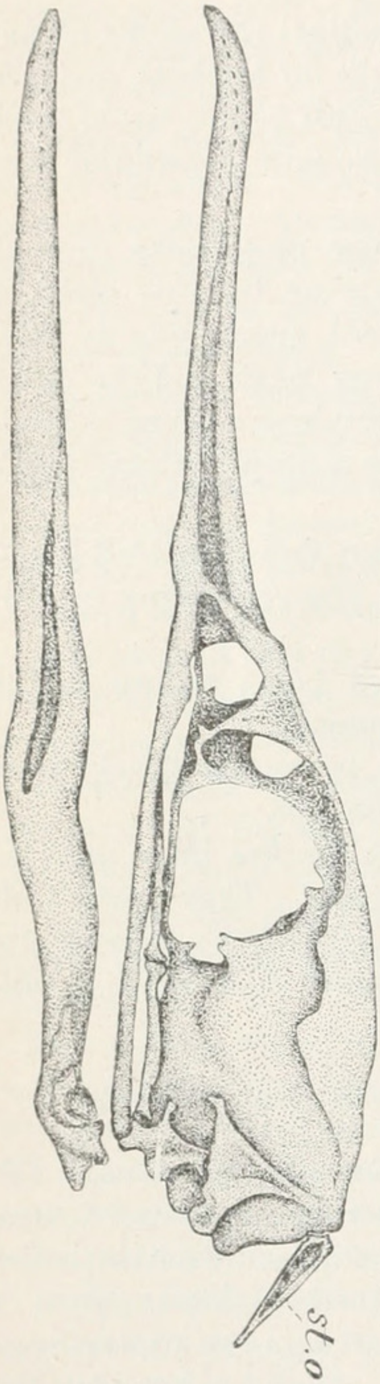


FIG. 39. Left lateral view of the skull of *Phalacrocorax urile*; life size. By the author, from a specimen in the Smithsonian Institution. *st. o.*, the occipital style.

OBSERVATIONS UPON A SKULL OF PELECANUS FUSCUS.

Twenty-four years ago I collected on the north side of Indian Cay a fine old male of this species of Pelican. Its skull was duly saved and now forms a part of my private cabinet. From it I made the drawing that accompanies these remarks. Huxley, in his Classification of Birds (P. Z. S., 1867), presents us with an excellent under view of the skull of *Pelecanus onocrotalus*, but the side view of the same is very indifferently drawn and a little misleading in some of the minor details.

Measuring from the transverse cranio-facial groove we find the osseous superior mandible in this specimen to be somewhat less than four times as long as the remaining part of the skull. A vertical section made through the middle of the posterior third of this mandible at right angles to its long axis gives an elliptical figure, with the minor axis on the horizontal plane. The anterior two-thirds has a sharp lateral edge, while the extremity is armed with a powerful decurved hook. About half of the fore part of this enormous beak is compressed from above downward, a compression that is accompanied by a gradual widening of the bone to near the end, where it slopes in toward the hook in the median line.

The maxillo-palatines constitute a great spongy mass that fills up a space anterior to the rhinal chamber. They unite in the median line, are bounded above by the premaxillary, below by the united palatines, while the anterior extremity of the maxillary fuses with the mass at about its middle on either side.

In form this maxillo-palatine mass is wedge-shaped, with the broad end anchylosed with the under side of the united nasal processes of the premaxillary.

Posteriorly its wall is composed of compact tissue, being at right angles to the longitudinal axis of the skull. It slants from the under side of the cranio facial hinge to the anterior margin of a median foramen, seen just anterior to the keel which is formed by the union of the palatines behind.

This posterior maxillo-palatine wall has a cleft in its lower two-thirds, while two conical pits, placed side by side, lined with compact osseous tissue, occupy its upper third. They have their bases opening in the rhinal chamber, and their apices are pierced by the small subcircular nostrils, one in each conical passage.

The hinder half of the jugal bar is compressed from side to side, slightly dilated, with its end crooked up, and in life simply bound to the upper and outer side of the quadrate.

The body of a *lachrymal* fuses completely with the cranial elements above, its upper surface assisting in forming the smooth superfices of the frontal region. From this portion it sends downward and slightly backward a descending process. This is composed of a cylindrical pedicel for its upper third and an antero-posteriorly compressed portion for the lower two thirds. It fails to reach the maxillary, its tip remaining free just above that perpendicularly compressed bar which passes immediately beneath it.

The interorbital septum is entire, with the exception of a semicircular perforation, which is immediately in front of the aperture in the anterior wall of the brain-case that gives egress to the optic nerves.

Each olfactory has a small foramen in either orbit at its usual site; the track for the nerve being a broad, shallow groove beneath the orbital vault.

The *mesethmoid* is very deep; its anterior border is sharp and thin. Commencing in the aperture of the angle between the pterygoidal shafts, it is carried directly upward and forward to the expanded portion beneath the roof of the cranio-facial region, the edge meeting the median division of the maxillo palatines (Fig. 40).

The lower fourth of this ethmoidal border is thickened and rounded for the articulation of the palatine and pterygoidal heads.

Coming, as usual, from the anterior apex of the basi-temporal triangle, the other portion of the rostrum is decurved and meets the point referred to above in the angle between the pterygoids.

A *quadrate* is a very large bone with a broad, triangular orbital process. Its mastoidal head can hardly be said to be divided into two, as

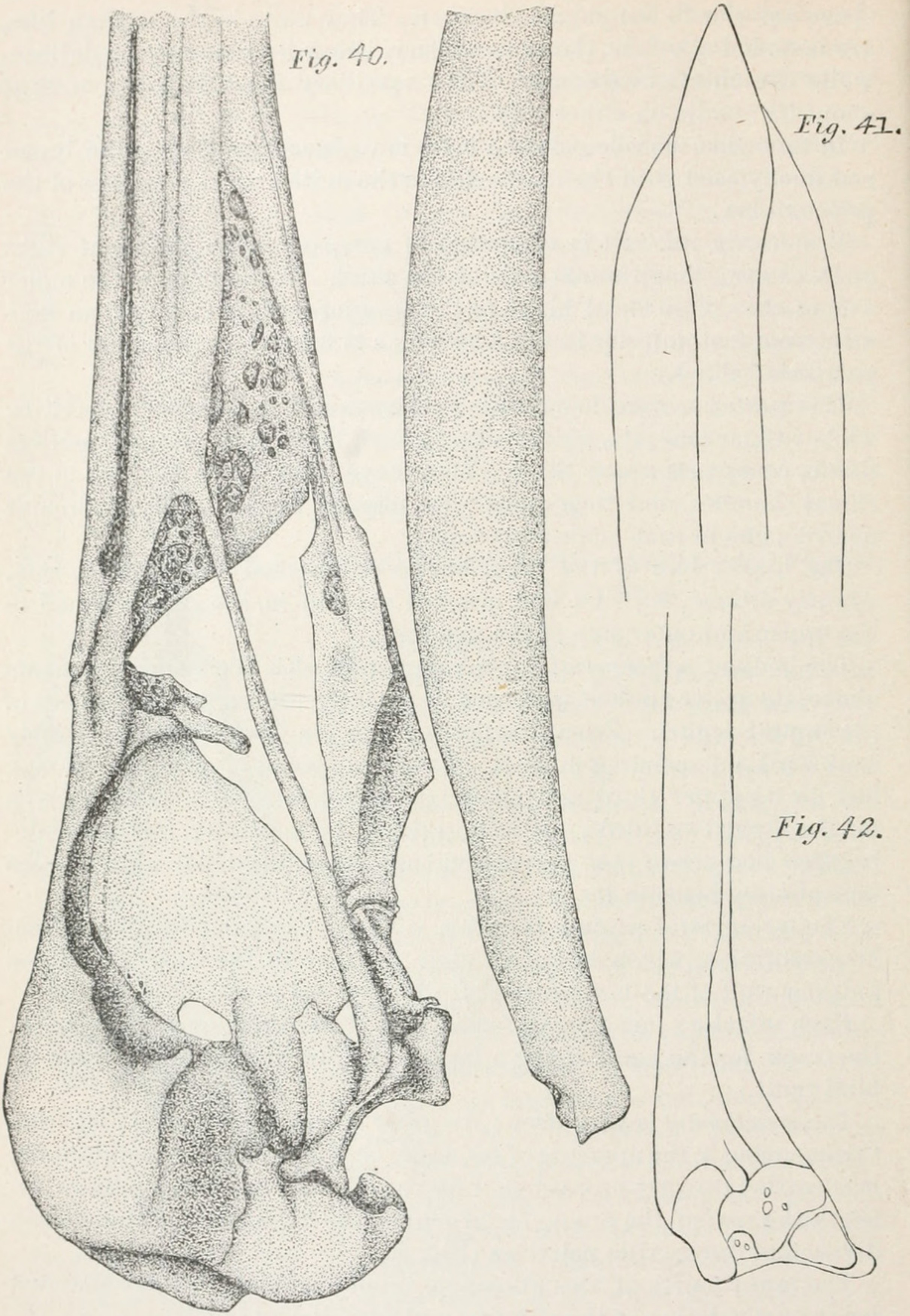


FIG. 40. Right lateral view of the skull and mandible of *Pelecanus fuscus;* anterior portion of mandibles not shown.

FIG. 41. Outline of anterior portion of superior mandible, viewed from above; horny sheath removed.

FIG. 42. Proximal extremity of left ramus, from above; drawn in outline.

All these figures life size. By the author, from a specimen he collected in the Bahama Islands in 1865, and at present in his private collection.

in most birds, and a large pneumatic foramen is seen upon its outer side—a very unusual place for this aperture.

Its mandibular foot is narrow antero-posteriorly and very wide transversely. Two facets occupy its lower surface, separated from each other by a concave notch which is deepest anteriorly.

The bone also presents a smooth articular surface for the quadrato-jugal at the point above mentioned, while a large convex facet is offered to the pterygoidal cup of the corresponding side.

We find the external opening to the ear to be very small, and hid from sight upon direct lateral view by the quadrate. A sphenotic process is well developed, but the mastoidal one is simply a roughened line; Between the two is a wide crotaphyte valley leading from the fossa of the same name, which is here small, inconspicuous, and entirely lateral.

The orbital cavity itself is thus seen to be deep and capacious, lacking bony walls principally upon its inferior and anterior aspects.

Upon its under side this skull presents a number of points of interest. The anterior moiety of the superior mandible is here seen to be longitudinally grooved by a broad and shallow furrow, which gradually becomes somewhat narrower as we proceed backward, to finally merge into the convex median portion of the hinder half of this great rostrum. Along its median line it is marked by a few scattered, slit-like foramina, that lead into its shallow interior, which latter is largely filled with an open mass of spongy, osseous tissue, continuous with the maxillo-palatines behind.

The palatine bodies, including their heads, fuse together for their entire extent in the median plane. Resulting from this union we have a single, descending, median carination, composed of the united inner keels of the palatine bodies and a similar superior median one composed of the ascending processes of the same.

The latter is truncated just before reaching the maxillo-palatine bodies.

This skull lacks basi pterygoid processes, while the pterygoids themselves are short, thick set bones, with large anterior and posterior heads, and sharpened longitudinal crests on the superior aspects of their shafts.

The basi-temporal triangle is small and its area concave. A thin, pointed lip of bone eaves over the entrance to the Eustachian tubes, which are here apparently thoroughly surrounded by bony walls.

We find the foramen magnum situated at the bottom of a broad, deep, and transverse concavity. This excavation is bounded on either side by the dome-like mastoid prominences, in front by the line of the base of the basi-temporal triangle, and behind by a low, smooth ridge which arches between its lateral boundaries.

The occipital condyle is rather large, ellipsoidal in form, and placed transversely, while the outline of the foramen is also a broad ellipse, but with its long axis placed just the other way. The plane passing through its periphery makes an angle with the plane of the basis-cranii of about 60 degrees.

Regarding this skull from a superior aspect we are to note the small,

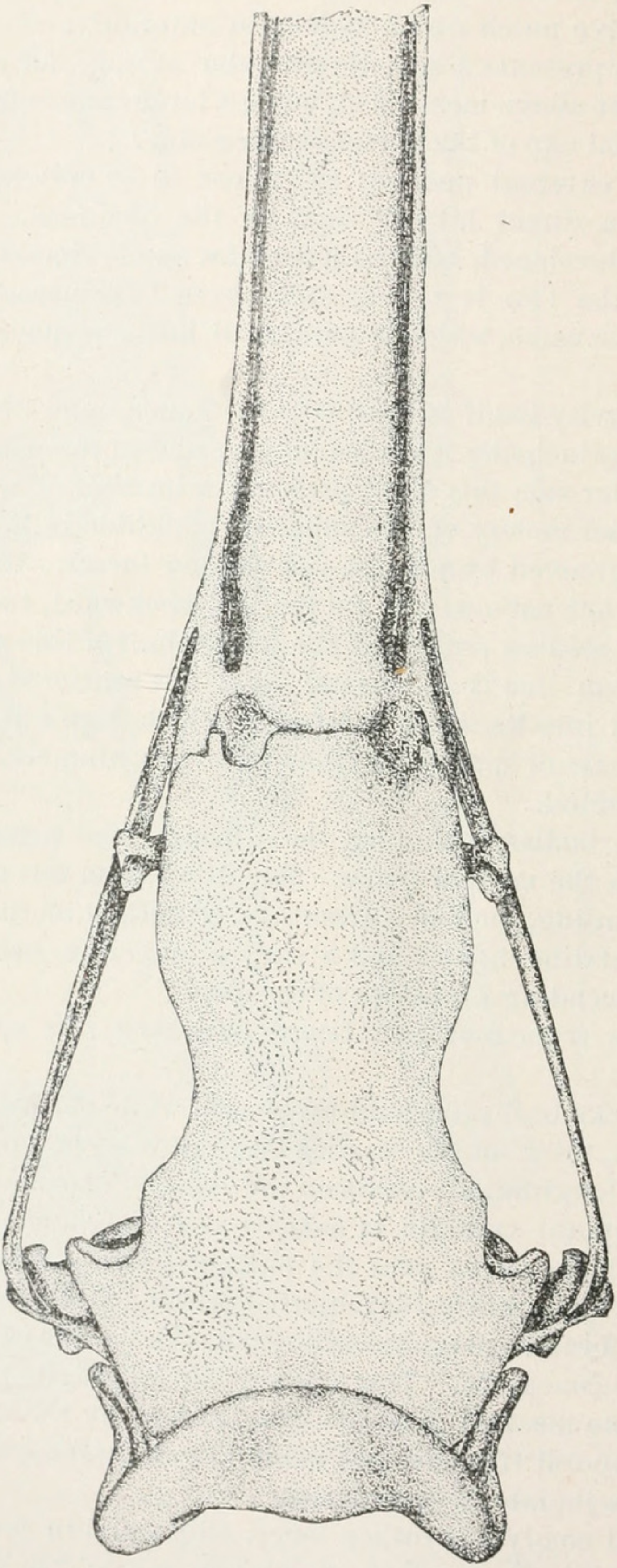


FIG. 43. Skull of *Pelecanus fuscus;* seen from above; mandible removed and anterior portion of superior mandible not drawn. Same specimen as given in Fig. 40; life size. By the author.

subcircular openings to the nostrils, situated a little beyond the irregular line marking the cranio-facial hinge. (Fig. 43.)

Their centers are about 2cm apart, and each one is situated at the posterior end of a groove. These grooves extend the entire length of the superior mandible, passing out on either side of the hook at its anterior extremity. At first each is rather on the lateral aspect of the bone, but beyond the posterior half they gradually converge and get on top, to include between them the prominent convex culmen. Just before reaching the hook, however, the included surface becomes flat and depressed, when the lines terminate, as pointed out above.

Fig. 43 shows the form and direction of the cranio-facial line, and also the broad, smooth surface of the top of the skull in this Pelican. This is very flat for the frontal region, being simply curved downward at the outer borders. As we proceed backward to the parietal region, however, it gradually becomes more convex and dome-like, though still retaining its absolutely smooth and polished character. This latter may also be seen from a posterior aspect, and below it the high, arching, and equally smooth occipital area. This latter extends down on either side over the enormous mastoidal elevations of this bird. We also notice that from this view we may see directly into the foramen magnum; the entire pterygoids are in sight, and the quadrates come down far below the basi cranial plane.

The *mandible* from the skeleton of a Pelican is represented by a long, narrow loop of bone, which is strikingly devoid of prominent characters. Its symphysis is very short and decurved, being slightly excavated on its superior aspect behind.

The upper and lower margins of either ramus are rounded for their entire length, while the sides included between them become gradually narrower as we proceed in the direction of the symphysis. These are smooth both internally and externally and both concave in the vertical direction.

Rather more than the posterior moiety of each ramus is hollow for the admission of air, and each presents two foramina, which seem to be intended for that purpose. One of these is on the inner and upper aspect of the ramal shaft, just beyond a concavity that occurs immediately anterior to the articular cup. The other, elliptical in form, is on the inner and lower aspect, and about 2cm beyond it.

Each articular cup presents two concavities—a central one and another occupying the inturned process of this extremity. Both have pneumatic foramina at their bases. The mandibular angle behind is truncate and much compressed in the perpendicular direction. The under surface of one of these ends is perfectly smooth and gradually merges into the inner and outer surface of the ramal shaft. Almost complete disappearance of the coronoids has taken place. Both the skull and its mandible are highly pneumatic.