

PUBLICATIONS OF THE NUTTALL ORNITHOLOGICAL CLUB, NO. 23

Editor, *Raymond A. Paynter, Jr.*

**HANDBOOK OF
AVIAN ANATOMY:
NOMINA ANATOMICA AVIUM**
Second Edition

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Prepared by the International Committee on Avian Anatomical
Nomenclature, a committee of the World Association of
Veterinary Anatomists.

CAMBRIDGE, MASSACHUSETTS

Published by the Club

1993

OSTEOLOGIA

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Among contemporary workers in avian osteology, Peter Ballmann for years has been concerned with standardization of anatomical terminology. His scholarly and painstaking assistance in the compilation of the postcranial osteological terminology is most commendable. In the first and second editions of *Nomina Anatomica* (NAA, 1979) R. L. Zusi, J. Vanden Berge, and R. Landolt have made important contributions in codifying the nomenclature of the skull and vertebral column. The dissertation of Butendieck (1980) provided a worthy review and critique of the osteology terminology of the NAA (1979).

The highly detailed nomenclature of the skeleton of birds presented here will be particularly useful to avian paleontologists, myologists, arthrologists, and systematists who use osteological characters. In the compilation of terms the major works most heavily drawn upon were those of Fürbringer (1888), Lambrecht (1933), and Ballmann (1969a) for the limb bones; Barkow (1856), Boas (1929, 1933), Komárek (1970, 1979), Landolt and Zweers (1985), and Zweers, et al. (1987) for the vertebral column; Hofer (1945, 1949, 1955) and Müller (1963) for the skull.

Nomenclature of digits of wing. The matter of homologies of the digits of the avian thoracic limb has long been a debatable point among avian morphologists. There is still no indisputable evidence for deciding if the elements of the avian manus represent digits I, II, III or II, III, IV. Berger (1966) summarized the controversy on the subject, citing the principal literature up to that time. Seichert and Rychter (1972) discussed and further reviewed the literature on this topic. Recently Hinchliffe (1985) and Müller and Alberch (1990), using more precise techniques than the older embryo-staining methods, have determined that the persisting digits in one species of modern birds

(chicken) are II, III, and IV. On the other hand, most workers regard birds as derivatives of theropod dinosaurs; in these dinosaurs, the evolutionary sequence clearly points to the presence of digits I-II-III as being the components of the tridactyl manus (Ostrom, 1976). Thus the problem is still unresolved.

Rather than perpetuate names of the skeleton and musculature of the manus based on the controversial numbering of the digits by arbitrarily choosing one of the systems in use, an alternative, less equivocal scheme was adopted in the first edition of the NAA (1979): P. Brodkorb originally suggested reviving the proposal of Milne-Edwards (1867-71), designating the digits and their skeletal elements by the descriptive names: Digitus alularis (the so-called pollex), Digitus major, and Digitus minor; Os metacarpale alulare, Os metacarpale majus, and Os metacarpale minus. This terminology has been well accepted, and continues in the present edition. See Annot. 214 and Myol. Intro.

Format for listing terms. The skeletal parts that are listed and described are mostly those of the *dried bones of mature individuals* from which the cartilaginous and ligamentous structures have been removed. Most of the anatomical names for skeletal features are listed under the name of the individual bone of which they are parts. For example, Foramen n. ophthalmici and Proc. postorbitalis are parts of Os laterosphenoidale.

On the other hand, numerous features of the skull, pelvis, and vertebral column are not limited to a single bone, but extend over two or more different, adjacent bones (e.g., crests, fissures, fossae, etc.). Extensive fusion of individual bones of the adult avian skeleton often makes it difficult or impossible to identify adjacent bones from one another; however, many of them can be readily distinguished in immature skeletons.

Names of such *compound shared features* in the mature skull involving more than one bone are listed under the headings **Facies** and **Cranium**; subheadings are Cavum nasi, Orbita, Cavum tympanicum, Cavitas cranialis, and Mandibula. In the adult skull *features confined to individual bones* are to be found under the headings: **Ossa faciei** and **Ossa cranii**; in some instances the same term may be listed in more than one place.

In the postcranial skeleton, other complexes of shared elements are: the Notarium and Synsacrum (parts of Columna vertebralis), the Carpometacarpus, Os coxae, Tibiotarsus, and Tarsometatarsus; these receive treatment similar to that of **Facies** and **Cranium**.

TERMINOLOGY

TERMINI GENERALES

Aditus	Angulus	Antrum
Ala	Anulus [Annulus]	Apertura

TERMINI GENERALES (cont.)

Apex	Excavatio	Os compactum
Apophysis	Extremitas	Os spongiosum ⁶
Arcus	Facies	Os medullare ⁶
Area	Facies articularis	Os pneumaticum
Basis	Fenestra	Os sesamoideum
Calvaria	Fissura	Ostium
Canalis	Fonticulus	Phalanx
Canalis nutriens	Foramen	Pila ⁴
Canaliculus	Foramen nutriens	Porus
Caput	Foramen pneumaticum ³	Pori pneumatici ³
Cellulae	Fossa	Processus
Cervix	Fossula	Radix
Collum	Fovea	Ramus
Cartilago epiphysialis ²	Foveola	Recessus
Cavitas	Hiatus	Rostrum
Cavum medullare	Incisura	Scapus ⁵
[Cavitas medullaris] ⁶	Impressio	Septum
Carina	Intumescencia	Sinus
Concavitas	Jugum	Spina
Condylus	Labium	Squama
Corpus	Labrum	Stylus
Cortex	Lacuna	Synostosis
Cornu	Lamina	Torus
Cotyla ¹	Linea	Trabeculae ossis
Crista	Meatus	Trochanter
Crus	Margo	Trochlea
Diaphysis ²	Medulla	Tuber
Discus	Metaphysis ²	Tuberculum
Diverticulum	Orificium	Tuberositas ⁷
Eminentia	Os, ossis	Zona flexoria (Arthr.)
Epicondylus	Os planum	Zona elastica (Arthr.)
Epiphysis ²	Os longum	Zygapophysis

SKELETON AXIALE

CRANIUM⁸

Zona flexoria [Ginglymus] craniofacialis (Arthr. Annot. 46)

CALVARIA¹⁶ (Figs. 4.1, 2, 5, 6)

Lamina externa	Depressio frontalis ¹⁴
Frons	Fossa temporalis ¹⁰⁴

(continued)

CALVARIA¹⁶ (Figs. 4.1, 2, 5, 6) (cont.)

Meatus acusticus externus ¹⁹	Lamina interna
Fossa glandulae nasalis ¹⁵	Crista vallearis ¹⁰⁶
Occiput	Crista frontalis interna ¹⁴
Prominentia cerebellaris ¹⁶	Tuberculum pineale ³⁷
Crista [Linea] nuchalis sagittalis ¹⁷	Fossa cerebelli ³⁶
Crista [Linea] nuchalis transversa ¹⁷	Crista maginalis ³⁶
Facies nuchalis	Impressio eminentiae sagittalis ¹⁰⁶
Foramen rami occipitalis ophthalmicae externae	Sulcus sinus sagittalis dorsalis (Ven. Annot. 31)
	Cellulae pneumaticae ⁶

BASIS CRANII EXTERNA²⁸ (see Figs. 4.4) and Ossa cranii)

Lamina parasphenoidalis [L. basitemporalis] ⁹⁶	Condylus occipitalis ⁸³
Ala parasphenoidalis	Tuberculum basilare ⁸³
Basis rostri parasphenoidali	Os exoccipitale
Proc. basiptyergoideus ⁹³	Fossa parabasalis ⁸⁶
Proc. lateralis parasphenoidalis ⁹⁷	Crista fossae parabasalis ⁸⁶
Proc. medialis parasphenoidalis ⁹⁷	Proc. paroccipitalis [P. paroticus] ⁸⁵
Os basioccipitale	Foramen magnum ¹⁸
Canales n. hypoglossi	Os laterosphenoidale [O. pleurosphenoidale] ⁸⁸

CAVUM CRANII [CAVITAS CRANIALIS] (see Fig. 4.6; Cranium and Ossa cranii for additional terminology)**BASIS CRANII INTERNA**

Eminentia aqueductus vestibuli	Crista tentorialis
Fossa cranii caudalis	Fossa cranii rostralis
Canales n. hypoglossi	Crista frontalis interna ¹⁴
Eminentia canalis semicircularis	Foramen ethmoidale ³⁴
Foramen magnum ¹⁸	Foramen n. olfactorii
Fossa acustica interna ¹⁰¹	Foramen opticum ³²
Fossa medullae oblongatae	Fossa bulbi olfactorii
Fovea ganglii vagoglossopharyngealis ³⁹	Septum osseum fossae bulbi ³³
Fossa cranii media ³⁵	Fossa cerebelli ³⁶
Fossa tecti mesencephali (CNS)	Crista marginalis ³⁶
Fossa ganglii trigemini	Fossa auriculae cerebelli ³⁸
	Sulcus v. semicircularis

OSSA CRANII⁸ (see Intro. Figs. 4.1-6)

Os basioccipitale	Foramen n. abducentis
Condylus occipitalis ⁸³	Foramen n. oculomotorii
Incisura mediana condyli ⁸³	Foramen n. trochlearis
Tuberculum basilare ⁸³	Foramen n. ophthalmici ⁹⁰
Facies externa	Incisura n. optici
Facies medullae oblongatae	Facies tecti mesencephali
Fossa subcondylaris	Fossa ganglii trigemini
Fovea ganglii vagoglossopharyngealis ³⁹	Sulcus n. ophthalmici
	Sulcus n. trochlearis
Os exoccipitale	Facies temporalis
Canalis semicircularis posterior	Os basisphenoidale (Fig. 4.6)
Facies cerebralis	Facies cerebralis
Facies externa (see Cav. cran.)	Canalis n. abducentis
Fossa parabasalis ⁸⁶	Sella turcica ⁹¹ (Fig. 4.6)
Crista fossae parabasalis ⁸⁶	Dorsum sellae ⁹¹
Foramen n. glossopharyngealis ³⁹	Fossa hypophysialis
Foramen n. vagi ³⁹	Foramen ophthalmicum internum ⁹¹
Ostium canalis carotici	Ostium canalis carotici (Canalis craniopharyngealis) ⁹²
Ostium canalis ophthalmici externi ^{27 86}	Os parasphenoidale (Figs. 4.4, 5)
Incisura foraminis magni	Rostrum parasphenoidale [R. sphenoidale] ⁹⁶
Proc. condylaris ⁸³	Canalis orbitalis ⁹⁵
Canales n. hypoglossi	Facies articularis palatina
Proc. paroccipitalis [P. paroticus] ^{85 20}	Facies articularis pterygoidea
	Facies articularis vomeralis
Os supraoccipitale	Basis rostri parasphenoidalis ⁹⁴
Crista [Linea] nuchalis transversa ¹⁷	Proc. basiptyergoideus ⁹³
Facies cerebellaris (see Cav. cran.)	Canalis orbitalis ⁹⁵
Facies nuchalis	Lamina parasphenoidalis [L. basitemporalis] ⁹⁶
Fonticulus occipitalis ⁸⁷	Ala parasphenoidalis ^{84 20}
Foramen v. occipitalis externae	Proc. lateralis parasphenoidalis ⁹⁷
Os laterosphenoidale [Os pleurosphenoidale] ⁸⁸	Proc. medialis parasphenoidalis ^{97 49}
Facies orbitalis	Canalis caroticus cranialis ^{99 121}
Area muscularis aspera ⁸⁹	Crista basilaris transversa
Proc. postorbitalis ^{30a}	Crista fossae parabasalis ⁸⁶
Facies cerebralis	Tuba auditiva [pharyngotympanica] communis ^{94 98}
Canalis n. maxillomandibularis ⁹⁰	
Foramen n. maxillomandibularis ⁹⁰	

(continued)

OSSA CRANII⁸ (see Intro. Figs. 4.1-6) (cont.)

Tuba auditiva [pharyngotympanica] ⁹⁸	Foramen n. ampullaris rostralis
Ostium pharyngeale	Foramen n. cochlearis
Ostium tympanicum	Foramen n. facialis
Os squamosum [Squamosum] ¹⁰²	Os parietale
Facies cerebralis	Crista [Linea] nuchalis transversa ¹⁷
Facies externa	Facies externa
Cotyla quadratica squamosi ¹⁰⁰	Facies interna
Fossa temporalis ¹⁰⁴	Os frontale ¹⁴
Crista temporalis ¹⁰⁴	Facies cerebralis
Fossa subtemporalis ¹⁰⁴	Crista vallearis ¹⁰⁶
Proc. postorbitalis ³⁰	Impressio eminentiae sagittalis (CNS Annot. 78)
Proc. suprameaticus ¹⁰³	Crista frontalis interna ¹⁴
Proc. zygomaticus ¹⁰²	Sulcus sinus sagittalis dorsalis (Ven. Annot. 31)
Ossa otica ¹⁰⁵ (see Cav. tymp.)	Facies dorsalis
Os epitoticum	Fossa glandulae nasalis ¹⁵
Os opisthoticum	Foramina neurovascularia
Os prooticum ²⁴	Facies orbitalis
Os metoticum	Impressio glandulae nasalis
Cotyla quadratica otici ²⁴	Margo supraorbitalis
Pila otica ²⁴	Proc. lacrimalis
Proc. paroccipitalis [P. parotica] ⁸⁵	[P. prefrontalis] ¹⁰⁷
Vestibulum	Os mesethmoidale ¹⁰⁸
Canales semicirculares ossei (Sens. Intro.)	Lamina dorsalis ¹⁰⁸
Canalis semicircularis anterior	Septum nasale osseum ^{55 108}
Canalis v. semicircularis anterioris (Ven. Annot. 32, 36)	Sulcus n. olfactorii ³¹
Canalis semicircularis lateralis	Os ectethmoidale [Os latero-ethmoidale] ¹⁰⁹
Canalis v. semicircularis lateralis (Ven. Annot. 32, 36)	Facies nasalis
Canalis semicircularis posterior	Facies orbitalis
Cochlea (Sens. Annot. 40-43)	Os lacrimale [Os prefrontale] ¹¹⁰
Lagena (Sens. Annot. 55)	Facies articularis frontonasalis ¹¹¹
Fossa acustica interna ¹⁰¹	Incisura ductus nasolacrimalis (Sens. Annot. 38)
Foramen n. ampullaris caudalis	Proc. orbitalis
Foramen n. ampullaris lateralis	Proc. supraorbitalis

CAVUM TYMPANICUM [CAVITAS TYMPANICA]^{21 19}

Canalis ophthalmicus externus ^{27 86}	Fenestra cochleae [F. pseudorotunda] ²²
Cotylae quadratica otici ^{24 100}	Recessus pneumatici paratympanici ^{23 49}
Cotyla quadratica squamosi ^{24 100}	Recessus tympanicus caudalis ²⁶
Ostium canalis tubae auditivae [pharyngotympanicae]	Foramen pneumaticum caudale
Columella (Sens. Annot. 55)	Recessus tympanicus dorsalis ²⁵
Foramen m. columellae	Foramen pneumaticum dorsale
Hiatus subtympanicus ²⁰	Recessus tympanicus rostralis ²⁶
Pila otica [P. prootica] ²⁴	Foramen pneumaticum rostrale
Recessus columellae [R. antevestibularis] ²²	Cellulae pneumaticae
Fenestra vestibuli ²²	Siphonium ⁴⁹

ORBITA²⁹ (Figs. 4.1, 2)

Paries caudalis orbitae	Fonticuli orbitocraniales ²⁹
Os laterosphenoidale [Os pleurosphenoidale] ⁸⁸	Foramen n. maxillomandibularis ⁹⁰
Proc. postorbitalis ^{30a}	Foramen n. olfactorii
Paries dorsalis orbitae	Foramen n. ophthalmici ⁹⁰
Impressio gl. nasalis ¹⁵	Foramen opticum ³² (see Os lat. sphen.)
Os frontale	Foramen orbitonasale laterale ³¹
Paries medialis orbitae	Foramen orbitonasale mediale ³¹
Septum interorbitale ²⁹	Margo supraorbitalis
Paries rostralis orbitae ¹⁰⁹	Margo infraorbitalis
Os ectethmoidale ¹⁰⁹	Arcus suborbitalis ^{30b}
Fonticuli interorbitales ²⁹	Sulcus n. olfactorii ³¹

FACIES⁸

MAXILLA (see Ossa max. et palati) (Fig. 4.4)

Fenestra antorbitalis [F. orbitonasalis] ⁹	Rostrum maxillae ⁴⁰
Hiatus craniofacialis septi ¹⁰	Palatum osseum
Arcus jugalis ¹¹	Concavitas palati
Arcus suborbitalis ³⁰	Fissura interpalatina
	Fenestra palatina ¹³

(continued)

MAXILLA (see *Ossa max. et palati*) (Fig. 4.4) (cont.)

Canalis neurovascularis maxillae ⁵⁷	Foveae corpusculorum
Canaliculi neurovasculares ⁵⁷	nervosorum ⁴¹
Foramina neurovascularia ⁵⁷	Dentes ⁸²

CAVUM NASI [CAVITAS NASALIS]

Apertura nasi [nasalis] ossea¹²
 Pila supranasalis¹²
 Septum nasi [nasale] osseum⁵⁵
 Conchae nasales⁵⁵ (Resp.)
 Recessus pneumatici paranasales (Resp.)
 Fossa antorbitalis⁹
 Os ectethmoidale¹⁰⁹

MANDIBULA (see *Ossa mand.*) (Figs. 4.1, 2)

Rostrum [Symphysis] mandibulae ⁴⁰	Foramina neurovascularia ⁵⁷
Ramus mandibulae	Foveae corpusculorum
Pars caudalis ⁴²	nervosorum ^{41 57}
Pars intermedia ⁴²	Tuberculum pseudotemporale ⁴⁵
Pars symphysialis ⁴²	Fossa articularis quadratica ^{49a}
Angulus mandibulae ⁴³	Cotylae fossae articularis ^{49a}
Crista tomialis ⁵⁶	Cotyla caudalis
Facies lateralis	Cotyla lateralis ⁷²
Facies medialis	Cotyla rostralis ⁷²
Proc. coronoideus ⁴⁴	Cotyla medialis (see <i>Quadr.</i>)
Proc. lateralis mandibulae ^{49d 84 96}	Sulcus intercotylaris ^{49a}
Proc. medialis mandibulae ^{49d 84 96}	Tuberculum intercotylare [Crista intercotylaris] ^{49a}
Facies articularis	Foramen pneumaticum
parasphenoidalis ^{49d}	articulare ^{49c}
Fenestra caudalis mandibulae ⁴⁶	Proc. retroarticularis ^{49b}
Fenestra rostralis mandibulae ⁴⁶	Incisura retroarticularis ^{49b}
Fossa aditus canalis	Fossa caudalis ⁵¹
neurovascularis ⁴⁸	Crista transversa fossae ⁵¹
Fossa lateralis mandibulae ⁴⁸	Recessus conicalis ⁵⁰
Canalis neurovascularis	Dentes ⁸²
mandibulae ⁴⁷	
Canaliculi neurovasculares ⁵⁷	

OSSA FACIEI ⁸ (Intro.)**OSSA MAXILLAE ET PALATI** (Figs. 4.4, 7)

Os nasale	Facies articularis vomeralis
Proc. frontalis	Fossa choanalis ⁶⁰
Proc. maxillaris ⁵⁴	Lamella choanalis ⁶⁴
Proc. premaxillaris ⁵⁴	Lamella dorsalis ⁶²
Os premaxillare	Proc. caudomedialis ⁶⁴
Corpus ossis premaxillare	Proc. rostralis ⁶³
Proc. frontalis	Pars lateralis [Lamella
Proc. maxillaris ⁵⁴	caudolateralis] ⁶⁰
Proc. palatinus	Angulus caudolateralis ⁶⁶
Crista tomialis ⁵⁶	Crista lateralis ⁶⁵
Canalis neurovascularis	Facies articularis pterygoidea
maxillae ⁵⁷	Fossa ventralis ⁶⁷
Canaliculi neurovasculares	Proc. maxillaris ⁶⁰
Foramina neurovascularia ⁵⁷	Proc. pterygoideus ^{60 61}
Foveae corpusculorum	Vomer ^{68 69}
nervosorum ⁴¹	Corpus vomeris
Rostrum maxillae ⁴⁰	Facies articularis palatina ^{68 69}
Os maxillare ⁵³	Facies articularis
Crista tomialis ⁵⁶	parasphenoidalis ⁶⁹
Proc. jugalis ^{59 11}	Facies articularis pterygoidea ^{68 69}
Proc. nasalis	Facies articularis maxillaris ^{68 69}
Proc. maxillopalatinus	Facies articularis premaxillaris ^{68 69}
[P. palatinus] ⁵⁸	Proc. pterygoideus
Proc. premaxillaris	Os pterygoideum ⁶¹ (Figs. 4.2, 4)
Canalis neurovascularis ⁵⁷	Facies articularis basipterygoidea ⁹³
Canaliculi neurovasculares	Facies articularis quadratica
Foramina neurovascularia ⁵⁷	Pes pterygoidei ⁶⁹
Foveae corpusculorum	Facies articularis palatina ⁶⁹
nervosorum ⁴¹	Facies articularis
Os palatinum [Os	parasphenoidalis ⁶⁹
pterygopalatinum] ⁶⁰	Pars palatina ⁶¹
Pars choanalis ⁶⁰	Proc. dorsalis ⁷⁰
Angulus caudomedialis ⁶⁴	Proc. quadraticus
Crista dorsolateralis ⁶²	Os jugale
Crista medialis ⁶²	Tuberculum lacrimale [T.
Crista ventralis ⁶⁴	prefrontale] (Arthr. Annot. 19)
Facies articularis	Os quadratojugale ¹¹
parasphenoidalis ⁶²	Condylus quadraticus ⁷³

(continued)

OSSA MAXILLAE ET PALATI (Figs. 4.4, 7) (cont.)

Os quadratum [Quadratum] ⁷¹	Condylus medialis
Corpus ossis quadrati	Condylus pterygoideus
Facies tympanica	Sulcus intercondylaris
Crista tympanica ¹⁹	Proc. orbitalis
Foramen pneumaticum	Proc. oticus ⁷¹ 24
Sulcus pneumaticus	Capitulum [Condylus] oticum ²⁴
Proc. mandibularis ⁷²	Capitulum [Condylus]
Condylus caudalis ⁷²	squamosum ⁷¹
Condylus lateralis	Crista tympanica ¹⁹
Cotyla quadratojugalis ⁷³	Incisura intercapitularis ⁷¹
Condylus rostralis ⁷²	Sulcus pneumaticus

OSSA MANDIBULAE (see also Mand.)

Os dentale ⁵²	Foramen pneumaticum articulare ⁴⁹
Pars dorsalis	Proc. medialis mandibulae ^{49d} 84 96
Pars ventralis	Os coronoideum ⁵²
Pars symphysialis	Os prearticulare ⁵²
Os angulare ^{49b}	Os spleniale ⁵²
Proc. retroarticularis	Os supra-angulare ⁵²
Os articulare ^{49c}	Proc. lateralis mandibulae ^{49d} 84 99

OSSA ACCESSORIA CRANII⁷⁵

Anulus [Annulus] tympanicus ⁷⁷	Ossa supraorbitalia ⁷⁴
Os nuchale ⁷⁶	Os lacrimopalatinum
Ossa sclerae (Sens. Annot. 8)	Ossa suturarum ⁷⁸
Os siphonium [Siphonium] ^{49c}	Os uncinatum ⁷⁸
Os suprajugale	

LARYNX

Skeleton laryngis (Resp. Larynx)

SYRINX

Skeleton syringis (Resp. Syrinx)

APPARATUS HYOBANCHIALIS [A. HYOLINGUALIS]⁷⁹

Paraglossum ⁸⁰	Urohyale [Basibranchiale caudale] ⁸¹
Cornua	Cornu branchiale
Basihyale [Basibranchiale rostrale] ⁸¹	Ceratobranchiale
Crista dorsalis	Epibranchiale
Proc. parahyalis ⁸¹	Pharyngobranchiale
Arcus parahyalis ⁸¹	

COLUMNA VERTEBRALIS¹¹² 113 129 139 141**PARTES VERTEBRAE¹¹³ (Figs. 4.8, 9)**

Corpus vertebrae ¹¹³	Proc. spinosus [arcus]
Facies articularis caudalis	Proc. transversus vertebrae ¹²³ 127a
Facies articularis cranialis	Facies dorsalis
Facies lateralis corporis	Facies ventralis
Concavitas lateralis	Fovea costalis ¹¹⁷
Sulcus lateralis ¹¹⁵	Zygopophys [Proc. articularis]
Eminentia costolateralis ¹¹⁶	caudalis ¹³²
Fovea costalis ¹¹⁷	Crista transverso-obliqua ¹²⁴
Proc. costalis ¹¹⁸	Facies articularis
Tuberositas lig. collateralis	Torus dorsalis ¹²⁵
(Arthr. Annot. 60)	Zygopophys [Proc. articularis]
Foramina pneumatica	cranialis ¹³²
Facies ventralis corporis	Facies articularis
Proc. postlateralis ¹²¹	Ansa costotransversaria ¹³⁵
Proc. caroticus ¹²¹	Foramen transversarium ^{134a} 138
Sulcus caroticus ¹²¹	Tuberculum ansae ¹³⁵
Crista [Proc.] ventralis	Cristae laterales ansae ¹³⁵
corporis ¹¹⁹	Proc. costalis
Alae cristae ventralis ¹²⁰	Lamina arcocostalis ^{127b} 134a
Crista ventrolateralis ¹²²	Foramen laterale arcus
Fovea cranioventralis ¹¹⁴	Lamina corporocostalis ^{127c}
Facies dorsalis corporis ¹¹³	Foramen vertebrae ¹¹³
Arcus vertebrae [A. neuralis] ^{127a}	Canalis vertebralis ¹¹³
Lamina lateralis arcus [Pediculus	Canalis caroticus cervicalis ¹²¹
arcus] ^{127a}	Hiatus interarcualis ^{128b}
Incisura cranialis arcus ^{128a}	Lacuna interzygapophysialis ^{128c}
Incisura caudalis arcus ^{128a}	Foramen intervertebrale ^{128a}
Lamina dorsalis arcus ^{127a}	Foramen transversarium ^{134a}
Area lig. elastici ¹²⁶	Canalis vertebrarterialis ^{134b}

VERTEBRAE CERVICALES SPECIALES¹²⁹ (see above for parts of a generalized free vertebra)

Atlas ¹³⁰ (Fig. 4.8)	Facies articularis atlantica
Corpus atlantis	Fovea lig. collateralis
Facies articularis axialis	atlantoaxialis (Arthr.)
Fossa condyloidea ¹³¹	Proc. ventralis corporis ¹¹⁹
Facies articularis dentalis	Arcus axis
Foramen fossae ¹³⁰	Lamina dorsalis arcus
Incisura fossae ¹³⁰	Ansa costotransversaria ¹³⁵
Tuberositas lig. transversi	Foramen transversarium ^{134 138}
Proc. ventralis corporis	Proc. costalis axis ¹³⁸
Arcus atlantis	Proc. spinosus [P. dorsalis] ¹³⁷
Ansa costotransversaria ¹³⁵	Lacuna interzygapophysialis ^{128c}
Foramen transversarium ^{134a}	Lamina lateralis arcus ^{127a}
Incisura caudalis arcus ^{136a}	Incisura caudalis arcus ^{128a}
Zygapophysis [Proc. articularis] caudalis ¹³²	Incisura cranialis arcus ^{128a}
Facies articularis	Zygapophysis [Proc. articularis] caudalis ¹³²
Proc. spinosus [P. dorsalis]	Facies articularis
Axis ¹³⁰ (Fig. 4.8)	Zygapophysis [Proc. articularis] cranialis ¹³²
Corpus axis	Facies articularis
Dens ^{136b}	
Fovea aspera	

VERTEBRAE THORACICAE, [LUMBICALES], ET SACRALES^{139 141b}

(see above for parts of a typical free vertebra)

NOTARIUM [Os dorsale]^{140a} (Fig. 4.9)

Canalis notarii [C. vertebralis] ^{140b}	Crista ventralis notarii ¹¹⁹
Crista spinosa [dorsalis] notarii ^{140b}	Fenestrae intercostales ¹¹⁹
Lamina transversa notarii ^{141c}	Foramina intervertebralia ^{128 143}
Fenestrae intertransversariae ^{141c}	Eminentia costolateralis ¹¹⁶
Corpus notarii ^{142a}	

VERTEBRAE SYNSACRALES^{141a} (Fig. 4.9)

SYNSACRUM^{141a} (see Os coxae)

Canalis synsacri [C. vertebralis] ^{143b}	Crista spinosa [C. dorsalis] synsacri ^{142c}
Extremitas cranialis synsacri	Lamina transversa synsacri ^{141c}
Facies dorsalis synsacri	

SYNSACRUM^{141a} (see Os coxae) (cont.)

Margo lateralis laminae transversae ^{141c}	Crista ventralis synsacri ¹¹⁹
Fenestrae intertransversariae ^{141c}	Sulcus ventralis corporis
Facies lateralis synsacri	Vertebra acetabularis ^{141b}
Foramina intervertebralia ^{143a 128a}	Proc. costalis
Eminentia costolateralis ¹¹⁶	Proc. transversus
Facies visceralis synsacri ^{142b}	Fossae renales (see Pelvis)
Corpus synsacri ^{142a}	Extremitas caudalis synsacri

VERTEBRAE CAUDALES (Figs. 4.9, 15) (see above for parts of a typical vertebra)

Vertebrae caudales stabiles ^{141a}	Proc. haemalis ¹⁴⁴
Vertebrae caudales liberae ¹⁴⁴	Canalis vascularis
Proc. haemalis ¹⁴⁴	Lamina pygostyli ¹⁴⁶
Pygostylus [Coccyx] ¹⁴⁵	Proc. transversus ¹⁴⁶
Apex pygostyli	Canalis pygostyli [C. vertebralis]
Basis pygostyli ¹⁴⁶	Margo cranialis
Corpus pygostyli	Margo caudalis
Crista ventralis	Discus pygostyli ¹⁴⁶
Facies articularis cranialis	

CAVUM THORACIS [CAVITAS THORACICA]

Apertura thoracica caudalis	Spatium intercostale
Apertura thoracica cranialis	Sulcus pulmonalis ¹⁴⁸ (Resp. Annot. 49)
Facies visceralis sterni (see Sternum)	

COSTAE¹⁴⁷ (see Cav. thor.)

Costa vertebralis	Facies lateralis
Extremitas dorsalis costae	Margo caudalis
Capitulum costae ¹¹⁶	Margo cranialis
Collum costae	Proc. uncinatus ¹⁴⁸ (Fig. 4.9)
Tuberculum costae ¹¹⁷	Extremitas ventralis costae
Incisura capitulotubercularis ¹⁴⁸	Facies articularis intercostalis (Arthr. Annot. 81)
Angulus costae	Costa sternalis
Corpus costae	Extremitas dorsalis costae
Facies medialis [F. pulmonalis]	

(continued)

COSTAE¹⁴⁷ (see Cav. thor.) (cont.)

Facies articularis intercostalis (<i>Arthr.</i> Annot. 81)	Extremitas ventralis costae Facies articularis sternalis ¹⁵⁷
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SKELETON APPENDICULARE**OSSA CINGULI MEMBRI THORACICI****STERNUM**¹⁴⁹ (Fig. 4.11)

<p>Corpus sterni¹⁴⁹ Facies muscularis sterni¹⁵² Linea intermuscularis¹⁵³ Planum postcarinale¹⁵⁴ Facies visceralis sterni¹⁵² Pars cardiaca Pars hepatica Foramen pneumaticum Pori pneumatici Sulcus medianus sterni Margo costalis [lateralis] sterni¹⁵⁷ Incisurae costales¹⁵⁷ Loculus costalis¹⁵⁷ Pila costalis¹⁵⁵ Proc. articularis sternocostalis¹⁵⁷ Facies articularis costalis¹⁵⁷ Margo cranialis sterni Pila coracoidea¹⁵⁸ Sulcus articularis coracoideus^{156 175a} Labrum externum Tuberculum labri externi (<i>Arthr.</i> 89, 90) Labrum internum Proc. craniolateralis sterni¹⁵⁰ Impressio m. sternocoracoidei Rostrum sterni¹⁵⁹ (<i>Arthr.</i> Annot. 86) Foramen rostri¹⁶⁰</p>	<p>Spina externa rostri¹⁵⁹ Alae spinae sternae Spina interna rostri¹⁵⁹ Spina communis¹⁵⁹ Septum interarticulare¹⁵⁹ Spatium intercoracoideale¹⁶⁰ Margo caudalis sterni¹⁵⁷ Fenestra lateralis¹⁵¹ Fenestra medialis¹⁵¹ Incisura lateralis¹⁵¹ Incisura medialis¹⁵¹ Trabecula intermedia¹⁵¹ Trabecula lateralis¹⁵¹ Trabecula mediana¹⁵¹ Proc. caudolateralis sterni¹⁵⁰ Carina sterni¹⁶¹ (Fig. 4.11) Apex carinae Facies articularis furculae Tuberositas lig. sternoclavicularis (<i>Arthr.</i> Annot. 85) Facies lateralis carinae Linea intermuscularis¹⁵³ Margo cranialis carinae Crista lateralis carinae¹⁶¹ Crista mediana carinae Pila carinae¹⁶¹ Sulcus carinae¹⁶¹ Margo ventralis carinae</p>
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CLAVICULA [FURCULA]¹⁶² (Fig. 4.10)

<p>Extremitas omalis claviculae [Epicleideum]¹⁶⁴ Proc. acrocoracoideus claviculae¹⁶⁵ Facies articularis acrocoracoidea Proc. acromialis claviculae¹⁶⁵ Facies articularis acromialis</p>	<p>Extremitas sternalis claviculae Apophysis furculae [Hypocleideum]¹⁶³ Scapus [Corpus] claviculae Proc. interclavicularis¹⁶³</p>
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SCAPULA¹⁶⁶ (Fig. 4.10)

<p>Extremitas cranialis [Caput] scapulae Acromion¹⁶⁶ Crista lig. acrocoracoacromialis¹⁶⁶ Facies articularis clavicularis Sulcus supracoracoideus¹⁷² Proc. glenoidalis scapulae^{167b} Facies articularis humeralis^{167a} Labrum glenoidale Facies articularis coracoidea^{168 173a}</p>	<p>Tuberculum coracoideum^{168 173a} Collum scapulae¹⁷⁰ Corpus scapulae¹⁷⁰ Facies medialis [F. costalis]¹⁶⁶ Facies lateralis¹⁶⁶ Margo dorsalis [M. vertebralis] Margo ventralis Tuberculum m. scapulotricipitis¹⁶⁹ Extremitas caudalis [Spina] scapulae</p>
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CORACOIDEUM [OS CORACOIDEUM] (Fig. 4.10)

<p>Extremitas omalis coracoidei^{171a} Proc. acrocoracoideus^{171a} Facies articularis clavicularis Impressio lig. acrocoracohumeralis Tuberculum brachiale^{171b} Proc. glenoidalis coracoidei^{167b} Facies articularis humeralis^{167a} Labrum glenoidale Facies articularis scapularis^{173a} Cotyla scapularis^{173b} Proc. procoracoideus¹⁷² Facies articularis scapularis^{173a} Sulcus supracoracoideus^{172 177} Corpus coracoidei Facies dorsalis Cotyla scapularis^{173b} Facies ventralis Margo lateralis</p>	<p>Margo medialis Foramen [Incisura] n. supracoracoidei Linea intermuscularis ventralis¹⁷⁴ Extremitas sternalis coracoidei Crista articularis sternalis^{175a} Facies externa Crista intermedia Facies interna Facies articularis intercoracoidea^{175b} Angulus medialis Proc. lateralis¹⁷⁶ Angulus lateralis Margo supra-angularis¹⁷⁶ Impressio m. sternocoracoidei Canalis triosseus¹⁷⁷ Cavitas glenoidalis¹⁶⁷</p>
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OSSA ALAE [MEMBRI THORACICI]¹⁷⁸

SKELETON BRACHII

HUMERUS¹⁷⁸ (Fig. 4.12)

Extremitas proximalis humeri	Margo caudalis ¹⁸⁸
Caput humeri ^{178 179}	Margo dorsalis
Incisura capitis humeri ¹⁸⁰	Margo ventralis
Crista incisurae capitis	Linea m. latissimi dorsi
Tuberculum dorsale ¹⁸²	Sulcus n. radialis ¹⁹¹
Crista deltopectoralis ¹⁸⁴	Extremitas distalis humeri
Angulus cristae	Condylus dorsalis humeri ¹⁹²
Impressio m. pectoralis	Condylus ventralis humeri ¹⁹²
Crista m. supracoracoidei ¹⁸³	Incisura intercondylaris ¹⁹³
Tuberculum ventrale ¹⁸⁷	Fossa m. brachialis
Crista bicipitalis ¹⁸⁴	Epicondylus dorsalis
Fossa pneumotricipitalis	[Ectepicondylus] ^{194 178}
[F. tricipitalis] ¹⁸⁸	Epicondylus ventralis
Foramen pneumaticum ¹⁸⁹	[Entepicondylus] ^{194 178}
Crus dorsale fossae ¹⁸⁸	Proc. flexorius ¹⁹⁵
Crus ventrale fossae ¹⁸⁸	Tuberculum supracondylare
Margo caudalis ¹⁸⁸	dorsale ¹⁹⁶
Planum intertuberculare ¹⁸¹	Proc. supracondylaris dorsalis ¹⁹⁶
Sulcus [Canalis] n.	Tuberculum supracondylare
coracobrachialis ¹⁸¹	ventrale ¹⁹⁶
Intumescencia humeri ¹⁹⁰	Fossa olecrani
Sulcus transversus ¹⁸⁵	Sulcus scapulo-tricipitalis ²⁰⁰
Impressio coracobrachialis ¹⁸⁶	Sulcus humero-tricipitalis ²⁰⁰
Corpus humeri	Os sesamoideum m.
Facies caudalis ¹⁷⁸	scapulo-tricipitis ²⁰²
Margo caudalis ¹⁸⁸	
Facies cranialis ¹⁷⁸	

SKELETON ANTEBRACHII (Fig. 4.13)

ULNA¹⁹⁸ (Fig. 4.13)

Extremitas proximalis ulnae	Impressio m. brachialis
Proc. cotylaris dorsalis ¹⁹⁷	Impressio m. scapulo-tricipitis
Cotyla dorsalis ¹⁹⁸	Incisura radialis ¹⁹⁹
Cotyla ventralis ¹⁹⁸	Olecranon ²⁰¹
Crista intercotylaris	Sulcus tendinosus ²⁰³

ULNA¹⁹⁸ (Fig. 4.13) (cont.)

Tuberculum bicipitale ulnae ²¹⁰	Papillae remigales ventrales ²⁰⁵
Tuberculum lig. collateralis	Extremitas distalis ulnae
ventralis ²⁰³	Trochlea carpalis ²⁰⁶
Corpus ulnae	Condylus dorsalis ulnae ²⁰⁶
Facies caudodorsalis ²⁰⁴	Labrum condyli dorsalis
Facies caudoventralis ²⁰⁴	Condylus ventralis ulnae ²⁰⁶
Facies cranialis ²⁰⁴	Sulcus intercondylaris ²⁰⁶
Lineae intermusculares	Tuberculum carpalis ²⁰⁷
Margo caudalis	Incisura tuberculi carpalis ²⁰⁷
Margo dorsalis	Depressio radialis ²⁰⁸
Margo interosseus [M. cranialis]	Incisura tendinosa ²⁰⁹
Papillae remigales caudales ²⁰⁵	

RADIUS (Fig. 4.13)

Extremitas proximalis radii	Margo ventralis
Caput radii	Extremitas distalis radii
Cotyla humeralis	Facies articularis radiocarpalis ²¹¹
Facies articularis ulnaris	Facies articularis ulnaris ²¹¹
Tuberculum bicipitale radii ²¹⁰	Depressio ligamentosa ²¹²
Corpus radii	Sulcus tendinosus ²¹¹
Lineae intermusculares	Tuberculum aponeurosis
Margo dorsalis	ventralis ²¹³
Margo interosseus [caudalis]	

SKELETON MANUS

OSSA CARPI²¹⁴ (Fig. 4.14)

(Ossa carpi proximalia) ²¹⁴	Corpus
(Ossa carpi centralia) ²¹⁴	Crus longum ²¹⁵
(Ossa carpi distalia) ²¹⁴	Crus breve ²¹⁵
Os carpi radiale ²¹⁵	Incisura metacarpalis ²¹⁵
Facies articularis metacarpalis ²¹⁵	Proc. muscularis ²¹⁵
Facies articularis radialis	Facies articularis ulnaris
Facies articularis ulnaris	Facies articularis metacarpalis ²¹⁵
Os carpi ulnare ²¹⁵	Os prominens ²¹⁶

CARPOMETACARPUS (Fig. 4.14) (**Osteo.** Intro.;
Arthr. Annot. 128)

Extremitas proximalis carpometacarpi	Facies ventralis
Os metacarpale alulare ²¹⁶	Margo caudalis
Proc. alularis	Margo cranialis
Facies articularis alularis	Os metacarpale majus
Proc. extensorius	Sulcus tendinosus
Trochlea carpalis ²¹⁵	Proc. intermetacarpalis ²²¹
Facies articularis radiocarpalis	Protuberantia metacarpalis ²²¹
Facies articularis ulnocarpalis	Os metacarpale minus
Fossa infratrochlearis ²¹⁸	Spatium intermetacarpale
Fossa supratrochlearis ²¹⁹	Extremitas distalis carpometacarpi
Fovea carpalis caudalis ²¹⁷	Symphysis metacarpalis distalis ²²²
Fovea carpalis cranialis ²¹⁷	Sulcus interosseus ²²³
Proc. pisiformis ²²⁰	Facies articularis digitalis major
Corpus carpometacarpi	Facies articularis digitalis minor
Facies dorsalis	

OSSA DIGITORUM MANUS ²²⁴ (**Osteo.** Intro.)

Phalanx digiti alulae	Fossa ventralis
Phalanx proximalis digiti majoris	Pila cranialis phalangis ²²⁵
Facies articularis metacarpalis	Phalanx distalis digiti majoris
Facies articularis phalangealis	Facies articularis metacarpalis
Fossa dorsalis	Phalanx digiti minoris

OSSA CINGULI MEMBRI PELVICI

PELVIS ET OS COXAE ²²⁶ (Figs. 4.9, 15) (For synsacrum see
Columna vertebralis; see below for elements of Os coxae).

Acetabulum ²²⁶	Foramen obturatum ^{227 252}
Foramen acetabuli ²²⁶	Fossa renalis ^{237 250}
Antitrochanter ²³²	Pars ischiadica fossae ²³⁷
Canalis [Sulcus] iliosynsacralis ²³⁴	Pars pudenda fossae ²³⁷
Crista iliosynsacralis ²³³	Recessus caudalis fossae ²⁵⁰
Concavitas infracristalis ²³⁵	Incisura caudalis pelvis ²³⁸
Fenestra ischiopubica ^{229 227}	Incisura marginis caudalis ²³¹
Foramen ilioischadicum ²³⁰	Proc. marginis caudalis ²³¹

OS COXAE ²²⁶ (Figs. 4.9, 15)

ILIUM (Figs. 4.9, 15)

Ala [Pars] preacetabularis ilii ²⁴⁵	Facies renalis ilii
Facies dorsalis	Crista caudalis fossae renalis
Fossa iliaca dorsalis	Margo caudalis ²³⁸
Crista iliaca dorsalis ²⁴⁵	Margo lateralis ²⁴⁷
Crista iliaca lateralis ²⁴⁷	Pila postrenalis ²⁴¹
Facies ventralis	Recessus caudalis fossae ²⁵⁰
Areae articulares vertebrales ²⁴⁶	Spina dorsolateralis ilii ²⁴⁸
Margo cranialis	Corpus ilii ²³⁹
Margo lateralis	Crista iliaca obliqua ²⁴²
Margo medialis [M. vertebralis]	Pila ilioischiadicca ²³⁶
Ala [Pars] postacetabularis ilii ²⁴⁵	Crista iliaca intermedia ²⁴³
Facies dorsalis	Facies renalis ilii
Fossa iliocaudalis ²⁴⁹	Incisura acetabularis ²⁴⁰
Crista dorsolateralis ilii ²⁴⁸	Antitrochanter ²³²
Spina dorsolateralis ilii ²⁴⁸	Facies articularis femoralis
Facies lateralis ²³⁵	Sulcus antitrochantericus ²³²
Crista dorsolateralis ilii ²⁴⁸	Tuberculum preacetabulare [Proc. pectinealis] ²⁴⁴
Lamina infracristalis ilii ^{251 235}	
Concavitas infracristalis ²³⁵	
Margo foraminis ilioischiadici	
Facies ventralis	

ISCHIUM (Figs. 4.9, 15)

Corpus ischii	Proc. obturatorius ²⁵²
Incisura acetabularis ²⁴⁰	Ala ischii
Margo [Incisura] foraminis ilioischiadici	Facies lateralis
Incisura foraminis obturatorii	Facies medialis (Arthr. Annot. 150)
Margo ventralis [M. pubica]	Margo ventralis [M. pubica]
Pila ilioischiadicca ²³⁶	Proc. terminalis ischii ²⁵³
Proc. antitrochantericus ²³²	Sulcus obturatorius ²²⁸
Facies articularis femoralis	

PUBIS ²⁵⁴ (see Os coxae)

Corpus pubis	Scapus pubis ^{5 254}
Incisura acetabularis	Apex pubis (Arthr. Annot. 149)
Tuberculum preacetabulare [Proc. pectinealis] ²⁴⁴	

OSSA MEMBRI PELVICI

FEMUR [OS FEMORIS] (Fig. 4.16)

Extremitas proximalis femoris	Trochlea fibularis ²⁶¹
Caput femoris	Crista tibiofibularis ²⁶²
Facies articularis acetabularis	Crista supracondylaris lateralis
Fovea lig. capitis	Tuberculum m.
Collum femoris	gastrocnemialis lateralis
Facies articularis	Condylus medialis ^{259 264}
antitrochanterica ²⁵⁵	Crista supracondylaris
Trochanter femoris ²⁵⁶	medialis ²⁶⁴
Crista trochanteris	Tuberculum m.
Fossa trochanteris	gastrocnemialis medialis
Impressiones musculares	Epicondylus lateralis
trochanteris ²⁵⁷	Impressio lig. collateralis
Impressiones ligamentosae	lateralis
trochanteris ²⁵⁷	Epicondylus medialis
Corpus femoris ²⁵⁸	Impressio lig. collateralis
Facies caudalis	medialis
Linea intermuscularis	Fossa poplitea
Facies cranialis	Impressiones ansae m.
Linea intermuscularis	iliofibularis ²⁶⁰
Facies lateralis	Sulcus intercondylaris
Facies medialis	Impressio lig. cruciati cranialis
Extremitas distalis femoris	Sulcus patellaris ²⁵⁹
Condylus lateralis ^{259 261}	Facies articularis patellaris
Fovea tendinis m. tibialis	Crista lateralis sulci patellaris ²⁵⁹
cranialis	Crista medialis sulci patellaris ²⁵⁹
Impressio lig. cruciati	Patella ²⁶⁵
caudalis ²⁶³	Facies articularis femoralis
Impressio lig. cruciati	Facies cranialis
cranialis ²⁶³	Sulcus [Canalis] m. ambientis ²⁶⁵

TIBIOTARSUS (Fig. 4.17) (Arthr. Annot. 167)

Extremitas proximalis tibiotalari	Crista patellaris ²⁶⁹
Caput tibiae ²⁶⁶	Facies articularis lateralis ²⁶⁶
Area interarticularis	Facies articularis medialis ²⁶⁶
Crista cnemialis cranialis ^{269 270}	Facies articularis fibularis ²⁶⁷
Crista cnemialis lateralis	Facies gastrocnemialis ²⁷¹

TIBIOTARSUS (Fig. 4.17) (Arthr. Annot. 167) (cont.)

Fossa flexoria ²⁷⁴	Epicondylus lateralis
Fossa retropatellaris ²⁶⁸	Depressio epicondylaris
Impressio lig. collateralis	lateralis ²⁸¹
medialis	Epicondylus medialis
Incisura tibialis ²⁷³	Depressio epicondylaris
Sulcus intercnemialis ²⁷²	medialis ²⁸¹
Corpus tibiotalari ²⁷⁵	Incisura intercondylaris
Crista fibularis (Arthr.	Area intercondylaris (Arthr.
Annot. 162)	Annot. 171)
Facies caudalis	Impressio lig. intercondylaris
Facies cranialis	Sulcus m. fibularis [peronei] ²⁸²
Facies medialis	Trochlea cartilaginis tibialis ²⁷⁹
Linea extensoria ²⁷⁶	Cristae trochleae ²⁷⁹
Lineae m. fibularis [peronei]	Tuberculum retinaculi m.
Margo lateralis [M. fibularis]	fibularis [peronei] ²⁸²
Margo medialis	Sulcus extensorius
Tuberositas poplitea ²⁷⁴	Tuberositas retinaculi extensori ²⁷⁸
Extremitas distalis tibiotalari	(Arthr. Annot. 187)
Condylus lateralis ²⁸⁰	Pons supratendineus ²⁷⁷
Condylus medialis ²⁸⁰	Canalis extensorius ²⁷⁸

FIBULA (Fig. 4.17)

Caput fibulae ²⁶¹	Crista articularis tibialis (Arthr.
Facies articularis femoralis	Annot. 161, 162)
Facies articularis tibialis ²⁶⁷	Tuberculum m. iliofibularis
Fovea m. poplitei	Spina fibulae
Tuberositas lig. collateralis lateralis	Os sesamoideum intertarsale (Arthr.
Corpus fibulae	Annot. 164)

OSSA PEDIS

OSSA TARSII²⁸³

Ossa proximalia tarsi
Tibiale [Astragalus] ²⁸³
Fibulare [Calcaneum] ²⁸³
Os tarsi distale ²⁸³

OSSA METATARSALIA (Fig. 4.18) (Arthr. Annot. 173, 174)

Os metatarsale I [primum] [hallucis] (Arthr. Fig. 5.9) Proc. articularis tarsometatarsalis Trochlea metatarsi I [primi] [hallucis]	Tuberculum laterale Tuberculum mediale Os metatarsale II [secundum] Os metatarsale III [tertium] Os metatarsale IV [quartum]
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TARSOMETATARSUS²⁸⁴ (Fig. 4.18) Arthr. Annot. 173, 174)

Extremitas proximalis tarsometatarsi Area intercotylaris ²⁸⁵ Fovea menisci lateralis Sulcus ligamentosus ²⁸⁶ Cotyla lateralis Cotyla medialis Eminentia intercotylaris (Arthr. Annot. 171) Impressio lig. collateralis lateralis Impressiones retinaculi extensorii Sulcus m. fibularis [peronei] longus Tuberculum m. fibularis [peronei] brevis Hypotarsus ²⁸⁸ (Fig. 4.18) Canales hypotarsi ²⁸⁸ Crista lateralis hypotarsi ²⁸⁹ Crista intermedia hypotarsi ²⁸⁹ Crista medialis hypotarsi ²⁸⁹ Fossa parahypotarsalis lateralis Fossa parahypotarsalis medialis Sulci hypotarsi ²⁸⁸ Corpus tarsometatarsi Facies dorsalis ²⁹² Facies plantaris ²⁹² Crista medianoplantaris ²⁹⁰ Facies subcutanea lateralis ²⁹³ Facies subcutanea medialis ²⁹³	Fossa metatarsi I [hallucis] (Arthr. Annot. 174, 175, 180) Proc. calcaris ²⁹⁶ Fossa infracotylaris dorsalis ²⁹¹ Foramen vasculare proximale (Art. Annot. 79) Tuberositas m. tibialis cranialis ²⁹¹ Sulcus extensorius ²⁹⁵ Arcus extensorius ²⁸⁷ Impressiones retinaculi extensorii Tuberositas m. tibialis cranialis Sulcus flexorius ²⁹⁴ Crista plantaris lateralis ²⁹⁴ Crista plantaris medialis ²⁹⁴ Extremitas distalis tarsometatarsi Canalis interosseus distalis ²⁹⁸ Foramen vasculare distale ²⁹⁸ Fossa supratrochlearis plantaris Incisura intertrochlearis lateralis Incisura intertrochlearis medialis Trochlea metatarsi II [secundi] Foveae ligg. collateralium Trochlea metatarsi III [tertii] Foveae ligg. collateralium Trochlea metatarsi IV [quarti] Foveae ligg. collateralium Trochlea accessoria ²⁹⁷ Os cuneatum (Arthr. Annot. 182)
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OSSA DIGITORUM PEDIS²⁹⁹

Phalanges proximales et intermediae Basis phalangis Cotyla articularis Corpus phalangis Facies dorsalis Facies plantaris Capitulum phalangis Trochlea articularis Fovea lig. collateralis Phalanx ungualis [terminalis] ³⁰⁰	Basis phalangis Cotyla articularis Tuberculum extensorium (Arthr. Annot. 183) Tuberculum flexorium (Arthr. Annot. 182) Corpus phalangis Sulcus neurovascularis ³⁰⁰ Apex phalangis
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ANNOTATIONS

(1) **Cotyla.** (Cotyla, Gk. cup). In this work "cotyla" is used for a shallow concave articular surface (Howard, 1929; Lambrecht, 1933).

(2) **Cartilago epiphysialis; Epiphysis; Diaphysis; Metaphysis.** During development and growth of a long bone, ossification begins in the middle of the shaft (Diaphysis), and extends proximally and distally by growth of ossifying zones (Metaphysis) into the cartilaginous end (Epiphysis). The epiphyses of birds, unlike mammals, do not ossify endochondrally from separate centers of ossification, but only by extension from the metaphysial centers.

(3) **Os pneumaticum.** Bone invaded by air sacs; the sacs are outgrowths of the lungs, tympanic cavity, or nasal cavity.

Foramen pneumaticum; Pori pneumatici. In the paleontological literature the foramina are commonly known as "pneumatopores". The skull, vertebrae, and bones of limb girdles are usually pneumatic; limb bones are variably pneumatic in different taxa of birds. Pneumaticity usually involves only the proximal elements of the limb, but in some forms may extend into its distal extremity. Since pneumaticity is so widespread in the skeleton, the foramina and smaller pores are listed only for the bones in which they form especially distinctive features. See Annot. 6 and Resp. Annot. 70, 75-77.

(4) **Pila** (L. pillar or column). Pila refers to a reinforcing element of a bone that may form a distinct, prominent bar, or may be a thickening that blends almost imperceptibly into the bone of which it is a part.

(5) **Scapus** (L. shaft, stem). Used in this work to refer to a slender, attenuated bone or part of a bone in the instances that "corpus" (body) is not applicable (e.g., clavicle, pubis). See *Integ. Partes pennae* for another usage of Scapus.

(6) **Os medullare.** Female birds are unique in possessing a special system of highly labile, secondary (medullary) bone within the marrow cavities of much of the skeleton during the reproductive period. This bone grows as spicules into the medullary cavity from the endosteal surface, serving as a labile reserve of mineral that can be mobilized to provide calcium for egg shell formation. Taylor, et al. (1971) present an extensive review of medullary bone (see also Hodges, 1974).

Os spongiosum. Spongy bone (also known as trabecular or cancellous bone) is found throughout the avian skeleton. In early postnatal life the spongy bone of the Calvaria (*Diploë*), vertebrae, limb bones, etc. is filled with red marrow (see Hodges, 1974). Later the red marrow is replaced by fatty marrow or by pneumatic mucosal diverticula invading the bones from the nasal or tympanic cavities (Stork, 1972; Warnke and Stork, 1977; Witmer, 1990) or lungs and air sacs.

The *Cellulae pneumaticae* are cavities or spaces, lined with mucosa, that are smooth-walled, e.g., long bones and skulls of nestlings, or highly strutted as in the skulls of adult birds. See Annot. 189; *Resp.* Annot. 21, 70, 72, 75-77.

(7) **Tuberositas.** (*L. tuberosus*, full of lumps). In anatomical usage "Tuberositas" usually refers to a roughened or knobby area of bone for attachment of tendons or ligaments (Donath and Crawford, 1969).

(8a) **Facies; Cranium.** Following the *Nomina Anatomica Veterinaria* (ICVGAN, 1983), "Facies" is used in this work for the facial skeleton ("splanchnocranium"), and "Cranium" refers to the part of the head skeleton enclosing the brain ("neurocranium").

(8b) **Ginglymus craniofacialis [G. nasofrontalis].** This term is treated with the flexible zones of the skull in *Arthr.* Annot. 46.

(9) **Fenestra antorbitalis** (Heilmann, 1926). Synonymy: antorbital vacuity (Shufeldt, 1909); Hiatus orbitonasalis (NAA, 1979). When the skull is viewed from the side, this is the pronounced gap, often triangular, bounded by the nasal process of the maxillary bone, the maxillary process of the nasal bone, the jugal and lacrimal bones, closed by skin laterally (Fig. 4.1). It represents the antorbital vacuity of archosaurian reptiles (Witmer, 1987).

Fossa antorbitalis [*F. infraorbitalis*]. The antorbital fossa is the space medial or deep to the Fenestra antorbitalis which houses the Sinus antorbitalis [Sinus infraorbitalis] (see *Resp.* Annot. 17), an evagination of the nasal cavity. The osseous walls of the Fossa are variable; often the palatine process of the maxilla, the palatine bone, and the ectethmoid contribute to its walls (Witmer, 1987). Witmer maintains that the antorbital fenestra and fossa are completely homologous with those of non-avian archosaurs. Fossa infraorbitalis is retained as an alternative term because of its widespread use.

(10) **Hiatus craniofacialis septi.** Synonymy: Fissura craniofacialis (Hofer, 1955). In the dried skull, the hiatus is the interval between the rostral edge of the interorbital septum and the caudal border of the osseous nasal septum in birds having such a septum (e.g., *Anser*). The hiatus is completed by a septum of cartilage in intact specimens (Butendieck, 1980). Bühler, et al. (1988) state that this hiatus is characteristic of all modern prokinetic birds as well as many neognathine rynchokinetic birds. Paleognathines have a continuous nasal/interorbital septum. See Annot. 55.

(11) **Arcus jugalis.** Synonymy: Arcus zygomaticus. The jugal arch is a slender, generally straight, bar that connects the upper jaw with the quadrate bone (Figs. 4.2, 4); exceptions include a strongly sigmoid shape in some penguins and a laterally bowed shape in *Nyctibeus* and *Caprimulgus*. The arch consists of three ankylosed elements: Proc. jugalis of Os maxillare, Os jugale proper, and Os quadratojugale. See *Arthr.* Intro.

(12) **Apertura nasi [nasale] ossea.** Synonymy: Naris. The shape of the nasal aperture (schizorhinal, holorhinal) is related to kinesis of the upper jaw (see Garrod,

1873; Hofer, 1955; Bock, 1964; Yudin, 1965; the reviews of Bühler 1981 and Zusi 1984). Some peleciform, sphenisciform, and other birds have paired, minute osseous apertures of the nasal cavity. See *Resp.* Annot. 1; *Arthr.* *Zonae flexoriae*.

Pila supranasalis. The median column of bone making up the dorsal border of the external nares; formed by processes of the nasal and premaxillary bones. See *Arthr.* Fig. 2.

(13) **Fenestra palatina.** Synonymy: Fonticulus palatinus (Hofer, 1949). Oval or elongate opening in the rostral part of the bony palate between the two premaxillae. In birds such as *Strix*, *Gallinula*, and anseriforms, the fenestra is set off distinctly from the more caudal **Fissura interpalatina**. The two are confluent in, e.g., *Diomedea*, *Cathartes*, and *Larus*.

(14) **Depressio frontalis.** The frontal region (forehead) of the skull in some birds (e.g., *Ardea*, *Anser*) is indented by this shallow, longitudinal concavity (Fig. 4.6); in other birds the frontal region may be flat or dorsally convex.

Crista frontalis interna. Median crest on the interior of the vault of the calvaria extending from the fossa of the olfactory bulb to the upper end of the cerebellar fossa.

(15) **Fossa glandulae nasalis.** In certain birds the Glandula nasalis (so-called "salt gland") occupies a pronounced depression on the dorsal aspect of the supraorbital margin of the orbit, involving mostly the frontal bone (e.g., penguins, albatrosses, loons, gulls). In others (e.g., peleciforms, grebes) the gland is intraorbital, i.e., ventral to the supraorbital wall of the orbit there occupying the shallow **Impressio gl. nasalis** (see Siegel-Causey (1990).

(16) **Calvaria.** The so-called cap or dome of the skull.

Prominentia cerebellaris (Shufeldt, 1909). The external, median convexity of Os supraoccipitale and Os parietale in the nuchal region of the skull dorsal to the Foramen magnum (Figs. 4.4, 5). The prominence overlies the dorsum of the Cerebellum, reflecting its contour externally, e.g., *Buteo*, *Columba*, *Corvus*, and trochilids. See Annot. 17.

(17) **Crista [Linea] nuchalis sagittalis.** This median crest is dorsal to the Foramen magnum, and provides attachment for the sheet of deep fascia separating the right and left columns of dorsal neck muscles. The Crista surmounts the Prominentia cerebellaris in some forms (e.g., *Gavia*, *Morus*).

Crista [Linea] nuchalis transversa. Synonymy: Crista temporalis (Hofer, 1945); Crista occipitalis (Davids, 1952). Arched, usually distinct, crest separating the nuchal plane of the supraoccipital bone (for attachment of the neck muscles) from the smoother part of the calvaria (parietal and squamosal bones) farther rostrally (Figs. 4.1, 5). This crest may extend caudolaterad to reach Proc. paroccipitalis (Annot. 85) (Figs. 4.2, 3).

(18) **Foramen magnum.** Synonymy: Foramen occipitale magnum. The opening in the base of the skull that transmits the spinal cord and its meninges; it is bounded by the supra-, ex-, and basioccipital bones. Duijm (1951) reviewed the position and plane of the Foramen magnum in the major skull types of birds.

(19) **Meatus acusticus externus.** Synonymy: Fossa auricularis cutanea (Freund, 1926). The wall of the Meatus is formed mostly by cutaneous, fibrous, and cartilaginous tissues. The osseous wall of the Meatus is formed by the parasphenoid ala (Annot. 20), lateral margin of the paroccipital process, and **Crista tympanica** of the body of the quadrate bone (see *Arthr.* Annot. 37).

(20) **Hiatus subtympanicus**. Synonymy: Hiatus alae tympanicae (NAA, 1979). Deficiency (notch or fenestra) in the junctional area between the Ala parasphenoidalis and the margin of Proc. paroccipitalis that partially bounds the external acoustic meatus. See Annot. 19, 84.

(21) **Cavum tympanicum [Cavitas tympanica]**. The middle ear cavity consists of a shallow, open concavity in the dried skull. Owing to the placement of Membrana tympanica, only the ventral part of the osseous concavity is tympanic cavity proper; the caudodorsal part is Meatus acusticus externus (Freund, 1926). See Annot. 19.

(22) **Recessus columellae** (new term). [**Recessus antevestibularis**] (NAA, 1979); Synonymy: Antivestibulum (Magnus, 1870); Recessus cavi tympani (Hasse, 1871); Recessus stapediae (Stresemann, 1934). "Recessus columellae" replaces Recessus antevestibularis which is retained as an alternative. "Recessus columellae" is a more descriptive memory aid since this evagination of the tympanic cavity houses the basal portion of the ear ossicle (Columella) (Fig. 4.3) in the complex of otic bones. Fenestra vestibuli, Fenestra cochleae, and Recessus tympanicus caudalis open into the recess of the columella (see Annot. 26); the recess is lacking in certain birds, e.g., diomedeids, Mesozoic birds (Witmer, 1990); shallow in *Larus*, but relatively deep in others (e.g., *Gallinula*, *Gallus*, *Strix*, *Ceryle*).

Fenestra cochleae [F. pseudorotunda]. Synonymy: Fenestra rotunda. Opening within Os opisthoticum (Fig. 4.3), closed in life by Membrana tympanica secundaria. The avian and mammalian fenestrae are considered nonhomologous (de Beer, 1937); hence the term Fenestra pseudorotunda.

Fenestra vestibuli. Synonymy: Fenestra ovalis. This opening into the vestibule of the osseous labyrinth is occupied by the footplate (base) of the Columella (see Sens. Fig. 16.7).

(23) **Recessus pneumatici paratympatici** (Resp. Annot. 21). Collective term for the three major, consistently occurring, air filled evaginations of the tympanic cavity into the surrounding bones; namely, the rostral, caudal, and dorsal tympanic recesses. The openings or ostia by which the sinuses communicate with the tympanic cavity are called **Foramina pneumatica** (see Witmer, 1990). Among the several putative functions of the pneumatization of the skull of birds, Warnke and Stork (1977) suggest thermoregulation and insulation.

(24) **Pila otica** (new term). Synonymy: opisthotic columella (Lowe, 1926); Pila prootica (NAA, 1979). This usually short pillar of bone articulates with the quadrate bone (see below); since it ossifies with varying contributions from the opisthotic and prootic bones, its name has been simplified to Pila otica. The pila intervenes between the foramen of the dorsal tympanic recess and Recessus columellae (Fig. 4.3; Annot. 22).

Cotyla quadratica otici. Cup-shaped surface of the otic complex for articulation with the otic capitulum of the quadrate bone (Fig. 4.3). The cotyla is largely prootic in most birds with some contribution from the opisthotic. In some birds, the cotyla is partly located on the free end of the Pila otica. See paragraph above and Annot. 100.

(25) **Recessus tympanicus dorsalis** (Resp. Annot. 21). Synonymy: Recessus tympanicus superior (Suschkin, 1899; Pycraft, 1902; Müller, 1963); Antrum pneumaticum dorsale (NAA, 1979). The **Foramen pneumaticum dorsale** leading to the dorsal tympanic recess is located near the squamosal and otic articular facets for the quadrate bone (Fig. 4.3). Diverticula from this recess invade the prootic, squamosal, parietal and occipital bones.

(26a) **Recessus tympanicus rostralis** (Resp. Annot. 21). Synonymy: Recessus tympanicus anterior (Parker, 1869; Suschkin, 1899; Pycraft, 1902; Müller, 1963); pre-sphenoid sinus (Saiff, 1974); Antrum pneumaticum rostrale (NAA, 1979).

Foramen pneumaticum rostrale of the rostral recess is located in the rostroventral part of the tympanic cavity, dorsal to the ostium of the auditory tube, and dorsolateral to the bony Canalis caroticus cranialis (see Figs. 4.2, 3, 5; Annot. 99). Diverticula from this recess invade the base of the skull (parasphenoid bone).

(26b) **Recessus tympanicus caudalis**. (Resp. Annot. 21) Synonymy: Recessus tympanicus inferior (Müller, 1963); Antrum pneumaticum caudale (NAA, 1979). The **Foramen pneumaticum caudale** connects this recess with the columellar recess or the caudal part of the tympanic cavity. The Recess is ventrolateral to the rostral semicircular canal, and sends diverticula into the exoccipital bone.

(27) **Canalis ophthalmicus externus**. Synonymy: Canalis facialis; Canalis stapediae. The canal conducts the A. et V. ophthalmica externa, and in some forms, the Chorda tympani of N. facialis. The caudal ostium of the canal is located in the Fossa parabasalis on the external skull base (Figs. 4, 5). The canal arches dorsal to the Columella then rostrally; its lateral wall may project in relief into the tympanic cavity, or may be incompletely ossified so that the lumen of the canal is visible in the dried skull. The rostral opening of the canal is medial to the otic process of the quadrate, lateral to Foramen n. maxillomandibularis.

(28) **Basis cranii externa**. Synonymy: basicranium. In this work "Basis cranii externa" is defined as limited to the exterior aspect of the bones forming the floor of the cranial cavity proper; thus Basis interna and externa of the cranium are opposites that correspond in area to one another. In some birds the cerebral surface of the base of the cranium is widely separated from the external surface by pneumatic spaces, evaginations of the tympanic cavity.

(29) **Orbita**. The osseous orbit of birds is bounded mainly by cranial bones. In most birds the floor of the orbit is not bone, but consists mainly of jaw muscles. Exceptions are the snipes and woodcocks (Scolapacidae) in which the orbit is almost completely enclosed by bone (Hofer, 1955). See Annot. 30.

Fonticuli interorbitales; Fonticuli orbitocraniales. Synonymy: Fonticuli orbitales, Barkow (1856); Foramina obturata orbitalia. In the dried skull these are unpaired deficiencies in the bone of the interorbital septum or paired ones in the caudal wall of the orbit; the latter communicate with the cranial cavity (Figs. 2, 3, 6). In intact specimens the fonticuli are closed by fibrous membranes.

(30a) **Proc. postorbitalis**. Synonymy: Proc. orbitalis posterior; Proc. postfrontalis. In most carinate birds, and the ratite *Rhea*, the postorbital process is formed largely by Os laterosphenoidale; Os squamosal (e.g., some galliforms) or Os frontale (*Struthio*) contribute to the base of the Proc. postorbitalis. Consult Müller (1963: 81) for discussion of the postorbital process.

The postorbital process commonly forms the caudoventral border of the orbit (Figs. 4.2, 5); however, in certain birds (e.g., anseriforms) it projects rostrally and contributes to the ventral margin of the orbit (see below, Arcus suborbitalis). The tips of Proc. postorbitalis and Proc. zygomaticus are joined in some birds (e.g., psittaciforms and galliforms). See below and Annot. 108.

(30b) **Arcus suborbitalis** (Portmann, 1950). A complete osseous arch bounds the orbit ventrally in some psittaciforms, scolopacids (Gadow and Selenka, 1891), and the anatid, *Dendrocygna* (Shufeldt, 1909). This arch is formed by junction of a lengthy caudal extension of Os lacrimale and the rostral extension of the Proc. postorbitalis or the postorbital/zygomatic complex; in other birds these structures form an arch connected by Lig. suborbitale (Arthr. Annot. 30).

(31) **Foramen orbitonasale laterale/mediale**. Longitudinal opening(s) between the orbital surface of Os frontale and the dorsal border of Os ectethmoidale. A single slit-like foramen is present in some birds (e.g., *Ardea*, *Aythya*); both medial and lateral foramina are found in other birds (e.g., *Columba*, *Gallus*, *Coragyps*, *Corvus*.) The medial foramen (Fig. 4.1) conducts N. olfactorius and the medial ramus of N. ophthalmicus from orbit to nasal cavity; the lateral foramen conducts the lateral ramus of N. ophthalmicus and duct(s) of Glandula nasalis.

Sulcus n. olfactorii. Longitudinal groove for the olfactory nerve and ethmoid artery; located in the angle between the upper part of the interorbital septum and the Lamina dorsalis of Os mesethmoidalis which is applied to the roof of the orbit (see Fig. 4, 1; Annot. 108).

(32) **Foramen opticum**. Located in the boundary zone between the caudal edge of the interorbital septum and the caudal wall of the orbit (Figs. 6, 2, 3). The foramen in carinates is usually a single opening inside the cranial cavity, but the foramen is divided by the relatively thin interorbital septum into a pair of closely related foramina, one in each orbit. In some psittaciforms (pers. obs.) and cardueline finches (Zusi, 1978) the two optic foramina are widely separated from one another by a thick septum. In other birds the optic foramina may be continuous with the Fonticuli orbitocraniales and other foramina (Annot. 29, 88).

(33) **Septum osseum fossae bulbi**. The fossa for the olfactory bulb is divided by a bony septum in *Apteryx* (Starck, 1955) and in the albatross (*Diomedea* sp.) and psittacids.

(34) **Foramen ethmoidale**. Transmits A. et V. ethmoidalis into the orbit from the cranial cavity; separate openings for the artery and vein are present in some birds. See Annot. 31.

(35) **Fossa cranii media**. Synonymy: Fossa mesencephalica. The middle cranial fossa houses the Diencephalon and Chiasma opticum medially and the Tectum mesencephali on each side. The Fossa is not homologous with the middle cranial fossa of mammals. See Os basisphenoidale and Os laterosphenoidale for additional terms.

(36) **Crista marginalis**. This crest separates each side of the **Fossa cerebelli** from the general chamber of the vault of the calvaria that houses the telencephalic hemispheres of the brain.

(37) **Tuberculum pineale**. On the internal surface of the Calvaria the Tuberculum pineale is a triangular eminence at the junction of Crista frontalis interna with the marginal crests of the cerebellar fossa. The dorsal expanded end of the body of Glandula pinealis is closely related to the Tuberculum.

(38) **Fossa auricularae cerebelli**. Synonymy: Fovea hemispherii cerebelli; Fossa subarcuata. The fossa in birds contains the cerebellar auricle (Fig. 4, 6). "Subarcuate fossa" is inappropriate, since in mammals it lodges the endolymphatic sac; therefore the avian and mammalian fossae are non-homologous. See Ven. Annot. 35.

(39) **Fovea ganglii vagoglossopharyngealis**. In the floor of the caudal fossa of the cranium, the fovea (pit) is located in the suture between the exoccipital and opisthotic bones; the fovea houses the combined proximal [root] ganglia of the X and IX cranial nerves (Fig. 4.6). Separate foramina for each nerve are found in the bottom of the fovea that lead to the parabasal fossa on the external skull base (Figs. 4.4, 5). See Annot. 86; and PNS.

(40) **Rostrum [Symphysis] mandibulae** (new term). (Rostrum, L. beak or prow). The rostrum is the pointed, apical region of the mandible formed by the union of the symphyseal segments of the right and left mandibular rami. Although this region of ankylosis of the mandibular rami is commonly called the "mandibular symphysis", in the strict sense, the symphysis is the actual joint connecting the two. See Annot. 42; Arthr. Annot. 21. and Topog. Annot. 12.

Rostrum maxillae (new term, R. Zusi, pers. comm.). This is the pointed, apical region of the upper jaw formed by the ankylosis of the bodies of right and left premaxillary bones that corresponds to the Rostrum mandibulae (Fig. 4.2). See Topog. Annot. 12.

(41) **Foveae corpusculorum nervosorum**. In the bones of the maxilla and mandible these small pits deep to the rhamphotheca house sensory corpuscles (Fig. 4.2); the foveae are especially numerous and conspicuous in the rostra of the upper and lower jaws of *Apteryx*, ibis and spoonbills, anseriforms, and sandpipers and snipes (Scolopacidae). See Annot. 57 and Sens. Annot. 66.

(42) **Pars symphysealis/intermedia/caudalis** (Lebedinsky, 1920). The symphyseal part of the mandibular ramus is the rostral segment that unites with the opposite ramus at the Symphysis mandibularis (see Annot. 40 and Arthr. Annot. 21 and Fig. 4.4). Pars intermedia extends caudally to Zona flexoria intramandibularis caudalis which is often marked by the **Fenestra rostralis mandibulae**. Pars caudalis extends from the caudal flexion zone to the retroarticular process, and includes the area of attachment of the jaw muscles, facets for articulation with Os quadratum, and Fenestra caudalis mandibulae in birds that have dual fenestrae on each side (Annot. 46). See Arthr. Annot. 46-48.

The Ramus mandibulae is peculiar in caprimulgids in that the rostral, attenuated one-third is set off by an oblique, moveable syndesmotomic joint from the bowed, stronger rear two-thirds.

(43) **Angulus mandibulae**. This is the point on the dorsal border of the Ramus mandibulae where the ramus becomes angulated or curved ventrally (e.g., charadriiforms, caprimulgiforms, columbiforms, falconiforms, and passerines). See Annot. 56. The angle marks the caudal extent of the rhamphothecal sheath covering the exposed part of the mandible.

(44) **Proc. coronoideus**. Synonymy: Proc. pseudocoronoideus; Proc. m. adductor mandibulae. Any process of Pars caudalis of the mandible to which is attached the strong "aponeurosis" of M. adductor mandibulae externus, pars rostralis (Myol. Annot. 18). In different birds it is commonly found on the dorsal margin of the mandible, often coincident with the Angulus mandibulae (Johnson, 1984); it may, however, be located on the lateral surface of the mandible as in anseriforms (Zweers, 1974). See Figs. 4.1, 2.

In finches, processes for the insertion of aponeuroses of M. adductor mandibulae externus "profundus" also occur caudal to Proc. coronoideus (Richards and Bock, 1973) (see Myol. Annot. 18).

(45) **Tuberculum pseudotemporale**. Synonymy: Proc. pseudotemporalis. The pseudotemporal tubercle which is located slightly rostral to the quadratomandibular joint near the base of Proc. medialis mandibulae (Fig. 4.1) is the point of insertion of the tendon of *M. pseudotemporalis superficialis* (Myol. Annot. 19). The tubercle is prominent in heavy-billed finches.

(46) **Fenestrae mandibulae**. Synonymy: Foramen mandibulare anterior; Foramen mandibulare posterior (Lebedinsky, 1920); Foramen ovale; interangular vacuity or fenestra (Shufeldt, 1909). **Fenestra rostralis mandibulae** is found in the region of the caudal intramandibular flexion zone (Arthr. Fig. 2); **Fenestra caudalis mandibulae** occurs in Pars caudalis of the mandibular ramus (see Annot. 42, 48). The fenestrae may be completely lacking in some taxa. Other birds may possess only one of the fenestrae (e.g., *Columba*). Two fenestrae occur in certain birds (e.g., some charadriiforms, gruiforms, psittaciforms, and strigiforms). Consult Lebedinsky (1920) for details.

(47) **Canalis neurovascularis mandibulae**. Synonymy: The canal conducts vessels and the intramandibular ramus of the mandibular nerve from the region of the coronoid process to the symphyseal region of Ramus mandibulae. See Annot. 48.

(48) **Fossa aditus canalis neurovascularis**. Synonymy: Fossa medialis mandibulae (Johnson, 1984). Depression on the internal aspect of Pars caudalis of the mandibular ramus that leads to the aditus or opening of the mandibular canal. The floor of the fossa often consists of thin bone, and may exhibit an opening(s), Fenestra caudalis mandibulae. The fossa is pronounced and extensive in many birds (e.g., *Pygoscelis*, *Gavia*, *Cathartes*, *Anser*).

Fossa lateralis mandibulae (Johnson, 1984). Shallow depression on the lateral aspect of the mandibular ramus at or near its rostral fenestra, e.g., *Diomedea*, *Larus*.

(49a) **Fossa articularis quadratica**. Area of the mandible for articulation with the condyles of Proc. mandibularis of Os quadratum (see Fig. 4.3; Annot. 72).

Cotylae fossae articularis. These are the facets for articulation with the condyles of the Os quadratum. The medial cotyla is separated from the others (see below); however, the lateral and caudal cotylae are merged into a common articular surface in some birds (e.g., *Larus*); distinct in others (e.g., *Ardea*, *Morus*).

Sulcus intercotylaris; Tuberculum intercotylare (Johnson, 1984); [**Crista intercotylaris**] (Zusi, 1987). The groove, boss of bone, or bony crest in the articular fossa of the mandible of different birds; these structures separate the medial and lateral cotylae (Fig. 4.3). The tuberculum is especially prominent in psittacids.

(49b) **Proc. retroarticularis**. Synonymy: Proc. mandibularis posterior (Lebedinsky, 1920); Proc. angularis posterior (Hofer, 1945); postarticular process. This process projects caudally past the articular fossa of the mandible; formed mainly by the **Os angulare** to the rear of Proc. lateralis mandibulae. Weakly developed, pointed, or stubby in most birds, the retroarticular process is prominent, e.g., in galliforms, ciconiiforms, psittaciforms, anseriforms and phoenicopterids (Arthr. Fig. 5.2D); in the last two taxa the process is attenuated and blade-like. The Proc. retroarticularis is also well developed in birds that forcefully open the jaws while foraging, probing into flowers or fruit (Zusi, 1967). Well developed in *Aechmophorus*, but not in other grebes (R. W. Storer, pers. comm.). See Annot. 50, 51.

Incisura retroarticularis (Johnson, 1984). In lateral view of the caudal segment of the mandibular ramus, this is a notch between the Proc. lateralis mandibulae and the retroarticular process; the incisura is the notched edge of the lateral cotyla.

(49c) **Foramen pneumaticum articulare**. An opening in the upper surface of Proc. medialis mandibulae (formed by **Os articulare**) that leads to pneumatic spaces in the caudal segment of the mandibular ramus (Figs. 4.1, 3); the lower jaw of some birds is extensively pneumatic (e.g., flamingos, hornbills, toucans).

The **Siphonium** is a connective tissue tube, ossified in some birds (e.g., *Corvus*), that connects the pneumatic foramen of Os articulare with the mandibular diverticulum of the tympanic cavity. See Cavum tympanicum; and Witmer (1990).

(49d) **Proc. medialis/lateralis mandibulae**. Both of these are processes of Pars caudalis of the mandible (mainly Os articulare); Proc. medialis mandibulae (Figs. 4.1, 3) is much the stronger of the two; it projects medially with its tip curved dorsally (exception: psittaciforms)(see below). The weak lateral process forms part of the cotyla for the lateral condyle of the quadrate bone; in some birds it is the attachment of Lig. postorbitale (Arthr. Annot. 42). See also Arthr. Annot. 32.

Facies articularis parasphenoidalis. In certain birds this articular surface near the tip of the Proc. medialis mandibulae forms a joint with the lateral or medial parasphenoidal process of Lamina parasphenoidalis of the external base of the skull (see Annot. 96 and Arthr. Annot. 32).

(50) **Recessus conicalis**. Synonymy: Fossa conicalis (Shufeldt, 1909). Recessus posterior (Lebedinsky, 1920); Cavum mandibulare (Zweers, 1974). In anseriform birds this is an unusual, deep recess ventral to the medial cotyla of the quadratomandibular joint. Its opening is located between the blade-like Proc. retroarticularis and Proc. medialis mandibulae. A somewhat similar deep recess is present in certain psittaciforms, however its opening faces dorsally rather than caudally. See Annot. 51.

(51) **Fossa caudalis**. Synonymy: Fossa posterior (Lebedinsky, 1920); postarticular surface (Milne-Edwards, 1867-71). In birds of many different taxa this term refers to the shallow concavity of the caudal surface of Proc. mandibulae medialis, located medial to the retroarticular process (Fig. 4.1). This is the area for insertion of *M. depressor mandibulae* (Myol. Annot. 24); (Arthr. Annot. 37). See Lebedinsky (1920) for a detailed, comparative account of Fossa caudalis in numerous avian taxa.

Crista transversa fossae (new term). This distinct transverse crest extends from the Proc. medialis mandibulae to Proc. lateralis mandibulae (Fig. 4.3). The crest separates two different fossae; it forms the caudal wall of the articular fossa for Os quadratum, and its rear surface is the upper part of Fossa caudalis (see above). The crest, which exhibits a distinct tubercle in some birds, is an attachment of Membrana postmeatica and Lig. occipitomandibulare. See Arthr. Annot. 37.

(52) **Ossa mandibulae**. Each ramus of the mandible is considered to consist of seven separate bones. Different names for the various elements abound in the literature. The tabular synonymy compiled by Müller (1963) is summarized below; terms selected by him are followed in this present terminology with one exception. Os coronoideum is not ordinarily present in birds.

Os dentale. Synonymy: dentary; dentosplenial; mentomandibulare. This is the principal element of each mandibular ramus (Fig. 4.1); it articulates with the supraangular and splenial elements at the junction of intermediate and caudal segments of the ramus. **Os articulare** forms most of Fossa articularis quadratica. See Lebedinsky (1920) and Jollie (1957) dealing with the mandible of carinates, and Müller (1963) regarding the ratite mandible.

Os prearticularis. Synonymy: Os goniale; **Os coronoideum**, Synonymy: Os complementare; **Os spleniale**, Synonymy: Os operculare; **Os supra-angulare**, Synon-

ymy: surangulare. **Os mentomandibulare.** According to Romanoff (1960:995) paired mentomandibular elements replace the cartilage at the mandibular symphysis, then ankylose with one another.

(53) **Os maxillare; Maxilla.** As an individual bone, *Os maxillare* is one of the components of the avian upper jaw. As a general term, "Maxilla" refers to the entire complex of structures that make up the upper jaw; i.e., the opposite of "Mandibula", the lower jaw (see Annot. 40 and **Topog.** Annot. 8).

(54) **Proc. maxillaris** Synonymy: *Proc. postnarialis* or *P. subnarialis*. **Proc. premaxillaris.** Synonymy: *Proc. dorsonarialis*. Process of the nasal bone.

(55) **Septum nasi [nasale] osseum; Conchae nasales.** These structures may be supported in part by the vomer, maxilla, and ectethmoid bones. The rostral part of the nasal septum and nasal conchae in the caudal part of the nasal cavity vary in the extent that they ossify in different birds, usually remaining more or less cartilaginous. These structures characteristically ossify extensively in, for example, *Diomedea*, some parrots, birds of prey (*Buteo*, *Strix*), herons and ibis (*Ardea*, *Eudocimus*), pelecaniiforms, trochilids, *Coccyzus*, some coraciiforms, and passeriforms. See Annot. 10; **Resp.** Annot. 6-9.

(56) **Crista tomialis.** Synonymy: tomial shelf (Johnson, 1984). The paired sharp edges of the upper and lower jaws (Figs. 4.2, 4). Hard keratinized rhamphotheca invests the crests from the tips of the rostra of mandible and maxilla caudally to the level of the *Angulus mandibulae*. See Annot. 43, 44; **Integ.**

(57) **Canalis neurovascularis maxillae.** Paired longitudinal canal that conducts the terminal branch of *N. ophthalmicus* and accompanying vessels from the rostral end of the nasal cavity into the *Rostrum maxillae* (Annot. 40) of the upper jaw (mainly in *Os premaxillae*). The canal is relatively long, e.g., in a heron or duck, quite short in a gull or vulture.

In birds with large maxillary bones (e.g., *Anas*, *Anser*, *Larus*, and *Hesperornis*) a separate neurovascular canal enters the maxilla near its junction with the jugal arch; this canal conducts parts of the nasopalatine branch of *N. maxillaris* to openings on both medial and lateral sides of the caudolateral maxillary tomial crest and adjacent palate (see below).

Foramina [Pori] neurovascularia. The ramifications of the branches of the ophthalmic and nasopalatine nerves (and companion vessels) leave their neurovascular canals (Fig. 4.2) via smaller **Canaliculi neurovasculares** that open on the surface of the bone of the upper jaw via foramina (pores) deep to the rhamphotheca (especially in the *Rostrum maxillae*). The foramina often open into **Foveae corpusculorum nervosorum**, pits or hollows beneath the rhamphotheca which house sensory corpuscles; the foveae are remarkably abundant in *Capella*. See Annot. 41; and **Sens.** Annot. 70.

(58) **Proc. maxillopalatinus [Proc. palatinus].** This process of *Os maxillare* in many birds arises from the maxilla near its junction with *Proc. maxillaris* of *Os palatinum* (Figs. 4.1, 4; Annot. 64). The maxillopalatine process of different birds exhibits a variety of orientations and configurations largely due to variation in the form of the maxillary diverticulum of the antorbital sinus (Witmer, 1990); it contributes to the formation of the nasal cavity in most birds and to the palate in the birds such as anseriforms, ciconiiforms, and passeriforms (see Hofer, 1949). In anseriforms the right and left maxillopalatines are synostosed in the median plane.

(59) **Proc. jugalis.** This process of *Os maxillare* has also been called *Proc. labialis* (see Annot. 11).

(60) **Os palatinum [Os pterygopalatinum]** (see Annot. 61 and Fig. 4.4, 7). Four features of the palatine bone are common to most birds: **Pars choanalis** which is associated with the Fossa choanalis (see below, this annot.); (2) **Pars lateralis** (see next paragraph) which is generally lateral to *Pars choanalis*, is associated mainly with the attachment of *M. pterygoideus*; (3) **Proc. maxillaris** (synonymy: *Proc. premaxillaris*, NAA, 1979; *prepalatine*, Parker, 1879), connected to the maxilla, is usually a slender bar which, in all neognathines, has a bending zone (*Zona flexoria palatina*, see **Arthr.**); (4) **Proc. pterygoideus** (synonymy: *postpalatine*, Parker, 1879) connects the palatine with the pterygoid bone, and may include a fused portion of *Os pterygoideus* (see Annot. 61). Certain features listed under *Pars choanalis* and *Pars lateralis* are absent in some birds; Parker (1879), Hofer (1945), and Richards and Bock (1979) discuss the variety of shapes and relationships of palatine bones in different avian taxa, and include other palatine features not presented in this terminology. Ziswiler (1985) provides a concise summary on types of avian palates; see Witmer and Martin (1987) for a critique of palatal typology.

Pars lateralis (Fig. 4.7) in part replaces the term "*Lamella caudolateralis*" of the NAA (1979), a term derived from *Proc. posterolateralis* of (Beddard, 1898; Hofer, 1945; and Bühler, 1970); **Lamella caudolateralis** is retained as an alternative (bracketed) term in the present edition. *Pars lateralis* is usually a flared plate facing ventrally in some birds, obliquely ventromedially in others, and medially as in psittacids (Beddard, 1898). *Pars lateralis* is convoluted in *Fulica*, and extremely expanded laterally in caprimulgids.

Fossa choanalis (Fig. 4.7). Synonymy: *Fossa medialis* (NAA, 1979). Paired, shallow furrow between the medial and ventral crests of **Pars choanalis** of *Os palatinum* (Fig. 4.4); the furrow faces medially, forming the lateral wall of the chamber of the Choana which connects nasal cavity with oropharynx (see Annot. 64; and **Resp.** Annot. 5).

(61) **Os pterygoideum** (Figs. 4.4, 2, 5). **Pars palatina** of *Os pterygoideum* that joins *Os palatinum* (Annot. 60) is also known as the antero-, hemi-, or mesopterygoid (Parker, 1879; Pycraft, 1900; Jollie, 1957). Bühler, et al. (1988) indicate that most modern prokinetic neognathines have this palatal ontogeny wherein an "intrapterygoid" joint forms between *Pars palatina* and the rest of the pterygoid bone from which it was detached in early postnatal life (see **Arthr.** Annot. 17). In paleognathine birds and some neognaths, no part of the pterygoid splits off (Jollie, 1957). According to Hofer (1945) *Os pterygoideum* may be arched (e.g., *Mergus*), bent (e.g., *Vanellus*), or extended (e.g., *Ardea*). See Annots. 69, 70, 93.

(62) **Facies articularis parasphenoidalis.** The surface at the zone of contact between the palatine bone and parasphenoid rostrum. Such contact and articulation are absent in some birds. In some passerines and a few other taxa, a winglike portion of the parasphenoid facies, the **Lamella dorsalis** (synonymy: *palatine hasp*, Richards and Bock, 1973), extends up alongside the lateral surface of the rostrum; the edge of *Lamella dorsalis* is **Crista dorsolateralis** (synonymy: *Cr. dorsalis*, NAA, 1979).

Crista medialis (Fig. 4.7). This is the medial edge of the border of the surface of *Pars choanalis* that articulates with the *Rostrum parasphenoidale*. In some birds the right and left medial crests fuse in the midline on the lower surface of the parasphenoid rostrum and exhibit an unpaired median crest (most pelecaniiforms, *Capella*, *Steatornis*, *Podargus*).

(63) **Proc. rostralis** (Jollie, 1958). Synonymy: Proc. choanalis rostralis (Bühler, 1970; NAA, 1979); ethmo-palatine bar (Parker, 1879). This is a rostral extension of the Crista medialis or Lamella dorsalis of Pars choanalis of the palatine bone for articulation with the Vomer; well exemplified in *Anser*, *Ardea*, *Caprimulgus*, *Corvus*.

(64) **Lamella choanalis** (Fig. 4.7). Synonymy: wall of palatine trough (Richards and Bock, 1973). A curved plate, often deeply concave, of Pars choanalis forming the lateral and dorsal wall of the Fossa choanalis of each palatine bone. In caprimulgids, the dorsal part of the lamella is curved medially and fused with its counterpart in the midline ventral to the parasphenoid rostrum, forming a palatine roof of the Pars caudalis of the choana (see *Resp.* Annot. 5). In some birds the plate is extended vertically ventrally forming the **Crista ventralis** which deepens the caudal part of the choana, pronounced, e.g., in *Larus* and *Diomedea*. In birds whose palatines are apposed or fused in the median plane, the right and left Cristae ventrales together form an unpaired, median ventral palatine crest (e.g., *Morus*).

Angulus caudomedialis. The angle formed by the caudal border of Lamella choanalis with its Crista ventralis.

Proc. caudomedialis. Synonymy: mediopalatine process (Richards and Bock, 1973). A caudal projection of Crista ventralis of some birds.

(65) **Crista lateralis**. The thickened lateral edge of the Pars lateralis of the palatine bone to which the aponeurosis of M. pterygoideus is attached.

(66) **Angulus caudolateralis**. Angle at the intersection of caudal and lateral margins of Pars lateralis of the palatine bone. In some forms (some passerines and a few other taxa) the angle is prolonged caudally as a pointed process which has been called the "transpalatine process", not an apt descriptive term.

(67) **Fossa ventralis**. Synonymy: Fossa muscularis. A usually shallow excavation on the ventral surface of Pars lateralis of the palatine bone between its Crista lateralis and Crista ventralis for attachment of part of M. pterygoideus. The fossa is deep in birds with prominent ventral crests of, e.g., *Diomedea*, *Cathartes*, *Larus*, *Capella*.

(68) **Vomer**. Synonymy: Prevomer. Paired elements, in adults most often fused into a single median structure that typically articulates with the parasphenoid rostrum and/or the Pars choanalis of the palatine bone (see below, this paragraph); not present in all birds; weakly developed in galliforms. The (fused) vomer varies in shape, ranging from a horizontally flattened plate, strongly V-shaped in cross section, to a laterally compressed, vertical plate. In passerine birds the vomer extends into the "ethmoid tissue" (Fig. 4.4), a condition unique to this group (see Hofer, 1949). In palaeognaths the vomer and pterygoids exclude the paired palatines from contact with one another and with the parasphenoid rostrum. In paleognaths the vomer has articular surfaces for pterygoid, palatine, maxillary, and premaxillary bones in addition to the Rostrum parasphenoidale.

(69) **Facies articularis parasphenoidalis**. In many neognathine birds the pterygoid, palatine bones, and the Vomer have surfaces for articulation with Rostrum parasphenoidale (*Arthr.* Annot. 29, 15, 16, 23).

Pes pterygoidei (Johnson, 1984). The "foot of the pterygoid", i.e., the expanded rostral end of the pterygoid bone (Fig. 4.4) that has articular surfaces for the parasphenoid rostrum and the palatine bone.

(70) **Proc. dorsalis**. Dorsal muscular process of Os pterygoideum of many birds, especially prominent in woodpeckers (Picidae) (Hofer, 1945). See *Myol.* Annot. 21.

(71) **Os quadratum**. Synonymy: Quadratum. Walker (1888) presented a comparative description (1888) of the variable form of the avian quadrate bone. **Proc. oticus** of the quadrate articulates with the prootic/opisthotic and squamosal (and sometimes laterosphenoid) elements by means of often separate otic and squamosal capitula. In some birds (e.g., *Hesperornis*, ratites, some neognaths; Witmer, 1990) the **Incisura intercapitularis** is indistinct and the capitula merge, lending the appearance of being "single-headed". See *Annot.* 24, 100; and Figs. 4.2, 3, 5).

Facies tympanica. The tympanic surface of the otic process and upper body of the quadrate bone forms with Ala parasphenoida the rostral wall of the tympanic cavity; the tympanic membrane is attached to the crest of this surface. See *Annot.* 19.

(72) **Condylus caudalis**. Synonymy: Proc. postmandibularis. The **Proc. mandibularis** of the quadrate bone of most taxa of birds possess three condyles (see Bock, 1960; and *Arthr.* Annot. 35). The three condyles are arranged in a somewhat triangular configuration, the caudal condyle projecting toward the rear.

Condylus pterygoideus. In most birds the condyle of Os quadratum for articulation with the lateral end of Os pterygoideum has a rounded, convex articular facet (Fig. 4.3). In ratites, tinamous, and the hesperornithiforms the facet is broad and flattened (Witmer, 1990).

Condylus lateralis. In most birds the lateral condyle of the quadrate bears only the articular facet on its ventral surface for the **Cotyla lateralis** of the mandible (Fig. 4.5); however, most endemic New World jays (e.g., *Aphelocoma*) possess an additional condyle (**Condylus rostralis**) on the rostral surface of the lateral condyle of the quadrate. This condyle fits into a caudally-facing **Cotyla rostralis** on the mandible directly above the lateral cotyla. This forms the "bustress complex" (Zusi, 1987), anchoring the mandible to the quadrate when the open lower jaw is used in pounding.

(73) **Cotyla quadratojugalis**. The cotyla of the quadrate bone for articulation with the **Condylus quadratus** of Os quadratojugale is located on the root of the lateral condyle of the mandibular process of Os quadratum.

(74) **Ossa supraorbitalia** (Beddard, 1898). Synonymy: Os supraciliare.

(75) **Ossa accessoria cranii**. See Jollie (1957) for a discussion of the accessory bones of the avian head.

(76) **Os nuchale**. Synonymy: Stylus postoccipitalis. Apparently unique to cormorants (*Phalacrocorax*) and the Anhinga in which it forms a moveable joint with a rounded protuberance of the occipital region of the skull (Dullemeijer, 1951).

(77) **Anulus [Annulus] tympanicus**. An osseous ring to which the periphery of the tympanic membrane is attached occurs in strigiforms and *Gallus* (Stellbogen, 1930). The ring is formed by parts of the exoccipital and parasphenoid bones (Kühne and Lewis, 1985).

(78) **Ossa suturarum**. Supernumerary bones developed in sutures between cranial bones; seen readily in young turkeys and ducks.

Os uncinatum (Burton, 1970). Located between the ventral end of Os lacrimale and the jugal bar in examples of musophagids.

(79) **Apparatus hyobranchialis** (Goodrich, 1958). Synonymy: Apparatus hyolin-gualis (consult *Myol.* Annot. 25); Apparatus hyoideus. The avian "tongue skeleton" is made up principally of elements from the hyoid arch and other more caudal branchial arches. The terminology adopted is that of McLelland (1968). Müller (1963:56)

provides a comprehensive synonymy. Zweers (1974, 1982) described the hyobranchial apparatus in *Anas* and *Columba*; he noted that the hyobranchial elements are commonly cartilage rather than bone.

(80) **Paraglossum**. Synonymy: Entoglossum. The paraglossum of most birds has the shape of an arrow head, bearing short, caudolaterally directed cornua. Psittaciforms possess a wide, flat paraglossum with a central foramen, or, more commonly, paired paraglossals united rostrally by a cartilaginous or bony isthmus (Beddard, 1898). In *Psittacus* (Hombberger, 1986) each of the paired paraglossals is bifurcate rostrally.

(81) **Basihyale**. Synonymy: Basibranchiale rostrale; Basihyoideum; Pars basihyalis copulae; Copula I (Müller, 1963). This element is a derivative of the hyoid arch. See below.

Proc. parahyalis; Arcus parahyalis. In parrots (Mivart, 1895; Hombberger, 1986) the Basihyale possesses a caudal enlargement from which the dorsolateral Proc. parahyalis arises on each side. These processes unite mid-dorsally to form the paraglossal arch in several Australian and Indopacific genera (*Melopsittacus*, *Eos*, *Vini*, *Lorius*, and *Nestor*).

Urohyale. [Basibranchiale caudale]; Synonymy: Urohyoideum; Pars urohyalis copulae; Basibranchiale I; copula II (Müller, 1963). The Basihyale and Urohyale are separate in young birds, but fused to one another in adults.

(82) **Dentes**. True teeth are known only from the fossil birds *Archaeopteryx*, *Parahesperornis*, *Hesperornis*, and *Ichthyornis* (Gingerich, 1972; Martin, 1984). Martin, et al. (1980) reviewed the morphology of avian dentitions. In *Osteodontornis* (Pseudodontornithidae) and its relatives the "teeth" are bony projections of the jaws, covered by rhamphotheca (Howard, 1957).

(83) **Condylus occipitalis**. The main part of the condyle is formed by Os basioccipitale; lateral contributions are from Os exoccipitale on each side. For a comprehensive comparative study of the avian occipital condyle see Goedbloed (1958).

Incisura mediana condyli. This is the median notch, usually present on the dorsum of the occipital condyle (Fig. 4.5); the tip of the Dens of the Axis rides in the incisure during dorsiflexion of the atlanto-occipital joint (Landolt and Zweers, 1985; Weisgram and Zweers, 1987). See **Arthr.** Annot. 64.

Tuberculum basilare. Synonymy: mamillary proc. (Pycraft, 1902; Saiff, 1974; Witmer, 1990). The basal tubercles originate as paired swellings at the rostral corners of the basioccipital bone; in later development they become sheathed ventrally by Lamina parasphenoidalis (Fig. 4.3). The tubercles serve for insertion of cervical muscles, principally *M. rectus capitis dorsalis*. They are best developed in long-skulled birds, e.g., *Morus*, *Hesperornis*. In some cases, the tubercles may coincide with Proc. medialis parasphenoidalis (see Annot. 97). Tuberculum basilare is an appropriate name in that it is clearly homologous with the "basal tubera" of nonavian archosaurs.

(84) **Ala parasphenoidalis**. Synonymy: Ala tympanica (NAA, 1979); alapasphenoidalis (Jollie, 1957). Although this part appears to be a lateral extension of Lamina parasphenoidalis (Erdmann, 1940), it is actually formed as a separate center of ossification that merges with the lamina in certain birds, remaining separate in others (Figs. 4.4). In some birds the Ala parasphenoidalis is flared and wing-like, forming part of the margin of the external acoustic meatus (Annot. 20). In others the ala is not wing-like, but a boss of bone, the Proc. lateralis parasphenoidalis (Annot. 97) that

forms a joint with the Proc. medialis mandibulae (as in *Diomedea*, *Morus*, and *Larus*). See **Arthr.** Annot. 32.

(85) **Proc. paroccipitalis** (Shufeldt, 1909) [**P. paroticus**] (NAA, 1979). Synonymy: Ala posttympanica; Proc. occipitalis lateralis (Davids, 1952); Proc. opisthoticus (Zusi, 1962). Proc. exoccipitalis (Richards and Bock, 1973; Johnson, 1984). The paraoccipital process forms the caudal wall of Cavum tympanicum and Meatus acusticus, and provides attachment for Lig. occipitomandibularis (**Arthr.** Annot. 37) and *M. depressor mandibulae* (Figs. 4.4, 3, 5). The paroccipital processes of Mesozoic birds are directed more or less laterally (Witmer, 1990), whereas those of most neornithine birds project ventrolaterally. These processes are especially prominent in *Gavia*, *Pelecanus*, *Anser*, and *Caprimulgus*.

The paroccipital process is a compound bone formed by three elements: (1) the opisthotic medially; (2) the metotic laterally (see Annot. 105); and (3) the exoccipital which forms a caudal sheath of variable lateral extent.

(86) **Fossa parabasalis** (Kesteven, 1925). Synonymy: Fossa jugularis. Depression on the exterior of the skull base, just medial to the ventral margin of the tympanic cavity. Canals for cranial nerves VII, IX, X, (X), the cerebral carotid and the external ophthalmic arteries open into the fossa (Fig. 4.5). Not present in all birds.

Crista fossae parabasalis. This crest forms the prominent raised medial margin of the parabasal fossa as in examples of anseriforms and phoenicopterids (flamingos).

(87) **Fonticulus occipitalis**. Synonymy: Fonticulus occipitalis lateralis (Barkow, 1829); occipital fontanelle. Large paired openings lateral or dorsolateral to the Foramen magnum as in the anseriforms, some alcids, scolopacids, gruids and aramids, threskiornithids, and phoenicopterids (Beddard, 1898). These openings, like the orbital fonticuli (Annot. 29), are closed by fibrous membranes in intact specimens. Olson and Feduccia (1980) discuss the taxonomic significance of the fonticuli.

(88) **Os laterosphenoidale** [**Os pleurosphenoidale**]. Synonymy: Os orbitosphenoidale (NAA, 1979); Os alisphenoidale. This bone forms much of the ventral part of the caudal wall of the orbit, and extends from the interorbital septum (where it is notched or perforated for cranial nerves II, III, IV, and VI) laterally to the temporal fossa and the postorbital process (see Annot. 30) and tympanic cavity; it forms part of the margin of Foramen n. maxillomandibularis (Lang, 1956). In addition to the large laterosphenoid ossification, there is often a separate late-appearing ossification, the orbitosphenoid, a dorsomedial element that fuses with its counterpart and the mesethmoid (Hogg, 1978; Goodrich, 1958; and Müller, 1963).

(89) **Area muscularis aspera**. The orbital surface of Os laterosphenoidale of many large birds exhibits a roughened area for attachment of the jaw muscles; extremely pronounced in *Phoenicopterus* (**Myol.** Annot. 19).

(90) **Foramen n. maxillomandibularis**. Synonymy: Foramen prooticum spurium (Müller, 1963). Single opening between the prootic and laterosphenoid bones in birds and other archosaurs that transmits the N. maxillomandibularis (Figs. 4.1, 3, 6). Apparently only a small proportion of birds possesses separate foramina for the maxillary and mandibular nerves, e.g., *Tyto*, *Buteo*, *Cathartes* (Barnikol, 1953), *Columba*, some *Gallus* (pers. obs.).

Canalis n. maxillomandibularis. In some forms (e.g., *Columba*) the maxillomandibular nerve traverses a relatively lengthy canal to exit the cranial cavity, whereas in others (e.g., *Corvus*) the opening is simply a hole in thin bone, a foramen.

Foramen n. ophthalmici. Synonymy: Foramen rami profundi V. This foramen is located between the laterosphenoid and the basisphenoid/parasphenoid/interorbital septum complex.

(91) **Sella turcica; Dorsum sellae.** Consult Jollie (1957) and Hogg (1978) for the development of the base of the skull in the chicken; Müller (1963) in *Rhea*. For the anatomy of the Sella turcica in different birds see Wingstrand (1951), Starck (1955), and Baumel (1968). The Sella houses the hypophysis. The rostral end of the cranial carotid canal is an opening in the rear wall of the Sella, the Dorsum sellae, which is completely osseous in some birds, fibrous in others (Baumel, 1968).

Foramen ophthalmicum internum. Conducts the internal ophthalmic vessels into the orbit from the Sella turcica.

(92) **(Canalis craniopharyngealis).** This vestige of the embryonic Rathke's pouch may be seen in a median section of the skull base. The canal connects the Sella turcica to a median foramen on the Basis cranii externa (Wingstrand, 1951; Müller, 1963; Witmer, 1990).

(93) **Proc. basipterygoideus.** Synonymy: Proc. pterygoideus. A process on each side of Rostrum parasphenoidale (see Annot. 96) for articulation with the pterygoid bone. Occurs in ratites, procellariiforms, anseriforms, and galliforms; many charadriiforms and cathartid vultures; some caprimulgiforms and strigiforms; and trogoniforms (see Beddard, 1898). The homologues of the basipterygoids in extant birds, Cretaceous fossil birds, as well as non-avian archosaurs are discussed by Witmer and Martin (1987) and Olson and Feduccia (1980).

(94) **Tuba auditiva [pharyngotympanica] communis.** In most birds, the common auditory tube or chamber is formed by the confluence of the right and left tubes (see Annot. 98 for exceptions). The common tube is located on the ventral aspect of the base of Rostrum parasphenoidale (Fig. 4.4) (**Basis rostri parasphenoidalis**), where it is well delineated (e.g., in *Anser*). The common tube opens into the Infundibulum tubarum, a chamber which itself passes through a median slit in the roof of the oropharynx. See Annot. 98; and *Digest*. Annot. 19.

(95) **Canalis orbitalis.** This short canal opens on each side of the base of Rostrum parasphenoidale (Fig. 4.3); it is an offshoot of the cranial carotid canal that transmits the carotid branch, A. sphenoida (*Art.* Annot. 18).

(96) **Lamina parasphenoidalis [L. basitemporalis].** Synonymy: basitemporal plate; Lamina basiparasphenoidalis (NAA, 1979). On the Basis cranii externa, this lamina is located rostral to the area where the ventral neck muscles insert on the basioccipital bone in front of the occipital condyle (Figs. 4.4, 5). The lamina assumes markedly different configurations in various birds (see Annot. 98), moreover, the lamina of certain birds exhibits processes (see below) that articulate with the medial process of the mandible, forming the so-called "mandibular brace" of Bock (1960). See Annot. 83 regarding Tuberculum basilare and *Arthr.* Annot. 32.

"Basitemporal" is inappropriate since the Lamina is not related to a "temporal" bone (see synonymy of Os squamosum) or region; it is retained as a bracketed alternative term because of its widespread use. "Lamina parasphenoidalis" is an abbreviated form that does not reflect its origin from the basiparasphenoid center of ossification.

Rostrum parasphenoidale [R. sphnoidale]. Synonymy: sphenoidal rostrum (Shufeldt, 1909; Os rostromparasphenoidale). Attenuated prolongation of the Basis cranii externa to which the lower border of the interorbital septum is joined and with which the pterygoid and palatine bones articulate. See Figs. 4.6, 3, 5.

(97) **Proc. lateralis parasphenoidalis; Proc. medialis parasphenoidalis.** Synonymy: medial and lateral basitemporal processes (Bock, 1960). Bock has described these processes of the parasphenoid lamina in detail for representatives of numerous avian taxa; Kozlova (1961) described them in alcids. See *Arthr.* Annot. 32 for particulars; see also Annot. 83 concerning Tuberculum basilare.

(98) **Tuba auditiva [T. pharyngotympanica].** Synonymy: Eustachian tube. This paired osseous tube is lined with mucosa continuous with that of the tympanic cavity and the oropharynx. The tube parallels the usually oblique, rostralateral border of Lamina parasphenoidalis (nearly transverse in *Phoenicopterus*). The tube extends from the tympanic cavity to the base of Rostrum parasphenoidale, and most often joins the opposite tube (Annot. 94). The rostral openings of the tubes in ratites and the Cretaceous hesperornithiforms (Witmer, 1990) are widely separated. In some birds (e.g., albatrosses, flamingos) the lateral osseous wall is lacking, completed by connective tissue (Saiff, 1974).

(99) **Canalis caroticus cranialis.** Synonymy: parabasal canal (Müller, 1963, p. 76); vidian or basipterygoid canal (Goodrich, 1930); carotid canal (Shufeldt, 1909:283). Here it is qualified as the "cranial carotid canal" to distinguish it from the cervical carotid canal (Annot. 121). The cranial carotid canal extends from the parabasal fossa through the skull base medial to the auditory tube, then into the Sella turcica (Annot. 91); not only does it conduct the carotid vessels, but branches of cranial nerve VII. See Wingstrand (1951), Jollie (1957), Müller (1963: 76); and Baumel (1968) for particulars.

(100) **Cotyla quadratica squamosi.** Cup-shaped surface of Os squamosum for articulation with the squamosal capitulum of the quadrate bone (see Fig. 4.3; Annot. 24, 103). In some birds (e.g., *Anas*) the laterosphenoid bone makes a substantial contribution to the squamosal coytyla.

(101) **Fossa acustica interna.** Located on the lateral wall of the caudal fossa of the cranial cavity near the fossa for the auricle of the cerebellum, this depression contains the exit foramina for the branches of the vestibulocochlear and facial nerves. See Ossa cranii for more terms.

(102) **Os squamosum [Squamosum].** Synonymy: Os temporale.

Proc. zygomaticus Synonymy: Proc. lateralis. This process of Os squamosum is situated ventral to the postorbital process and is strongly developed in some birds, e.g., ratites, gaviiforms, galliforms, piciforms, and passeriforms (Figs. 4.4, 5). The tip of Proc. zygomaticus is fused with the postorbital process in some birds (e.g., galliforms). See Annot. 30b.

(103) **Proc. suprameaticus.** This process of Os squamosum forms part of the cotyla for the squamosal capitulum of the quadrate bone; and contributes to the upper boundary of the external acoustic meatus.

(104) **Fossa temporalis.** Excavation on the lateral aspect of the cranium dorsal to the external acoustic meatus and caudal to the postorbital process (Figs. 4.1, 5). In some birds (e.g., larids and ardeids) the fossa is strongly etched into the cranium (mainly Os squamosum). In some birds its sharp border, **Crista temporalis** nearly

reaches the median plane dorsally (Fig. 4.5). A tough fibrous membrane invests the jaw muscles occupying the fossa (Arthr. Annot. 31).

Fossa subtemporalis. In some birds (e.g., *Morus*, *Gallus*, *Haematopus*, *Ardea*, *Fulica*) this is a shallow concavity between the caudal margin of the temporal fossa and the lateral part of the transverse nuchal crest (Fig. 4.1; Annot. 17).

(105) **Ossa otica.** In early postnatal development the three major otic elements (**Os prooticum**, **Os epioticum**, **Os opisthoticum**) coalesce with one another and adjacent surrounding bones. This complex contains the osseous labyrinth of the inner ear (Sandoval, 1963; Hogg, 1978). **Os metoticum** is an additional element lateral to the auditory capsule and forms much of the paroccipital process (see Toerien, 1971; and Annot. 85). The metotic cartilage is a neomorph of embryonic birds, and perhaps other archosaurs, that attaches to the basal plate, occipital arch, and auditory capsule (de Beer and Barrington, 1934). See Cavum tympanicum.

(106) **Crista vallearis.** Crest of bone on the inner aspect of the calvaria that marks the lateral border of the **Eminentia sagittalis** of the cerebrum (CNS Annot. 78). The crest occupies the longitudinal groove in the brain surface known as the Vallecule telencephali.

(107) **Proc. lacrimalis [P. prefrontalis].** Lateral flared projection of the lateral margin of the frontal bone immediately caudal to its articulation with **Os lacrimale**; present, e.g., in *Larus*, *Morus*, *Cathartes*. See Annot. 110.

(108) **Os mesethmoidale.** This bone forms much of the rostral osseous part of the interorbital septum and, in some birds, part of the nasal septum (Fig. 4.1); it also forms the **Lamina dorsalis** (see below).

Lamina dorsalis (Shufeldt, 1909). The transverse plate of **Os mesethmoidale** that lies perpendicular to the interorbital septum. The **Lamina** articulates with the ventral surface of the frontal bone; prior to fusion of these two elements it is seen readily in skulls of young chickens and ducks (e.g., *Aythya*). In rynchokinetic skulls the **Lamina dorsalis** extends rostrad to the level of the craniofacial flexion zone. See Arthr. Sut. front. eth.

(109) **Os ectethmoidale. [Os lateroethmoidale];** Synonymy: Proc. or (Planum) antorbitalis(e); Aliethmoid and Pars plana (Shufeldt, 1909). Vertical, transverse plate of bone forming part of the rostral wall of the orbit, separating it from the nasal cavity (Figs. 4.1, 2). In certain birds the lacrimal is fused with the ectethmoid forming the lacrimal-ectethmoid complex (Cracraft, 1968), e.g., in some charadriiforms (*Larus*, *Haematopus*) (Johnson, 1984).

(110) **Os lacrimale [Os prefrontale].** Müller (1963) reviewed the controversy over the homology of the lacrimal/prefrontal bone. Witmer notes that most evidence points to the homology of the lacrimal bone of birds with that of the nonavian archosaurs: (1) the lacrimal always forms the caudal margin of the antorbital fenestra in all archosaurs, including birds; and (2) in the dinosaurs leading to birds the prefrontal is progressively reduced in size and the lacrimal is enlarged. See Cracraft (1968) for a comprehensive review on variation of the lacrimal bone. See Annot. 107, 111.

(111) **Facies articularis frontonasalis.** This is the surface of **Os lacrimale** that articulates with both **Os frontale** and **Os nasale**; in some birds the lacrimal bone articulates medially with the ectethmoid and occasionally with **Os jugale**. See Arthr. Fig. 5.2.

(112) **Columna vertebralis.** The total number of vertebrae as well as the number of regional vertebrae varies in different avian taxa. The total number ranges from 39-64 (pygostyle counted as one vertebra). Fewest vertebrae occur in passerine birds; most occur in the swans and ratites. Most interspecific variation in numbers occurs in the cervical series of vertebrae (see Annot. 129). Individual variation in number of vertebrae within taxa is common.

(113) **Partes vertebrae.** See the review papers of Komárek (1970), and Zweers, et al. (1987) for a detailed treatment of the nomenclature of the features of avian vertebrae. Following Boas (1929) the names of the parts of a vertebra listed herein are based mainly on a hypothetical "typical" cervical vertebra of Boas' Segment II (see Annot. 129); however, the cervical vertebrae lack distinct, prominent transverse processes such as possessed by the thoracic, synsacral, and caudal vertebrae.

Dorsally each vertebra consists of an arch (**Arcus vertebrae**) and a ventral body (**Corpus vertebrae**). The opening enclosed by the two is the **Foramen vertebrale**. Collectively the entire series of the vertebral foramina produce the **Canalis vertebralis** that houses the spinal cord, its meninges, and the internal vertebral venous sinus (**Ven.** Annot. 46). The arch and body bear several processes which are lever arms for muscle attachment or articular surfaces connecting vertebrae (see Annot. 127a; and Arthr. Annot. 60).

Corpus vertebrae. The **Corpus** of typical cervical and thoracic vertebrae has expanded cranial and caudal ends, with a constricted midsection, the **Concavitas lateralis**. The **Facies dorsalis corporis** (the spinal cord surface of the vertebral body) is not flat, but forms a longitudinal sulcus.

Birds are the only vertebrate animals in which most of the intercorporeal articular surfaces are heterocoelous or saddle-shaped (Fig. 4.8). Of infrequent occurrence (e.g., penguins, auks, gulls) the vertebrae in the thoracic region are opisthocelous, having concave caudal articular surfaces (Beddard, 1898). Martin (1987) notes that certain modern birds (e.g., charadriiforms) still retain amphicoelous vertebrae in the region "just anterior to the sacrum" (see Arthr. Annot. 60). The vertebrae of *Archaeopteryx* and *Ichthyornis* are amphicoelous, although hesperornithiformes are heterocoelous.

(114) **Fovea cranioventralis.** Synonymy: Fovea anteroventralis (Boas, 1929). This pit (Fig. 4.8) accommodates the ventral lip of the articular surface of the body of the vertebra cranial to it upon ventral flexion of the neck.

(115) **Sulcus lateralis.** The groove on the side of the body of a cervical vertebra (**Facies lateralis**) accommodating the ascending vertebral artery and vein.

Tuberositas lig. collateralis. Synonymy: Tuberositas lateralis corporis (Landolt and Zweers, 1985). The caudal end of each vertebral body exhibits on its lateral side a distinct marking for attachment of **Lig. collateralis**. See Arthr. Annot. 60.

(116) **Eminentia costolateralis.** Synonymy: Proc. costolateralis (Boas, 1929); parapophysis; Tuberculum costarium (Komárek, 1979). The costolateral eminence is a small prominence of the lateral surface of the bodies of thoracic vertebrae that bears an articular facet, **Fovea costalis**, for the head of a rib, **Capitulum costae**. The fovea occurs on free thoracic vertebrae as well as those of the notarium and synsacrum. Replacement of Komárek's term "tuberculum costarium" avoids confusion with the tuberculum of a rib (see below, Annot. 117 and Arthr. Annot. 79).

(117) **Fovea costalis.** Articular surface on the lateral end of a transverse process of a vertebra for the tubercle of the rib, **Tuberculum costae**. The costal fovea also occurs on the **Eminentia costolateralis** (see Annot. 116; and Arthr. 79).

(118) **Proc. costalis**. Synonymy: Spina laminae ventralis (Komárek, 1970); Pleuropophysis. A rudimentary rib with its proximal end ankylosed to the Corpus and Proc. transversus of a cervical vertebra, its free caudal end forming an attenuated style or spine (Fig. 4.8). See Annot. 141b regarding the costal processes of sacral vertebrae.

(119) **Crista [Proc.] ventralis corporis**. Synonymy: Hypapophysis; Proc. latus (Boas, 1929); Crista ventralis (Komárek, 1979). These median, ventral crests (processes) display interspecific variability in shape and relative development. "Crest" is descriptively apt for laterally compressed, plate-like processes. The crests are present on the ventral side of the bodies of the cranial and caudal series of cervical vertebrae, but lacking in the intermediate series (see Annot. 129). The size of the ventral crest on the Atlas of different avian taxa is variable; that of the Axis is quite strong in many birds (see Boas, 1929).

Ventral crests are most strongly developed on the cranial series of thoracic vertebrae and the cervicothoracic transitional vertebrae of spheniscids, *Gavia*, alcids, and some anseriforms (Beddard, 1898). They are considered adaptations for powerful underwater use of the neck (Kuroda, 1954). See below Annot. 122; and **Arthr.** Annot. 72. The paired ventral longus colli muscles are attached to the crests (**Myol.** Annot. 56).

Fenestrae intercrustales. Synonymy: Foramina intercrustales (Komárek, 1979). The ventral crests of cranial thoracic vertebrae (including those of the Notarium) of some taxa are ankylosed to one another. The fenestrae are windows (openings) of variable size and shape where the ventral intercrustal ligaments are incompletely ossified, in other words, incomplete fusion of adjacent ventral crests (see Annot. 140); **Arthr.** Annot. 63).

(120) **Alae cristae ventralis**. Paired wing-like lateral extensions of the ventral edge of the Crista ventralis; seen in the cranial series of thoracic vertebrae of certain diving birds, e.g., *Gavia* (Kuroda, 1954); slightly developed in *Anas* (Landolt and Zweers, 1985) and alcids (Strauch, 1985). According to R. W. Storer (pers. comm.) the alae are best developed in the loons, next in some penguins (*Aptenodytes*), present in all alcids, and fairly well developed in the larger alcid species (*Alca*, *Uria*, *Pinguinus*, *Fratercula*) and the diving ducks (e.g., *Clangula*).

(121) **Proc. caroticus**. Synonymy: Catapophysis (Beddard, 1898); Proc. sublateralis (Boas, 1929); Proc. hemalis (Komárek, 1970a). Paired incurved processes on the ventral side of vertebral bodies of the intermediate group of cervical vertebrae (Fig. 4.8B; Annot. 129). The carotid processes are not homologous with the haemal processes of the tail region of birds and other vertebrates (Annot. 144).

Each of the carotid processes forms the lateral wall of the **Sulcus caroticus**. Slips of *M. longus colli ventralis* (**Myol.** Annot. 56) are attached to the carotid processes.

In most birds the free ends of a pair of carotid processes are connected by a ligamentous bridge producing a short canal. In certain birds, e.g., *Pelecanus*, *Ardea*, *Dendrocopos*, the paired processes become ankylosed, forming a complete osseous canal (see below). Fused processes are thought to be convergent features in species having the ability to throw the head forward (Jenni, 1981). In *Dendrocopos* the fused carotid processes are equipped with a ventral median crest; Jenni (1981) considers that the crests are adaptations for drilling and drumming (see Annot. 119).

Canalis caroticus cervicalis. Synonymy: subvertebral canal. On the ventral surface of the intermediate segment of the cervical vertebral column the internal carotid arteries course in this osseo-fibrous canal that is partially formed by the carotid processes (Annot. 121a, 99). See **Art.** Annot. 15.

Proc. postlateralis (Zusi and Storer, 1969). Synonymy: Proc. inferolateralis (Boas, 1929); Proc. ventrolateralis (Landolt and Zweers, 1985). Seen in ventral view of cervical vertebrae, this process in grebes is a paired caudolateral projection of the vertebral body; for attachment of *M. longus colli ventrales* (Zusi and Storer, 1969). Present also in *Morus* and *Phoenicopterus*.

(122) **Crista ventrolateralis**. Synonymy: Proc. inferolateralis (Boas, 1929); Proc. ventrolateralis (NAA, 1979). Ventrolaterally oriented, paired projections attached to the ventrolateral border of the body of certain thoracic vertebra; the ventrolateral crests flank the Crista ventralis on each side; present, e.g., in *Larus*, and the owls, *Strix*, *Nyctea*. See Fig. 4.8A.

(123) **Proc. transversus vertebrae**. Synonymy: Diapophysis. Paired process that projects laterally from each side of the vertebral arch. During postnatal maturation of the skeleton the transverse processes of cervical vertebrae become fused with cervical ribs (see Annot. 134, 138). The transverse process of most of the cervical vertebrae is not a pronounced feature as in the thoracic, synsacral, and caudal regions (see Annot. 134, 135); it is often indistinguishable from the Ansa costotransversaria of cervical vertebrae in mature birds (Annot. 135).

(124) **Crista transverso-obliqua** (Boas, 1929). The cervical vertebrae of long-necked birds best exhibit this crest on the dorsal surface of the vertebral arch. The crest of each side extends obliquely caudolaterally onto its caudal zygapophysis.

(125) **Torus dorsalis**. Synonymy: Hyperapophysis (Beddard, 1898); Processus dorsalis (Boas, 1929). This boss of bone is found on the Crista transverso-obliqua of the dorsum of the caudal zygapophysis (Fig. 4.8D); for attachment of *Mm. ascendentes* (see **Myol.** Annot. 46-49). The location of the torus varies from the base to near the tip of the zygapophysis; it is strongly developed on cervical vertebrae of some forms (e.g., *Alca*, *Haliaeetus*, *Morus*). The use of "Torus" is preferable since it avoids confusion with the spinous [dorsal] process of the vertebral arch.

(126) **Area lig. elastici**. Synonymy: Facies lig. elastici (Komárek, 1970). Interlaminar and interspinous elastic ligaments are usually attached cranially and caudally on the dorsal lamina of the vertebral arch at the base of Proc. spinosus [dorsalis]. Bony markings of the ligaments are variously developed as roughened tuberosities, facies, fossae, or foveae that are here designated generically as "areae". See **Arthr.** Annot. 63.

(127a) **Arcus vertebrae**. Each end of the vertebral arch is attached to the dorsolateral border of its vertebral body; the arch forms the lateral wall (Lamina lateralis arcus) and the dorsal wall (Lamina dorsalis arcus) of the vertebral canal (see below). The transverse process is a lateral projection of the arch; its base marks the dividing line between lateral lamina and dorsal lamina, best exhibited in thoracic vertebrae since cervical vertebrae lack prominent transverse processes. The level of the zygapophyses indicates the dividing line between dorsal and lateral laminae in cervical vertebrae.

Lamina lateralis arcus [Pediculus arcus]. Lamina lateralis is a substitute name for the mammalian "Pediculus". In birds the lateral part of the vertebral arch is plate-like rather than a constricted stalk (pedicle) as in mammals; this lamina is especially expansive in the "long vertebrae" of birds (Komárek, 1970a). See Annot. 128a.

Lamina dorsalis arcus is the segment of the vertebral arch that extends from the base of the transverse process of one side to that of the opposite side; it bears the Proc. spinosus on the midline of its dorsal aspect. See Annot. 128 b, c.

(127b) **Lamina arcocostalis** (Landolt and Zweers, 1985). This lamina is a thin shelf of bone continuous with the caudal margin of Ansa costotransversaria (Fig. 4.8D); the lamina extends lateroventrad from the vertebral arch often over the entire length of the spine of the costal process in anserids and anatids. In *Gallus* and *Phoenicopterus* the arcocostal lamina is less extensive, not reaching the tip of the costal process. The lamina may be considered as an extension of the Ansa which forms the dorsolateral wall of a craniocaudally-attenuated transverse foramen whereby the foramen becomes converted into a canal (see Annot. 127c).

(127c) **Lamina corporocostalis** (new term; well illustrated, but not named by Komárek, 1979:106). In conjunction with the occurrence of the arcocostal lamina, another lamina, the corporocostal lamina, extends medially from the costal spine to the vertebral body. It forms the ventral floor of the attenuated transverse foramen (canal) in the birds noted in the paragraph above. Both the arco- and corporocostal laminae are derived by ossification of intermuscular aponeuroses or fascial sheaths (see *Myol.*).

(128a) **Incisura caudalis/cranialis arcus**. Synonymy: *Incisura vertebralis* (Komárek, 1979). These are notches in the cranial and caudal borders of the Lamina lateralis arcus. The cranial notch of one vertebra and the caudal notch of the vertebra in front of it together form the boundaries of a **Foramen intervertebrale** for passage of the spinal nerve and vessels into and out of the vertebral canal. The caudal incisura is generally markedly the deeper of the two (Annot. 143a).

(128b) **Hiatus interarcualis**. The opening or gap between the dorsal laminae of the arches of adjacent (articulated) vertebrae as seen in dorsal view (see Zusi, 1962; Komárek, 1979). The hiatus is closed by the interlaminar elastic ligaments and membranes (see *Arthr.*). The hiatus is bounded by the Lacunae interzygapophysiales of the dorsal laminae of the arches of two adjoining vertebrae (see below), most pronounced in the cervical region (see below).

(128c) **Lacuna interzygapophysialis** (new term). "Incisura arcualis" (Komárek, 1970), has been replaced to avoid confusion with the *Incisurae cranialis/caudalis arcus* (of Lamina lateralis) that are boundaries of the intervertebral foramina. The Lacuna is the V-shaped or often broadly U-shaped indentation of the Lamina dorsalis of the vertebral arch, located between the right and left zygapophyses (Fig. 4.8C) at each end of a vertebra (see paragraph above); two adjoining lacunae form the cranial and caudal boundaries of the Hiatus interarcualis.

(129) **Vertebrae cervicales**. The greatest number of cervical vertebrae are found in ratites (ca. 20) and in swans (23-25); fewest in coraciiforms and passeriforms. Boas (1929) characterized the cervical vertebral column as consisting of three morphologically and functionally distinct sections: Segment I, the most cranial series, Segment II, the intermediate series, and Segment III, the most caudal series. Zusi (1962) noted that the joints within and between the segments permit I and III to be flexed ventrally, but Segment II can be flexed only dorsally; this arrangement allows the neck to be held in its characteristic S-shaped retracted position.

In birds generally, most of the cervical vertebrae are invaded by diverticula of the cervical system of air sacs (see below); however Boas (1929) reported that all of the cervical vertebrae were apneumatic in the following diving birds: *Colymbus* (*Gavia*), *Plonus* (*Anhinga*), *Podiceps*, *Alca*, and *Spheniscus*.

(130) **Atlas; Axis**. These are the specialized first and second cervical vertebrae, respectively. The Axis is also known as *Epistropheus*. The Atlas is apneumatic in all birds examined, the Axis being apneumatic in many birds (Boas, 1929).

(131) **Fossa condyloidea**. Synonymy: ventral semi-ring (Boas, 1929). Cupped-shaped or semicircular concave surface of the Atlas for articulation with the occipital condyle of the base of the skull.

Incisura fossae; Foramen fossae. The condyloid fossa on the cranial aspect of the Atlas may be perforated (Foramen fossae) or have an open dorsal notch (*Incisura fossae*) in which the apex of the dens rides. See *Arthr.* *Fibrocartilago atlantis*.

(132) **Zygapophysis caudalis [Proc. articularis caudalis]**. Synonymy: postzygapophysis. **Zygapophysis cranialis [Proc. articularis cranialis]**. Synonymy: prezygapophysis. The zygapophysis is one of four processes of each vertebra that project from the vertebral arch or the base of the transverse process. The pair of cranial zygapophyses of one vertebra and the pair of caudal zygapophyses of the vertebra in front form freely moveable synovial joints on each side. The free caudal vertebrae of most birds lack zygapophyses; exception: the albatross *Diomedea* (see Annot. 128c; *Arthr.* Annot. 65).

Caudal zygapophyses are present on the Atlas of most birds studied by Boas (1929), thus paired atlantoaxial zygapophysial articulations exist. See *Arthr.* Annot. 68.

(133) **Proc. costalis atlantis**. A rudimentary rib is not evident on the Atlas of most birds (Boas, 1929); therefore the Atlas of relatively few birds exhibits transverse foramina (see Annot. 134, 135). Boas (1929) depicted well developed, complete transverse foramina of the Atlas in *Rhea* and *Cygnus*, incomplete ones in other forms. See Annot. 118, 123, 134, 138.

(134a) **Foramen transversarium**. Synonymy: Foramen costotransversarium. The transverse foramen characterizes most of the cervical vertebrae of birds (for exception, see Annot. 133). Even though the avian transverse foramina may have considerable length and might be referred to as canals (Annot. 127b, c), the term "Foramen transversarium" is retained for consistency with the mammalian nomenclatures. See below, Annot. 135 for the fetal derivation of the foramen.

(134b) **Canalis vertebrarterialis** (Boas, 1929). On each side of the cervical vertebral column the series of transverse foramina forms this canal that extends the length of the cervical column and conducts the ascending vertebral artery and companion vein(s) (*Art.* Annot. 11).

The cervical transverse foramen is the equivalent of the opening formed in the angle between the tuberculum and capitulum of each rib and the transverse process of a thoracic vertebra (see Fig. 4.8A, B; Annot. 148). Thus the series of thoracic costovertebral openings is morphologically equivalent to the cervical vertebrarterial canal; moreover, it carries the descending vertebral vessels (*Art.* Annot. 11) as well as loops of the paravertebral autonomic nerve trunk.

(135) **Ansa costotransversaria** (Boas, 1929). Synonymy: Lamina ventralis (Komárek, 1970). The Ansa (L. loop) is formed by postnatal ankylosis of the rudimentary cervical rib (*Costa cervicalis*) with the transverse process and vertebral body of a vertebra. Thus the ansa represents part of the external wall of a transverse foramen, and the body (and lateral lamina of the vertebral arch) form the medial wall (Fig. 4.8B) The ansa demonstrates surface features: a knob-like **Tuberculum ansae** (*Knopffortsatz*, Boas, 1929) and a series of linear **Cristae laterales** (*Langskanten*,

Boas, 1929). These features mark the attachment of tendons of lateral cervical musculature (*Myol. Annot.* 53, 54).

(136a) **Incisura caudalis arcus**. The caudal notch of the arch of the Atlas forms the rostral boundary of the atlanto-axial intervertebral foramen for the second cervical spinal nerve (see *Annot.* 128a).

(136b) **Dens axis**. Synonymy: Proc. odontoideus. The joints between the avian Axis and Atlas differ from those of mammals: in addition to the articulation of the Dens with the Atlas, an Artc. intercorporea and paired zygapophysial articulations are present. The atlas and axis are ankylosed in adult hornbills (*Bucerotidae*) (Kemp, 1985).

(137) **Proc. spinosus [P. dorsalis] axis**. Although commonly present, the spinous process is lacking from the Axis of some forms (e.g., the scolapacid, *Gallinago delicata*).

(138) **Proc. costalis axis**. The rudiment of a rib is present on the Axis of many, but not all, birds that have been studied; occasionally weak projecting tips of the costal processes are found (Boas, 1929). When present, Proc. costalis forms an arch and completes the transverse foramen. See *Annot.* 133, 135.

(139) **Vertebrae thoracicae**. Synonymy: Vertebrae dorsales. The first thoracic vertebra is defined as the cranialmost vertebra with a complete rib (i.e., having vertebral and sternal segments) that articulates directly or indirectly with the sternum (see *Annot.* 147). The vertebrae at the root of the neck that bear moveable ribs, not reaching the sternum, have been called "Vertebrae cervicodorsales" (Newton, 1896; Zusi, 1962); these are transitional in configuration between cervical and thoracic vertebrae. See *Annot.* 141a; and *Arthr.* Fig. 5.10).

(140a) **Notarium**. Synonymy: Os dorsale. The Notarium (Gk. noton, back) is a unit of several (2-6) (Barkow, 1856; Storer, 1982) thoracic vertebrae that are coalesced rather completely in adults, but not fused with the synsacrum (see *Arthr.* for significance of the joint between the notarium and synsacrum). The Notarium (Fig. 4.9) is characteristically present in at least 17 families of birds, occasional in several others: tinamous, *Pelecanus*, threskiornithids (ibis and spoonbills), galliforms, columbiforms, as well as all podicipediforms and most falconids (Storer, 1982). The Mesozoic birds *Archaeopteryx* and *Gobipteryx* possess several "fused anterior dorsal (thoracic) vertebrae" (Martin, 1987).

In certain birds (e.g., larids, rhynchopids, gruids, *Branta* and *Anser*) consolidation of the thoracic vertebral column is achieved by ossification or calcification of the epaxial muscle tendons that interdigitate and may fuse to one another and to the transverse and spinous processes of adjacent vertebrae. This sort of consolidation as well as the rather complete synostotic coalescence (above) are both found in some groups (e.g., grebes and cranes; R. W. Storer, pers. comm.). See *Arthr.* *Annot.* 71.

(140b) **Canalis notarii**. The segment of the vertebral canal that traverses the Notarium (see *Annot.* 144). **Crista spinosa [dorsalis] notarii**. Synonymy: Crista dorsalis notarii (NAA, 1979). Crest formed by the ankylosed spinous processes.

(141a) **Synsacrum**. Synonymy: Os lumbosacrale; Os pelvium. A rigid unit consisting of ankylosed vertebrae in mature birds (Figs. 4.9, 11). The preacetabular part of the Synsacrum incorporates one or several thoracic vertebrae and the "lumbar series" (synsacral segment II of Boas, 1933) that are attached to the preacetabular ilium; the proper sacral vertebrae are opposite the acetabulum (see below); several more of the proximal caudal vertebrae caudales (urocaudals, Parker, 1888) comprise

the postacetabular series. Interspecific variation exists in the number of vertebrae forming the synsacrum. See Barkow (1856), Boas, (1933), and van Oort (1905) for detailed comparative studies of the synsacrum in different taxa.

The synsacrum is synostosed on each side with the Os coxae, the three elements forming the bony pelvis; the pelvis and uropygium (**Topog.** *Annot.* 36) together form the dorsal abdominal wall (Baumel, 1988). See *Arthr.* *Artcc.* *synsacri*.

(141b) **Vertebrae sacrales**. One or two "true" sacral vertebrae (Segment III vertebrae of Boas, 1933) are identified by their conspicuous costal processes, lacking in the vertebrae to the front and rear of them. In some birds the costal processes of the sacral vertebra(e) extend laterally to the hip bone near the acetabulum, thus the name, **Vertebra acetabularis** (Du Toit, 1912-13; Komárek, 1979; Radu, 1975) which is well exemplified in the pelvis of *Larus*, *Strix*, *Gallinula*. See Fig. 4.9.

(141c) **Lamina transversa notarii/synsacri**. During skeletal maturation the transverse processes of the notarium and synsacral vertebrae become coalesced, producing on each side a continuous transverse lamina. In mature birds the lateral border of each Lamina of the synsacrum becomes firmly ankylosed with the hip bone (Os coxae) of its side. In instances where the fusion between the transverse processes is incomplete, the persistent windows are known as **Fenestrae intertransversariae**. The fenestrae as well as smaller foramina are traversed by nerves and vessels. See Figs. 4.9, 11.

(142a) **Corpus notarii/synsacri**. This is the unit of consolidated vertebral bodies (corpora) that form the median, ventral column of bone of the notarium and that of the synsacrum.

(142b) **Facies visceralis synsacri**. Synonymy: Facies abdominalis. See Barkow (1856) and Boas (1933) for features of this ventral (internal) surface of the synsacrum which is in contact with abdominal organs (viscera).

(142c) **Crista spinosa [dorsalis] synsacri**. The crest formed by the ankylosed spinous processes of the synsacral vertebrae.

(143a) **Foramina intervertebralia**. Dual intervertebral foramina may exist in some birds over part of the length of the synsacrum, especially immature ones; these are separate openings for the dorsal and ventral roots of the spinal nerve, the roots uniting external to the vertebral canal (e.g., *Struthio*, *Rhea*, *Somateria*, *Porphyrio*, *Alca*, *Corvus*) (Boas, 1933).

(143b) **Canalis synsacri [vertebralis]**. See *Annot.* 140b. The part of the vertebral canal of the synsacrum. The canal is enlarged along the middle of its length; the enlarged chamber contains the lumbosacral intumescence of the spinal cord which is known as the Cranium inferior (or ischiadicus) by older authors (Barkow, 1856).

(144) **Proc. haemalis**. Synonymy: intercentrum; chevron bones. Found only on the rear three or so caudal vertebrae on their ventral surfaces, including the pygostyle. Prominent in large birds (e.g., albatross, penguin, heron, pelican) and in some smaller forms (e.g., *Crotophaga*, *Dendrocopos*); inconspicuous and vestigial, e.g., in the pigeon and chicken. The haemal processes are usually ankylosed to the cranial ends of the vertebral bodies, projecting ventrocranially and underlying the intervertebral discs and rear of the vertebra ahead. In *Crotophaga* the processes are fused at their bases with the vertebral body, and also articulate firmly with the body of the vertebra cranial to it.

In some mature birds certain of the haemal processes occur as distinct nodular elements attached by ligaments to the discs and/or to the vertebral bodies (*Diomedea* sp.). The haemal processes are persistent intercentra (Piiper, 1928), an element of embryonic vertebrae; absent in other vertebral regions except the atlas and axis. Archosaurs closest to birds lack intercentra in the vertebral column except in the tail and C1, C2. See Annot. 121 for comparison with cervical carotid processes.

(145) **Pygostylus**. Synonymy: Urostylus; Coccyx. Compound bone formed by post-natal ankylosis of 3-6, commonly 5-6, of the terminal free caudal vertebrae. The fetal development of the pygostyle is reviewed by Steiner (1938) and van Oort (1905). Holmgren (1955) contended that the Ostrich pygostyle is not homologous with that of carinate birds, a claim refuted by de Beer (1956). See Baumel (1988) for the structures attached to the pygostyle, its relationships, and remarks on its evolutionary significance.

(146) **Basis pygostyli**. Derived from fusion of the several vertebral bodies incorporated into the pygostyle. **Lamina pygostyli**. Blade-like portion of pygostyle derived from vertebral spinous processes and arches. Rudimentary transverse processes are present on the pygostyle of certain piciforms (Burt, 1930: 478). **Discus pygostyli**: In woodpeckers (piciforms) especially, and other scansorial birds, the pygostyle is distinguished by a strong transverse, shield-like disc on its caudal margin (Burt, 1930), the disc serving as an expanded area of attachment for the extraordinarily well developed muscles that depress the tail.

(147) **Costae**. The freely moveable ribs of different avian taxa vary in number. Ribs of the cervicothoracic transitional region of the vertebral column are short "floating ribs" that fail to reach the sternum (Costae incompletae). The so-called "true ribs" (Costae completae verae) consist of vertebral and sternal elements; the sternal segments articulate with Margo costalis sterni (see Annot. 157). In some instances the sternal part of one or more of the ribs do not articulate directly with the sternum (Costae completae spuriae), but with the sternal parts of true complete ribs cranial to them. Caudal to the true ribs a variable number of floating vertebral ribs may occur; the last of the series of true ribs often articulates with the ventral side of the preacetabular ilium in various birds (Arthr. Annot. 80).

(148) **Proc. uncinatus**. Synonymy: Appendix epipleuralis (Shufeldt, 1890). Dorsocaudally oriented process attached to the caudal border of the vertebral ribs. Screamers (Anhimidae) and megapodids lack uncinat processes (R. W. Storer, pers. comm.). See Myol. Annot. 59.

Incisura capitulotubercularis. The neck region (collum) of a vertebral rib exhibits this notch between its capitulum and tubercle. The interval between the neck and the transverse process of the vertebral rib corresponds to the transverse foramen of the cervical vertebrae. See Fig. 4.9; Annot. 134.

Sulcus pulmonalis. The elongated sulcus between the dorsal parts of adjacent ribs. The sulcus is occupied by lung tissue, the **Torus intercostalis** (Resp. Annot. 49); each Torus is in contact with the ribs cranial and caudal to it, as well as with the intercostal muscles and parietal pleura.

(149) **Sternum**. See Fürbringer (1888) for a detailed synonymy for the parts of the avian sternum. He distinguished a cranial part, the "Costosternum", to which the ribs are attached, and a caudal part, the "Xiphosternum", also referred to as Meta-sternum.

Corpus sterni. Synonymy: Tabula sterni.

(150) **Proc. craniolateralis sterni**. Synonymy: Proc. sternocoracoideus; Proc. precostalis.

Proc. caudolateralis sterni. Synonymy: Proc. posterior lateralis sterni or Proc. xiphoideus lateralis sterni (Fürbringer, 1888). Fürbringer noted that some galliforms possess this distinctive, extraordinarily elongated, lateral process of the sternum that branches into strong lateral and medial trabeculae. See Annot. 151.

(151) **Incisurae et fenestrae sterni**. The caudal part of the sternum is notched (incisurae) or perforated (fenestrae) in a variety of ways in different avian taxa (Fig. 4.11). Bars of bone between incisurae/fenestrae are referred to as "trabeculae"; the openings in the sternum are closed by fibrous membranes. See Fürbringer (1888) for illustrations of the various patterns.

(152) **Facies muscularis sterni**. Synonymy: Facies ventralis or externa. The surface of Corpus sterni lateral to the base of the carina to which the pectoralis and supracoracoideid muscles are attached.

Facies visceralis sterni. Synonymy: Facies dorsalis or interna. Inner surface of sternum related to heart and liver.

(153) **Linea intermuscularis**. M. supracoracoideus is attached to the ventral surface of the Corpus sterni and to the adjacent lateral aspect of the Carina sterni (Myol. Annot. 76). The intermuscular lines on each surface mark the bony attachment of the dense fascia that invests the muscle and separates it from M. pectoralis.

(154) **Planum postcarinale**. Synonym: Planum postpectorale (Fürbringer, 1902). The Carina sterni does not reach the caudal margin of the sternum in some forms (e.g., peleciforms). The planum is therefore the continuous bilateral flat surface of Facies muscularis of the sternum caudal to the carina.

(155) **Pila costalis**. The column of bone that reinforces the costal margin of the sternum, prolonged onto the Trabecula lateralis in some birds (Fig. 4.11).

(156) **Sulcus articularis coracoideus**. Synonymy: coracoid groove or depression. Located at the cranial margin of the Corpus sterni, this is the surface for articulation with the coracoid. The sulcus is a narrow, attenuated, curved groove on each side of the sternum; it extends from the base of the craniolateral process medially to the side of Rostrum sterni or onto its dorsal surface (e.g., *Larus*, *Branta*). In some birds the Sulcus is directed caudolaterally from the midline Rostrum; however in others it is oriented nearly transversely (e.g., *Gallus*, *Coccyzus*, *Dendrocopos*, *Progne*). In several groups the coracoid sulci overlap in the median plane (see Arthr. Annot. 89, 90). Commonly the length of the Sulcus is nearly perpendicular to the median plane, but its lateral end is depressed or elevated in some birds. See Fig. 4.11.

(157) The **Margo costalis sterni**, when viewed from the side, exhibits a series of notches (**Incisurae costales**) separated from one another by partitions, each known as a **Proc. articularis sternocostalis** (Komárek, 1979). Between two adjacent processes is a small compartment called the **Loculus costalis** (new term); the head of the sternal rib partly occupies a locule, and articulates with the caudal surface of a sternocostal articular process, **Facies articularis costalis**. In some avian taxa dual articular facets exist for the corresponding facets on the dual-headed sternal ribs (see Arthr. Annot. 83).

Margo caudalis sterni. The caudal margin of the sternum is highly variable in shape; it may be squared, rounded, intact, or notched. See Fürbringer (1888) for characteristic shapes of sterna of numerous taxa.

(158) **Pila coracoidea**. The transversely oriented, curved pillar of bone along the cranial margin of the Corpus sterni (Fig. 4.11) that strengthens the articular sulcus for Os coracoideum.

(159) **Rostrum sterni**. Synonymy: Manubrium sterni; Spina intercoracoidea sterni (see Fürbringer, 1888, for complete synonymy and descriptions and summary of variation of the Rostrum). Serves as an attachment of parts of Membrana sternocoracoclavicularis (Arthr. Annot. 86). The spines of the Rostrum are designated **Spina externa** and **Spina interna** because of their continuity with the external and internal labra of the Sulcus articularis coracoideus. Spina externa is usually present; in some psittacines, picids, and most passerines, including the Menurae, the external spine is forked, its processes are called the **Alae spinae externae**. The Spina interna is of much less frequent occurrence (occurring in, e.g., galliforms, cuculids, meropids, upupids, and bucerotids), and is frequently represented by a tubercle(s) between the two Labra interna of the coracoidal articular sulcus. The external and internal spines may coalesce producing the **Spina communis** (see Fig. 4.11; Annot. 160).

(160) **Foramen rostri**. Synonymy: Foramen interspinale. The foramen is an opening at the base of the ankylosed external and internal spines of the sternal rostrum (e.g., galliform and coraciiform birds). In some birds the **Septum-interarticulare** connects the external and internal spines, and separates the right and left coracoidal sulci in the midline by bone or membrane; in birds having side-to-side or overlapping contact between the two coracoids the **Spatium intercoracoidale** is open (Arthr. Annot. 90).

(161) **Carina sterni**. Synonymy: Crista sterni (Fürbringer, 1888); (Carina, L. keel). The vertical plate of bone attached to the median line of the Corpus sterni found in most birds (thus "carinate birds"). In the psittaciform, *Strigops*, the carina is lacking. Ratites generally lack a distinct, well developed carina, e.g., *Struthio*. The sternum of *Apteryx*, *Casuaris*, and *Rhea* exhibits a slight crest (Beddard, 1898).

Crista lateralis carinae. A paired crest on each side of the dorsal, thick part of the cranial margin of the carina (e.g., *Gallus*, *Cathartes*). The **Sulcus carinae** is the shallow groove between the two lateral crests; the Sulcus is an elongated triangle in *Gallus*. The **Pila carinae** (Fig. 4.11) is the thick reinforcing pillar of bone of the cranial margin of the carina.

(162) **Clavicula [Furcula]**. (Fig. 4.10. (Furcula, L. fork). Furcula refers to the united, paired clavicles. When not ankylosed at their ventral ends, the clavicles may be joined by cartilage or fibrous tissue (many parrots, owls, *Buceros*, *Alcedo*; Newton, 1896). Glenny and Friedmann (1954) discussed the reduction or suppression of the clavicle in various birds (e.g., Australian parrots). According to Austin (1961) the scrub bird *Atrichornis* is the only passerine with noncoalesced clavicles (see Rich, et al., 1985). The clavicles are absent in all ratites except for the emu (Elznowski, 1989).

Fürbringer (1888) describes subcoracoid, acrocoracoid, and supracoracoid segments of the clavicle, the last extending to the scapula, and presented a summary of the form of the clavicle. See Stegmann (1964) for the functional implications of the configuration of the clavicle. Jenkins, et al. (1988) have observed cineradiographically movements of the clavicle during flight. See Arthr. Annot. 85.

(163) **Apophysis furculae [Hypocleideum]**. Synonymy: Lamina interclavicularis. In most birds the ventral part of the Furcula is drawn out into a median projecting blade, rod, or knob that is attached to the Apex carinae directly or indirectly (see

Arthr. Annot. 85). Fürbringer (1888) describes three varieties of the **Proc. interclavicularis**, one of which projects proximally into the angle formed by the junction of the two furcular rami.

(164) **Extremitas omalis clavicularae [Epicleidium]**. Synonymy: Extremitas scapularis. (Omos, Gk. shoulder). This is the dorsal expanded end of each clavicle at the shoulder (see below, Annot. 165; and Topog. Annot. 32).

(165) **Proc. acromialis clavicularae; Proc. acrocoracoideus clavicularae**. Clavicles of certain birds possess distinct processes for articulation with the cranial tip of the scapula (Proc. acromialis) and the upper, pointed end of the coracoid bone (Proc. acrocoracoideus). In diomedids, ciconiiforms, and falconiforms only the caudally directed Proc. acromialis of the clavicle is well developed. Both processes are present, e.g., in *Alcedo*, *Merops*, *Ramphastos*, and *Sturnus* (Fürbringer, 1888).

(166) **Scapula**. See Fürbringer (1888) for additional terms and comparative descriptions of the avian scapula not listed here. His illustrations depict the range of shapes of avian scapulae. **Facies lateralis**. Synonymy: Facies externa or dorsolateralis of the scapula. **Facies medialis [costalis]**. Synonymy: Facies interna or ventromedialis of the scapula.

Acromion. (Omon, Gk. small shoulder). The pointed cranial end of the scapula, near its glenoid process. In *Menura* and *Atrichornis* (passerine suborder Menurae) the acromion is bifurcate, having two blunt knob-like processes (Rich, et al., 1985).

Crista lig. acrocoracoacromiali. In some birds this short crest on the dorsum of the acromion is continuous with the dorsal margin of the scapula; for attachment of the acrocoracoacromiale ligament (Fig. 4.10; Arthr. Annot. 95). The crest is pronounced, e.g., in *Cathartes*, *Ardea*, *Branta*, *Phoenicopterus*, and *Columba*.

(167a) **Facies articularis humeralis**. Synonymy: Pars scapulae fossae glenoidalis; Pars coracoidea fossae glenoidalis (Fürbringer, 1888). The humeral articular facet of the glenoid process of the scapula adjoins the humeral articular facet of the glenoid process of the coracoid, the two surfaces together forming the **Cavitas glenoidalis** for articulation with the head of the humerus. The coracoid generally contributes much the larger area to the humeral articular surface (e.g., *Strix varia*). The slightly concave articular facets of both bones are invested with the thick elastic cartilage (J. Baumel and R. Brown, pers. obs.), Lig. coracoscapulare interosseum, with which the humerus actually articulates; the elevated margins (labra) of this ligament deepen the shallow glenoid cavity (Arthr. Annot. 93).

(167b) **Proc. glenoidalis scapulae**. Set off somewhat perpendicular to the body of the scapula, the glenoid process of the scapula bears the surface for articulation with the head of the humerus; the glenoid process in certain birds also articulates directly with the procoracoid process of the coracoid. See Fig. 4.10.

Proc. glenoidalis coracoidei. This is the low, lateral offset of the shaft of the coracoid bone that bears the humeral articular surface, usually continuous with the base of the procoracoid process.

(168) **Facies articularis coracoidea**. Linear articular surface on the cranial extremity of the scapula extending between the acromion and the glenoid process; forms a joint with the procoracoid and adjacent glenoid process of the coracoid bone.

Tuberculum coracoideum. Some birds (e.g., *Ardea*, *Larus*, *Branta*) possess this convex spherical or ellipsoidal boss of the cranial surface of the Proc. glenoidalis of the scapula; the Tuberculum fits into a cupped surface on the coracoid together forming the coracoscapular joint (see Fig. 4.10; and below, Annot. 173b). The

coracoscapular joint surfaces in most birds are less elaborate than those just described (see above paragraph).

(169) **Tuberculum m. scapulo-tricipitis.** In some birds this distinct tubercle for attachment of the scapulo-triceps muscle is located on the ventral border of the scapula directly caudal to its Proc. glenoidalis (Fig. 4.10).

(170) **Corpus scapulae.** The neck (**Collum scapulae**) and cranial half of the body (**Corpus**) of the scapula is generally a rounded cylinder in cross section; its caudal half is flattened and usually blade-like, straight, or curved. The caudal half of the atypical scapula of penguins (spheniscids) is a wide paddle-shape.

(171a) **Extremitas omalis coracoidei.** The shoulder or dorsal end of the coracoid bone (Omos, Gk. shoulder).

Proc. acrocoracoideus. (Acro-, Gk. combining form, an extremity or highest point of a structure). This is the dorsal end of the coracoid bone that projects past its glenoid process.

(171b) **Tuberculum brachiale.** Synonymy: Tuber brachialis (Ballmann, 1969a); Tuberositas brachialis (Lambrecht, 1933; Howard, 1929); Tuberositas humeralis. This term refers to the low projection on the medial side of the acrocoracoideus process of the coracoid of some forms which is directed ventrally, overhanging the supracoracoideus sulcus to some degree. In the birds in which it exists, the tuberculum is the attachment of the acrocoraco-acromial ligament which forms part of the medial wall of the triosseal canal (Annot. 177) in some birds. Although "Tuberculum brachialis" (sic) is used frequently in avian paleontology, it is not descriptively apt, as the tubercle has no direct relationship to the brachium or humerus.

(172) **Proc. procoracoideus** (Sabatier, 1880). Synonymy: see Fürbringer (1888: 41). This is a projection of the medial border of the coracoid, its upper edge roughly perpendicular to the coracoid shaft, its medial border gradually merging with the shaft ventrally. In some birds its tip is curved abruptly dorsally forming the medial boundary of the smoothly curved Sulcus supracoracoideus. See **Arthr.** Annot. 87, 97.

Sulcus supracoracoideus (Ballmann, 1969a). Groove for the tendon of M. supracoracoideus on the base of Proc. procoracoideus and adjacent part of the upper shaft of the coracoid bone that forms a pulley for the tendon of M. supracoracoideus (Fig. 4.10).

(173a) **Facies articularis scapularis.** In some birds this narrow, linear facet is on the internal surface of the upper edge of the procoracoideus process, and is prolonged laterally onto the base of Proc. glenoidalis (Annot. 168); the continuous surface makes contact with a corresponding surface on the scapula, producing a simple coracoscapular joint (**Arthr.** Annot. 93). Other birds possess a more complicated joint (see Annot. 173b).

(173b) **Cotyla scapularis.** Synonymy: Facies scapularis (Ballmann, 1969a). Occurring in some birds (e.g., *Ardea*, *Larus*, *Branta*), this is the spherical or ellipsoidal concavity on the glenoid process/procoracoideus process of Os coracoideum adjacent to its glenoid facet (Fig. 4.10). The cotyla receives the corresponding Tuberculum coracoideum of the scapula, the two forming the coracoscapular joint (**Arthr.** Annot. 93). In most birds the joint surfaces of the coracoscapular joint are less elaborate than those described here (see Annot. 168 and 173a). The Cretaceous birds *Ambiortus* and *Apatornis* exhibit the Cotyla/Tuberculum type of coracoscapular joint that Martin (1987) considers primitive for modern birds.

(174) **Linea intermuscularis ventralis** (Lambrecht, 1933). Synonymy: anterior intermuscular line (Fisher, 1945). These intermuscular lines on the coracoid are illustrated by Ballmann (1969a). See **Myol.** Annot. 74, 76.

(175a) **Crista articularis sternalis.** This surface of the coracoid for articulation with the sternum is divided into ventral and dorsal facets (**Facies externa** and **F. interna**). In some birds (e.g., *Ardea*, *Columba*, *Corvus*) they are not continuous with one another. The margins of each of the facets are sharply defined where they meet the superficial and deep surfaces of the coracoid. The external and internal articular facets are set off from one another by a slightly curved ridge (**Crista intermedia**) that articulates with a corresponding groove at the bottom of the coracoid articular sulcus of the sternum. In some birds the sternal articular facets of the coracoid are subdivided into medial and lateral parts by a non-articular segment. See **Arthr.** Annot. 89, 90.

(175b) **Facies articularis intercoracoidea.** Articular facet located on the medial angle of the sternal end of the coracoid in birds whose coracoids articulate with one another in the median plane. See Annot. 160; **Arthr.** Annot. 90.

(176) **Proc. lateralis.** Synonymy: Proc. lateralis posterior; Proc. externus; Proc. sternocoracoideus. In many birds this process of the sternal end of the coracoid is drawn out into a point, the **Angulus lateralis**. The upper border of the lateral process is known as the **Margo supra-angularis** (E. N. Kurochkin, pers. comm.).

(177) **Canalis triosseus.** Synonymy: Foramen triosseum; Canalis supracoracoideus (Fürbringer, 1888). The canal transmits, and serves as a pulley for, the tendon of M. supracoracoideus. In some birds the canal is produced by only two bones, the procoracoideus process of the coracoid and the scapula, with no contribution from the clavicle; the canal may be formed completely by the coracoid alone in birds having an ossified bridge connecting the acrocoracoideus and procoracoideus processes (e.g., *Musophagidae*, *Meropidae*, *Upupidae*, *Bucerotidae*, *Columba livia*, and *trochilids*). See **Arthr.** Annot. 87, 95, 171.

(178) **Ossa alae [Ossa membri thoracici].** Bones of the wing or thoracic limb. Terms of direction of the wing bones are based on the defined anatomical position of the avian wing, i.e., extended and abducted (see **Gen. Intro.**). In this anatomical position the extensor (dorsal) aspect of the humerus faces caudally and the flexor (ventral or palmar) aspect faces cranially. The long axis of the ellipsoidal articular surface of the Caput humeri is nearly vertical with the wing outstretched (Fürbringer, 1888); the epicondyles at the distal end of the humerus are situated dorsally and ventrally.

Of special interest to paleontologists is the work of Ballmann (1969a) which contains a comprehensive terminology for all the skeletal elements of the wing, including attachments of ligaments and muscles. See also Komárek (1979).

Humerus. Consult Fürbringer (1888) for a synonymy of terms on parts of the humerus. **Facies caudalis** of the humerus is also known as its anconal surface; **Facies cranialis** is also known as its volar or palmar surface.

(179) **Caput humeri.** Synonymy: Caput articulare humeri (Fürbringer, 1888). The head of the proximal end of the humerus, specifically its articular surface.

(180) **Incisura capitis humeri.** Synonymy: capital groove (Howard, 1929); Incisura collaris. The pronounced notch of the head of the humerus, located between the articular surface of the Caput humeri and Tuberculum ventrale (Fig. 4.12A). With the

wing folded against the trunk, the incisure accommodates the scapular labrum of *Cavitas glenoidalis*.

Crista incisurae capitis. The crest or ridge of bone that connects the head of the humerus with the ventral tubercle; the crest separates the proximal end of the incisure of the head of the humerus from the *Sulcus transversus* (see Annot. 185).

(181) **Planum intertuberculare** (Fürbringer, 1888). Synonymy: *Planum* [*Facies*] *bicipitale*. The intertubercular plane refers to much of the cranial surface of the expanded proximal end of the humerus distal to its *Caput*, i.e., the area between the dorsal and ventral tubercles and part of the surface between the bicipital and deltopectoral crests. Features included in this plane are: *Sulcus transversus*, *Impressio coracobrachialis*, and *Intumescencia humeri*. The *Planum* in most birds is covered by the tendon and aponeurosis of origin of *M. biceps brachii*.

Sulcus [Canalis] n. coracobrachialis. In many different birds this is a shallow transverse groove at the distal margin of the intertubercular plane of the humerus (see above) which conducts *N. coracobrachialis* from the distal end of the bicipital crest to the ventral border of the *Impressio coracobrachialis* (Fig. 4.12).

Characteristic of charadriiforms (Ballmann, 1979), the nerve is transmitted by an osseous canal deep to the distal part of the surface of the *Intumescencia humeri*.

(182) **Tuberculum dorsale.** Synonymy: *Tuberculum minus* or *laterale*; *Tuberculum m. supracoracoidei*. Located at the proximal end of the deltopectoral crest, for insertion of the principal part of the tendon of *M. supracoracoideus*. See Fig. 4.12; Annot. 183.

(183) **Crista m. supracoracoidei** (Fürbringer, 1888). This crest is an accessory insertion of the tendon of the *supracoracoideus* muscle, its main insertion being the *Tuberculum dorsale*. The crest extends distally from the *Tuberculum* to the base of *Crista deltopectoralis*. Well displayed in examples of phasianids, alcids, psittacids, and columbids. See Annot. 182.

(184) **Crista deltopectoralis.** Synonymy: *Crista deltoidea*; *Crista pectoralis*; *Crista tuberculi minoris*, or *lateralis*, or *dorsalis*. "*Crista deltopectoralis*" is used in the paleontological literature (e.g., Ostrom, 1979), and is a reasonable name inasmuch as both *M. pectoralis* and the cranial head of *M. deltoideus major* are attached to opposite surfaces of the crest.

Crista bicipitalis. Synonymy: *Crista tuberculi majoris*, or *medialis*, or *ventralis*. Origin of the aponeurosis of the humeral head of *M. biceps brachii*.

(185) **Sulcus transversus** (Lambrecht, 1933). Synonymy: *Ligamental furrow* (Howard, 1929). Located on the cranial surface of the humerus just distal to *Caput humeri* (Fig. 4.12); for attachment of the *Lig. acrocoracohumerale*. The *sulcus* is strongly defined in, e.g., *Larus*.

(186) **Impressio coracobrachialis.** An impression for insertion of *M. coracobrachialis* cranialis. The impression is a fairly distinct shallow excavation in many birds, e.g., *Branta*, *Chordeiles*, *Aegolius*, *Crotophaga*; a deeply etched triangular fossa in larids and charadriids (Fürbringer, 1888).

(187) **Tuberculum ventrale.** Synonymy: *Tuberculum mediale* or *majus* (Fürbringer, 1888). The ventral tubercle of the humerus is continuous with the proximal end of *Crista bicipitalis* (Fig. 4.12), and is much stronger than *Tuberculum dorsale*. The ventral tubercle is extraordinarily prominent in ratite birds (Fürbringer,

1888); it is a common point of insertion of several of the short muscles of the shoulder region arising from the scapula and coracoid.

(188) **Fossa pneumotricipitalis [Fossa tricipitalis].** Synonymy: *Fossa pneumoanconaea* (Fürbringer, 1888); *Fossa pneumatica*. This excavation in the proximal humerus varies in its form and development in different avian groups. Its name indicates that parts of the triceps muscle complex and the pneumatic foramen of the humerus are housed in the fossa. The name *M. triceps brachii* has replaced the term *M. anconaeus*, requiring a change in Fürbringer's name of the fossa. The humerus is hardly, or not at all, pneumatic in some avian groups (Fürbringer, 1888) (e.g., *Gavia*, *Pygoscelis*, *Alca*); in the forms having apneumatic humeri the fossa is present nonetheless, thus "*Fossa tricipitalis*" is appropriate as suggested by Fürbringer's term, *Fossa anconaea*.

Well developed pneumotricipital fossae extend into the *Caput humeri* and *Tuberculum ventrale* (e.g., *Larus*). In most birds the fossa is a single continuous excavation, bounded ventrally and dorsally by *Crus ventrale fossae* and *Crus dorsale fossae* (Fig. 4.12) which converge on the apex of the ventral tubercle. The single fossa is occupied by both heads of *M. humerotriceps*, the insertion of *M. scapulohumeralis* cranialis and the pneumatic foramen. See *Myol.* 71-74, 82).

In other birds (also well exemplified by *Larus*) a second or additional fossa is formed between the *Crus dorsalis fossae* (medial bar of Bock (1962); *Crista coracoidea* of Komárek (1979) and the *Caput humeri*). This second fossa is bounded dorsally by the *Margo caudalis* of the humerus (Fig. 4.12) that extends from the *Caput* distally onto the caudal aspect of the shaft of the humerus; the *Margo caudalis* is a pronounced ridge in many birds, lacking in others. The second fossa is occupied by the dorsal head of *M. humerotriceps*. Consult Bock (1962) for a comprehensive treatment of this topic in passerine birds; see below, Annot. 189.

(189) **Foramen pneumaticum.** When present, this foramen (or multiple foramina) is located in the *Fossa pneumotricipitalis* of the humerus (Annot. 188). The pneumatic foramen is not found in the humeri of all birds; humeri of birds with dual fossae generally are not pneumatised. The pneumatic foramen is lacking in: penguins, procellariiforms (except albatrosses), loons, grebes, cormorants and anhingas, several tribes of ducks (mainly the diving ones); most charadriiforms, rallids, and many oscine passerines (S. Olson, P. Ballmann, pers. comms.).

(190) **Intumescencia humeri.** Term used by Fürbringer (1888) and Buri (1900) for the convex, smooth swelling distal to, and continuous with, the intertubercular plane (Annot. 181) of the cranial aspect of the proximal end of the humerus; the intumescence is directly opposite *Fossa pneumotricipitalis* on the caudal side (see Fig. 4.12).

(191) **Sulcus n. radialis.** A distinct sulcus on the dorsal surface of the shaft of the humerus for *N. radialis* occurs only rarely: *Casuaris*, hummingbirds and swifts (*Apodiformes*).

(192) **Condylus dorsalis humeri.** Synonymy: *Condylus* [*Trochlea*] *radialis*, or *medialis*, or *internus*. With the limb in the anatomical position this condyle on the dorsal (radial) side of the distal end of the humerus articulates with both *Radius* and *Ulna*. **Condylus ventralis humeri.** Synonymy: *Condylus* [*Trochlea*] *ulnaris*, *medialis*, or *internus*; this condyle articulates only with the ulna (see *Arthr.* Fig. 5.4).

(193) **Incisura intercondylaris.** Synonymy: *Vallis intertrochlearis* (Fürbringer, 1888); *Vallis intercondylaris* (Ballmann, 1969a). Notch separating the dorsal and ventral condyles of the humerus.

(194) **Epicondylus dorsalis**. [**Ectepicondylus**]; **Epicondylus radialis**, or **lateralis**, or **externus**. **Epicondylus ventralis**. [**Entepicondylaris**]; **Epicondylaris ulnaris**, or **medialis**, or **internus** (see Fig. 4.12; Annot. 178; **Myol.** Annot. 91, 92).

(195) **Proc. flexorius**. Process at distal end of humerus, ventral to **Condylus ventralis** of the distal humerus for attachment of the tendinous head of *M. flexor carpi ulnaris* (Ballmann, 1969a). See Fig. 4.12; **Arthr.** Annot. 110 (*Trochlea humeroulnaris*).

(196) **Tuberculum supracondylare dorsale**. Synonymy: *Eminentia m. extensoris metacarpi radialis* (E. N. Kurochkin, pers. comm). Most birds possess a relatively compact tubercle on the dorsal border of the distal humerus, a short distance from the dorsal epicondyle (Fig. 4.12) for the origin of *M. extensor carpi [metacarpi] radialis* (see **Myol.** Annot. 87). In some birds the **Tuberculum** is displaced distally, thus so close to the dorsal epicondyle that the two are nearly indistinguishable. In some birds (e.g., diomedids, charadriiforms, passeriforms) the muscle is attached to a stout, pointed **Proc. supracondylaris dorsalis**. Swifts and hummingbirds are unusual in having the tubercle for *M. extensor carpi [metacarpi] radialis* displaced far proximally on the humeral shaft (Zusi and Bentz, 1982). See **Arthr.** Annot. 141; **Myol.** Annot. 77, 78.

Tuberculum supracondylare ventrale. Attachment of *Lig. collaterale ventrale* of the elbow joint (**Arthr.** Annot. 105).

(197) **Proc. cotylaris dorsalis**. Prominent dorsal extension of the proximal *Ulna* that bears the *Cotyla dorsalis* on its cranial surface and *Impressio m. scapulotriceps* on its dorsal surface.

(198) **Cotyla dorsalis**; **Cotyla ventralis**. Synonymy: *Cotyla externa/interna* (Lambrecht, 1933); *Facies glenoidalis externa et interna* (Ballmann, 1969a). The concave articular surfaces of the *ulna* for the dorsal and ventral condyles of the humerus. The ventral *cotyla* is the larger of the two, and is located at the base of the *Olecranon* (see above and Fig. 4.13).

(199) **Incisura radialis**. Synonymy: *Depressio radialis proximalis* (Howard, 1929; Ballmann, 1969a). The concave facet on the proximal *ulna* for articulation with *Caput radii*; situated just past the distal margin of *Cotyla dorsalis* (Fig. 4.12).

(200) **Sulcus scapulotricipitalis**. Synonymy: *Sulcus m. scapulotricipitis*; *Sulcus dorsalis m. tricipitis*. **Sulcus humerotricipitalis**. Synonymy: *Sulcus m. humerotricipitis*; *Sulcus ventralis m. tricipitis*. Located on the dorsal aspect of the distal humerus, the sulci for the two tendons of the *triceps brachii* complex are separated by a low ridge; the *Sulcus humerotricipitalis* is the larger of the two.

(201) **Olecranon**. Synonymy: *Proc. coronioideus ulnaris* (Lambrecht, 1933). Strong, pointed process of the proximal end of the *ulna* for attachment of *M. humerotriceps* and *Trochlea humeroulnaris* (**Arthr.** Annot. 110). Barnett and Lewis (1958) note that the *olecranon* is lacking in some birds, e.g., the swift *Micropus*, the penguin *Aptenodytes*; however this process appears to be replaced by sesamoid bones in the tendons of the *triceps* muscles in these forms. See Annot. 202.

(202) **Os sesamoideum m. scapulotricipitis**. Synonymy: *Patella ulnaris* (Fürbringer, 1888). This is a sesamoid bone in the tendon of *M. scapulotriceps* of some species; unusually well developed in the hummingbirds (Zusi and Bentz, 1984) and in spheniscids.

(203) **Tuberculum lig. collateralis ventralis** (Fig. 9). Synonymy: *Facies lig. interni* (Ballmann, 1969a). Point of attachment to the *ulna* of the ventral collateral ligament of the elbow joint (see Fig. 4.13).

Sulcus tendinosus. In some birds this sulcus is a well delineated feature on the ventral surface of the proximal *Ulna*, located between the *Olecranon* and the edge of the ventral *cotyla*; the tendon of *M. flexor carpi ulnaris* glides in this sulcus, separated from the sulcus by part of *Trochlea humeroulnaris* (see **Arthr.** Fig. 5.4).

(204) **Facies corporis ulnae**. Of the three surfaces of the body of the *ulna*, **Facies caudodorsalis** is subcutaneous; the caudodorsal surface is separated from **Facies caudoventralis** by the row of *Papillae remigales caudales* (Annot. 205). **Facies cranialis** is shallowly concave; its proximal half exhibits pronounced intermuscular crests in some of the larger birds. The flattened *ulna* (and radius) in spheniscids possesses only dorsal and ventral surfaces.

(205) **Papillae remigales caudales**; **Papillae remigales ventrales**. Synonymy: *Papillae ulnares anconales* (Lambrecht, 1933); quill knobs (Edington and Miller, 1941). Markings on the *ulna* for attachment of the ligaments of the follicles of the secondary flight feathers. See Fig. 4.13; and **Arthr.** Annot. 199, 204.

(206) **Condylus dorsalis ulnae**. Synonymy: *Condylus externus* or *caudalis*. **Condylus ventralis ulnae**. Synonymy: *Condylus internus*, or *cranialis*, or *metacarpalis*. As a result of the torsion of the ulnar shaft, the dorsal condyle is located somewhat more caudally than the ventral condyle. At the distal end of the *ulna* the two condyles and the groove between them form the **Trochlea carpalis**. On the ventral surface of the distal *ulna* the *trochlea* is markedly deepened in some birds (e.g., *Phoenicopterus*) forming the **Sulcus intercondylaris** (Fig. 4.13) between the two condyles. *Os carpi radiale* and *Meniscus intercarpalis* articulate with both condyles; *Os carpi ulnare* articulates mainly with the dorsal condyle. See **Arthr.** Annot. 117-119.

(207) **Tuberculum carpale**. Synonymy: *Tuberositas carpalis* (Lambrecht, 1933). The carpal tubercle is a conspicuous, in some birds pointed, process (e.g., *Larus*) on the ventral aspect of the distal end of the *ulna*, closely related to the ventral condyle of its *trochlea*, for the attachment of the *Lig. ulno-ulnocarpale distale* and *Lig. ulno-metacarpale ventrale* (see Fig. 4.13).

Incisura tuberculi carpalis (new term). This notch between the ventral condyle of the *ulna* and the *Tuberculum carpale* is pronounced in some forms (e.g., the vultures *Cathartes* and *Coragyps*); in these forms the notch contains pneumatic pores. The deep part of *Lig. ulno-ulnocarpale distale* occupies much of the *incisura* (*Columba*).

(208) **Depressio radialis**. Synonymy: *Depressio radialis distalis* (Lambrecht, 1933; Ballmann, 1969a); *Sulcus radialis* (NAA, 1979). This surface of the distal end of the *ulna* is involved in the distal radioulnar joint, the counterpart of the proximal radioulnar joint. Located on the dorsal surface of the *ulna* near the carpal tubercle, this surface is the ulnar attachment of *Lig. interosseum radioulnare* which prevents direct contact of the two bones; the radius glides against the ligament in flexion and extension of the wrist joints. See Fig. 4.12; **Arthr.** Annot. 116.

(209) **Incisura tendinosa** (Lambrecht, 1933; Ballmann, 1969a). Situated on the distal end of the ulna near its dorsal condyle, the curved *Incisura* acts as a pulley for the tendons of *M. extensor metacarpi ulnaris* and *extensor digitorum communis* as they change direction and enter the manus. The tendons are held in the incisura by a fibrous retinaculum (ossified in *Gavia*). See Fig. 4.13.

(210) **Tuberculum bicipitale radii** (Howard, 1929). Synonymy: *Tuberculum extertum* (Lambrecht, 1933). Tubercle on the proximal radius for insertion of *M. biceps brachii*. In most birds the tendon of *M. biceps brachii* bifurcates, the main branch inserting on the proximal end of the radius, the other to the proximal ulna **Tuberculum bicipitale ulnae** (Berger, 1966). In the higher passeriforms the radial tendon of the biceps inserts into a fovea (pit), considered by Ballmann (1969a) to be a diagnostic feature. See Fig. 4.13.

(211) **Facies articularis radiocarpalis**. Synonymy: *Articulatio scapholunaris* (Lambrecht, 1933). Surface on the distal radius for articulation with *Os carpi radiale*. **Facies articularis ulnaris**. The distal ends of radius and ulna do not directly articulate; the two are closely related but separated by *Lig. radioulnare interosseum* (see Annot. 208; and *Arthr.* Annot. 116).

Sulcus tendinosus. A single wide groove, or two parallel grooves (e.g., *gaviiforms*, McKittrick, 1991), on the dorsum of the distal end of the radius occupied by tendons of extensor muscles of the wrist joint passing across the carpus into the hand.

(212) **Depressio ligamentosa**. Synonymy: ulnar depression (Howard, 1929). Located on the caudal surface of the distal radius this depression is occupied by the *Lig. interosseum radioulnare distale* (see Annot. 208; and *Arthr.* Annot. 116).

(213) **Tuberculum aponeurosis ventralis**. Synonymy: *Ligamentum process* (Howard, 1929). The *Tuberculum* is located on the distal end of the radius ventral to the articular surface for *Os carpi radiale*. The tubercle serves as the attachment of the *Aponeurosis ventralis* that fans out onto the remiges in the wrist region (*Arthr.* Annot. 113 and Fig. 4.13).

(214) **Ossa carpi**. Recently Hinchliffe (1985) has restudied the embryological development of the carpal bones and metacarpals in *Gallus*, using more precise techniques than those of earlier works. He contends that of the five embryonic carpal elements, the "radiale" becomes the definitive *Os carpi radiale*. The embryonic "ulnare" regresses and disappears; it is replaced by carpal 'x'. The "pisiform", however, becomes *Os carpi ulnare*, the definitive adult proximal carpal bone; the latter name is retained because of familiarity.

In early postnatal life the three remaining carpals become incorporated with the proximal ends of the metacarpals, forming the compound bone, the *Carpometacarpus*. For details of the development of the avian wrist and homologies of the digits see Steiner (1922), Montagna (1945), Holmgren (1955), Romanoff (1960), Berger (1966), Seichert and Richter (1972), and Hinchliffe (1985). See *Osteo.* Intro. "Nomenclature of digits of wing"; and *Arthr.* Annot. 112, 122, 128.

(215) **Os carpi ulnare** (*Arthr.* Annot. 112, 122). Synonymy: *Os cuneiform* (Lambrecht, 1933); *ulnare*. U-shaped carpal bone in the caudal angle of the wrist region; unusual triangular-shaped in spheniscids. **Crus longum et Crus breve**. These are the two limbs of *Os carpi ulnare*; *Crus longum* is situated ventrally, *Crus breve* dorsally. **Proc. muscularis**. At the proximal end of the *Os carpi ulnare* the muscular process projects from the body of the ulnare that connects its two crura; *M. flexor carpi*

ulnaris, *Retinaculum ulnocaroremigiale* and *Lig. humerocarpale* attach to the muscular process. See *Myol.* Annot. 85.

Incisura metacarpalis is the U-shaped notch between the two crura of *Os carpi ulnare* which clasp the proximal end of the *Carpometacarpus*. **Facies articularis metacarpalis** is the surface of the *Os carpi ulnare* that articulates with the caudal part of the *Trochlea carpalis* of the *Carpometacarpus*.

Os carpi radiale. Synonymy: *Os scapholunare* (Lambrecht, 1933). On the cranial aspect of the wrist, the radial carpal bone articulates with the distal end of the radius, carpal trochlea of the distal ulna, and the *Trochlea carpalis* of the *Carpometacarpus* (see *Arthr.* Annot. 112, 122).

(216) **Os metacarpale alulare**. Synonymy: *Metacarpus pollicis*; *Proc. metacarpalis pollicis* [digit I or II]. See *Osteo.* Intro. for remarks on the nomenclature of digits of the manus.

Extremitas proximalis carpometacarpi. The proximal end of this compound bone is formed by ankylosis of some of the distal carpal bones with the fused proximal ends of the three metacarpal bones (see Annot. 214).

Os prominens. Sesamoid bone in the propatagial ligament (see *Arthr.* Annot. 141) near its attachment to the extensor process of the *carpometacarpus*; it is *not* a carpal bone, but is listed with the carpals because of its topographic proximity to them. *Os prominens* occurs, e.g., in *buteos*, *falconids*, and *strigids*.

(217) **Fovea carpalis caudalis**. Synonymy: *Fossa carpalis posterior*; **Fovea carpalis cranialis**. *Fossa carpalis anterior* (Ballmann, 1969a). The foveae are located at the cranial and caudal ends of the articular surfaces of *Trochlea carpalis* of the *Carpometacarpus* (Fig. 4.14). With the wrist joint in extension, the edge of the *Os carpi radiale* fits into the *Fovea cranialis*; with the joint flexed the *Fovea caudalis* accommodates the distal edge of the *Os carpi ulnare*.

(218) **Fossa infratrochlearis**. Synonymy: *Fossa carpalis interna* (Ballmann, 1969a). The depressed area of attachment of the *Lig. radiocarpometacarpale ventrale* at the proximal end of the ventral side of the *Carpometacarpus*. See Fig. 4.14; and *Arthr.* Fig. 5.5.

(219) **Fossa supratrochlearis**. Synonymy: *Facies ligamentalis externa* (Ballmann, 1969a). At the proximal end of the dorsal side of the *Carpometacarpus* this is the depression for attachment of the dorsal *ulnocarpometacarpal* ligament. See Fig. 4.14; and *Arthr.* Fig. 5.5.

(220) **Proc. pisiformis**. Synonymy: *Apophysis pisiformis* (Lambrecht, 1933). Stubby process of the ventral surface of the proximal end of the *Carpometacarpus* (Fig. 4.14); serves for attachment of the *Retinaculum flexorum*, and as a pulley changing the direction of the tendon of *M. flexor digitorum profundus*.

(221) **Proc. intermetacarpalis** (Milne-Edwards, 1867-71). Synonymy: *Tuberositas muscularis* (Ballmann, 1969a). This is a process of the major metacarpal bone that projects caudally overlapping, and often fusing with, the dorsum of the minor metacarpal bone (Fig. 4.14); it receives the insertion of *M. extensor metacarpi ulnaris*. Not present in all birds, it occurs in examples of *galli-*, *pici-*, *coracii-*, and *passeriform* birds, as well as *colliiforms* (Ballmann, pers. comm.).

Protuberantia metacarpalis (new term). Synonymy: *carpometacarpal process* (Harrison, 1968); *carpometacarpal protuberance* (Feduccia and Olson, 1982). In certain birds the cranial border of the major metacarpal bone bears this hump-like process at about its middle, e.g., in the oscine passerines *Menura* and *Chlamydera*

(Feduccia and Olson, 1982); in yet other passerines, *Progne* and *Sturnus* (pers. obs.), the protuberance is situated farther distally than the above examples.

(222) **Symphysis metacarpalis proximalis/distalis** (Lambrecht, 1933; Ballmann, 1969a). The regions of ankylosis of the proximal and distal ends of the major and minor metacarpal bones to one another in early postnatal maturation. These so-called "symphyses" are in reality synchondroses which when ankylosed become synostoses. See *Arthr.* Annot. 129.

(223) **Sulcus interosseus**. Longitudinal groove on the dorsal aspect of the region of the distal metacarpal symphysis (Fig. 4.14); the sulcus is occupied by tendons of *Mm. interossei*.

(224) **Ossa digitorum manus**. The most common phalangeal formula of birds: one alular phalanx, two phalanges of *Digitus major*, and one phalanx of *Digitus minor*. In a number of avian orders the alular digit possesses two phalanges, the terminal phalanx often bearing a claw (hoatzins and turacos, R. W. Storer, pers. comm.); *Digitus major* often has a third phalanx in anatids (R. W. Storer, pers. comm). See *Integ.* Annot. 87 for comment on supernumerary digital claws (phalanges); *Arthr.* Annot. 137.

(225) **Pila cranialis phalangis**. This is the thickened leading edge of the large proximal phalanx of *Digitus major* that forms a strong reinforcing bar of bone (Fig. 4.14). The caudal border of the phalanx is thin and fenestrate in some avian taxa.

(226) **Os coxae** (Coxa, L. hip). Each hip bone is formed by the postnatal ankylosis of Ilium, Ischium, and Pubis. The **Pelvis** is formed by consolidation of the two hip bones with the **synsacrum** (see *Arthr.*).

Acetabulum. The socket in the *Os coxae* into which the head of the femur fits. **Foramen acetabuli**. The opening in the floor of the **Acetabulum** varies in size in different birds. See *Arthr.* Annot. 151.

(227) **Foramen obturatum**. This oval opening situated caudoventral to the **Acetabulum** transmits the tendon of *M. obturatorius medialis* and *N. obturatorius*. The foramen is the detached cranial part of *Fenestra ischiopubica* (Boas, 1933). See Fig. 4.15; Annot. 252.

(228) **Sulcus obturatorius**. Long, wide, shallow groove on the medial surface of *Ala ischii*. *M. obturatorius medialis* lies in the **Sulcus** as well as on the adjacent medial surface of the pubis and *Membrana ischiopubica*.

(229) **Fenestra ischiopubica**. Synonymy: **Foramen obturatorium, pars caudalis**; **Foramen oblongum**. This gap between the shaft of the pubis and the ischium is of variable shape: from slit-like to elongated oval or triangular; very wide in some forms, e.g., *Gavia*, *Diomedea*, *Dendrocopus*; it is open at its caudal end in *Apteryx*.

(230) **Foramen ilioischadicum**. Situated just caudal to the acetabulum, the foramen is bounded dorsally by the ilium and ventrally by the ischium (Fig. 4.15). The foramen transmits the ischiadic nerves and vessels (*Arthr.* Mem. ilio. isch.). Generally round or short oval shape; at its caudal end the foramen is incompletely enclosed by bone in tinamous and *Apteryx*, and extends caudally most of the length of the postacetabular ilium in *Rhea*, *Struthio*, and *Casuarium*.

(231) **Incisura marginis caudalis** (Fig. 4.9). In lateral view the caudal border of the hip bone (*Os coxae*) of many birds is indented between *Spina dorsolateralis ilii*

and the tip of *Proc. terminalis ischii*; this notch is in the region of the ilioischadic synostosis (see Annot. 230; and *Arthr.* 148).

Proc. marginis caudalis. Synonymy: *Spina iliocaudalis* (Boas, 1933). This projection of the caudal margin of the *Os coxae* of the pelvis between *Spina dorsolateralis ilii* and the *Proc. terminalis ischii* is present in some birds (e.g., *Gallus*, *Ardea*); not to be confused with the *Spina dorsolateralis ilii* itself (see Annot. 249).

(232) **Antitrochanter**. Located caudodorsal to the **Acetabulum**, this projection of *Os coxae* bears an articular surface which is in contact with the neck and trochanter of the *Femur*; formed mainly by the ischium and to a lesser degree by the ilium.

Sulcus antitrochantericus (Fig. 4.15). Usually a relatively narrow groove dorsal to the **Antitrochanter** which is the caudal prolongation of the extensive, shallow *Fossa iliaca dorsalis* of the preacetabular ilium. The sulcus is especially prominent in loons (R. W. Storer, pers. comm).

(233) **Crista iliosynsacralis**. A median ridge formed by fusion of the right and left dorsal iliac crests with the *Crista dorsalis* of the **synsacrum** (see Annot. 143, and below, Annot. 234).

(234) **Sulcus iliosynsacralis**. In birds in which the dorsal **synsacral crest** and the dorsal iliac crests remain separate a furrow, the **iliosynsacral sulcus**, is present on each side of the **synsacral crest**; the **Sulcus** contains epaxial muscles. This condition is seen for example in *Columba*, *Ceryle*, *Corvus*.

Canalis iliosynsacralis (Fig. 4.15). Synonymy: **Canalis iliosacralis** (Nauk, 1938); **subiliac space** (Howard, 1929); **canalis ilioneuralis** (Shufeldt, 1888). Paired canals occur in the pelvis of birds having an **iliosynsacral crest** (Annot. 233) (see Komárek, 1979, for illustrations). The paired canals are separated by the dorsal **synsacral crest**; each is roofed dorsally by the *Ala preacetabularis* of the ilium; the ventral wall of each canal is the *Lamina transversa* of the **synsacrum** (Annot. 141). The canal contains epaxial muscles, occurring, e.g., in *Diomedea*, *Cathartes*, *Strix*, *Gallus*, *Branta*, *Phoenicopterus*.

(235) **Concavitas infracristalis**. The shallow, wide depression on the lateral surface of the pelvis caudal to the ilioischadic foramen in many birds; formed largely by the **infracristal lamina** of the ilium (Annot. 251). The depth of the concavity is exaggerated by the overhanging *Crista dorsolateralis ilii* (Fig. 4.15). *M. ischiofemoralis* arises from this surface. Consult Boas (1933).

(236) **Pila ilioischadica**. This is the reinforcing pillar of bone along the ventral border of each side of the pelvis extending from the level of the cranial end of the *Fossa renalis* toward *Proc. terminalis ischii*. The cranial part of the *Pila* forms *Crista iliaca obliqua* (Annot. 242); caudally it contributes to the ventral acetabular wall and ilioischadic foramen, merging with *Ala ischii*. See Fig. 4.9.

(237) **Fossa renalis** (Fig. 4.9). The *Fossa renalis* is the paired deep fossa on each side of the **Corpus synsacri** which accommodates the kidney; formed partly by the **Synsacrum** and partly by the *Os coxae* (mainly ilium). In general, the cranial division of the kidney is not housed in the fossa, but occupies the shallow depression on the ventral surface of the preacetabular ilium.

Pars ischiadica fossae is the smaller cranial part of the *Fossa renalis* that contains the middle division of the kidney and the ischiadic (lumbosacral) nerve plexus; the acetabular foramen is an opening in the side of *Pars ischiadica*.

Pars pudenda fossae is the larger, wider caudal part of the renal fossa that contains the caudal division of the kidney and the pudendal nerve plexus; the ilioischadic foramen is an opening in the lateral wall of Pars pudenda. See Annot. 250; consult Radu (1975) for comparison of Fossa renalis in galliforms and anseriforms.

(238) **Incisura caudalis pelvis**. When viewed from its dorsal or ventral aspect, the intact bony pelvis of many birds demonstrates just past its Margo caudalis a wide, semilunar, or rectangular indentation, bounded on each side by the Spina dorsolateralis ilii (Annot. 248). The incisura is notably deep in falconiform, ciconiiform and strigiform pelvis; its middle part is occupied by the basal part of the free caudal vertebral column; laterally it is completed by the iliocaudal membrane (Arthr. Annot. 185).

(239) **Corpus ilii**. This is the strongly developed central part of the Ilium, cranial and dorsal to the Acetabulum, from which its pre- and postacetabular alae (wings) emanate.

(240) **Incisura acetabularis**. The body of each of the three elements (ilium, ischium, and pubis) of the Os coxae contributes a segment of the circumference of the acetabulum; each part thus displays a C-shaped Incisura acetabularis prior to synostosis of the three elements (see Arthr. Annot. 146).

(241) **Pila postrenalis**. The transverse pillar of bone that strengthens the caudal border of the pudendal part of the renal fossa. Well exemplified in *Strix*, *Larus*, and *Columba*. See Annot. 250.

(242) **Crista iliaca obliqua** (Boas, 1933). The heavy oblique bar of bone that forms the ventrolateral border of Pars ischiadica of Fossa renalis; the Crista extends between the ventral surface of Ala preacetabularis ilii to the ventral wall of the Acetabulum (see Fig. 4.9; Annot. 236).

(243) **Crista iliaca intermedia** (Boas, 1933; synsacral strut, Strauch, 1985). Slightly developed in most birds. In some birds this transverse crest is formed on the ventral surface of Ala postacetabularis ilii, within the renal fossa, at the level of the acetabular foramen. The costal process(es) of the so-called true sacral or "acetabular" vertebrae (see Fig. 4.9 and Annot. 141) articulate with the medial end of the crest. The crest is well developed in most charadriiforms (Strauch, 1985); exhibited also, e.g., in *Morus*, *Cathartes*, and *Columba*. See Arthr. Annot. 76.

(244) **Tuberculum preacetabulare [Proc. pectinealis]**. Synonymy: Proc. preacetabularis; Proc. prepública. The name, Tuberculum preacetabulare (Boas, 1933), indicates its location at the ventrocranial margin of the acetabulum. It serves as the rear attachment of the Lig. inguinale (Arthr. Annot. 184) which bounds the neurovascular lacuna for the external iliac vessels and branches of the lumbar nerve plexus. In most birds the Tuberculum is formed by the ilium, in ratites primarily by the pubis (Beddard, 1898). The Tuberculum preacetabulare is generally a stubby torus of bone; however, it is an elongated process in *Struthio*, tinamous, galliforms (Beddard, 1898), and the cuculiform *Geococcyx* (Larson, 1930). See Fig. 4.15.

(245) **Ala [Pars] preacetabularis ilii; Ala [Pars] postacetabularis ilii**. Synonymy: pre-ilium; post-ilium (Parker, 1888).

Crista iliaca dorsalis. Synonymy: Crista iliaca superior (Milne Edwards, 1867-71); Linea iliodorsalis (Lambrecht, 1933). The dorsal (or dorsomedial) border of the preacetabular ilium (see Fig. 4.15 and Annot. 234).

(246) **Areae articulares vertebrales**. Several areas of the ventral surface of the preacetabular ilium that articulate with the transverse processes of the cranialmost series of synsacral vertebrae. These areas can be seen only in immature birds in which the synsacrum and ilium may be disarticulated (see illustrations in Boas, 1933); most frequently the synsacrum and ilium are ankylosed (synostoses) in mature individuals.

(247) **Crista iliaca lateralis** (Milne-Edwards, 1867-71). [**Margo lateralis**] (NAA, 1979). In dorsal view this is the lateral free edge of the preacetabular ilium that in some birds forms a pronounced ledge (Fig. 4.9) (see Annot. 245).

(248) **Crista dorsolateralis ilii**. Synonymy: Crista dorsolateralis (Boas, 1933); Linea iliolateralis (Lambrecht, 1933); Crista iliaca dorsolateralis (NAA, 1979). Lateral ledge of the postacetabular ilium that marks the boundary between its dorsal and lateral surfaces; indistinct or lacking in some birds, e.g., in the pelecaniforms (*Morus*, *Pelecanus*) and anseriforms (*Branta*, *Aythya*). The crest serves as an attachment of the aponeurosis of origin of M. iliotibialis (see Fig. 4.15 and Myol. Annot. 100).

Spina dorsolateralis ilii. Synonymy: Proc. iliolateralis (Boas, 1933); Spina iliaca dorsalis (NAA, 1979). This is the caudal prolongation of the Crista dorsolateralis ilii (Fig. 4.15). In *Columba* (Baumel, 1988) the base of the spine forms part of the pulley for change of direction of M. caudofemoralis as the latter enters the lower surface of the uropygium.

(249) **Fossa iliocaudalis**. This depression on the dorsal surface of the caudal part of the postacetabular ilium on either side of the caudal end of the synsacrum serves as a point of attachment of M. levator caudae (Fig. 4.15).

(250) **Recessus caudalis fossae**. Synonymy: Recessus iliacus (Boas, 1933); obturator depression (Harvey, et al., 1968). This is the recess of the renal fossa that invaginates the caudalmost junctional region of the postacetabular ilium and ischium. The recess is deep in *Gallus* and *Meleagris*, some strigids and gruiforms (e.g., *Gallinula*); it does not enclose part of the kidney, but is filled by the origin of M. obturator medialis (Butendieck, 1980). See Fig. 4.9 and Annot. 237.

(251) **Lamina infracristalis ilii** (Fig. 4.15). Synonymy: Superficies infracrista (Boas, 1933); Lamina ischiadica ilii (NAA, 1979). The vertical lamina of the postacetabular ilium just ventral to Crista dorsolateralis ilii; the lower margin of the Lamina ankyloses with the Ala ischii caudal to the Foramen ilioischiadica (exception: some ratites). See Annot. 235.

(252) **Proc. obturatorius** (Fig. 4.15). Synonymy: Proc. ventralis. This ventrally directed process of the ischium separates the obturator foramen from the ischiopubic fenestra; formed by ossification of Lig. ischiopubicum.

(253) **Proc. terminalis ischii**. Synonymy: Proc. terminalis ischiadicus (Boas, 1933); Angulus ischiadicus (Lambrecht, 1933). This process is the most caudal extent of the ischium, often pointed; its lower border articulates with the pubis (Fig. 4.15). See Annot. 231.

(254) **Pubis.** The shaft (*Scapus pubis*) of the rather delicate pubis of most birds closely parallels the ventral border of *Ala ischii*. The two are separated by the obturator foramen and the ischiopubic fenestra (see Fig. 4.15; Annot. 229). In some birds the free ends of the pubes curve inward and closely approximate one another.

(255) **Facies articularis antitrochanterica.** Synonymy: *Articulatio iliaca* (Lambrecht, 1933); *Facies glenoidea proximalis* (Ballmann, 1969b). Articular surfaces located on the dorsal aspect of the *Collum femoris* and the medial surface of the *Trochanter femoris*. See Fig. 4.16; Annot. 232, 262; *Arthr.* Annot. 152.

(256) **Trochanter femoris.** Synonymy: *Trochanter major*. On the proximal end of the femur this structure is the elevated, expanded part of the femur continuous with its neck (Annot. 257). Ametov (1971) observed that certain saltatorial birds (e.g., *Passer domesticus*, *Parus major*, and *Sitta europaea*), birds that progress by leaping, lack the femoral trochanter. See Fig. 4.16; *Arthr.* Annot. 182.

Fossa trochanteris. The concavity of the medial surface of the elevated trochanter of the femur; often deepened by the overhang of the **Crista trochanteris** (e.g., *Larus*, *Gallus*, *Phoenicopterus*).

(257) **Impressiones mm. trochanteris; Impressiones ligg. trochanteris** (Fig. 4.16). Markings on the lateral aspect of the *Trochanter femoris* for the obturator and ilirotrochanteric muscles and certain ligaments which are detailed by Ballmann (1969b).

(258) **Corpus femoris.** The body or shaft of the avian femur is commonly circular in cross section; no sharply defined borders are present except in atypical femora (e.g., *Gavia*) which has a laterally compressed, truncated femur, somewhat quadrate in cross section.

(259) **Sulcus patellaris** (Fig. 4.16). Synonymy: *Fossa patellaris* (Lambrecht, 1933); rotular groove (Howard, 1929). Articular groove for the *Patella* at the distal end of the femur.

Crista lateralis/medialis sulci patellaris. The crests of the patellar sulcus are sharply defined in some taxa.

Condylus medialis; Condylus lateralis. These articular condyles of the distal femur are also known as *Condylus internus* and *Condylus externus*. See Annot. 261.

(260) **Impressiones ansae m. iliofibularis.** Synonymy: impressions of the biceps loop. The ligamentous ansa (L. loop) for *M. iliofibularis* has two femoral attachments: one on the caudal surface of the distal femur just proximal to the lateral condyle, the other a distinct scar on the cranial surface of the femur proximal to the lateral crest of the patellar sulcus; a third attachment is the fibula just distal to its neck. See Berger (1966); *Myol.* Annot. 102; *Arthr.* Annot. 186.

(261) **Trochlea fibularis** (Fig. 4.16). Synonymy: *Sulcus fibularis*. The spool-shaped joint surface on the lateral femoral condyle for articulation with the **Caput fibulae**. See *Arthr.* Fig. 5.7.

(262) **Crista tibiofibularis** (Howard, 1929). Synonymy: *Crista peroneo-tibialis* (Ballmann, 1969b). Crest on the lateral condyle of the femur that separates its tibial articular surface from that for the fibula; the *Crista* forms the medial wall of the *Trochlea fibularis* (see Annot. 261; and *Arthr.* Fig. 5.7; Annot. 154). See Fig. 4.16.

(263) **Impressio lig. cruciati caudalis/cranialis.** The impression for the caudal cruciate ligament is located on the caudal aspect of the distal end of the femur just proximal to the lateral condyle; the impression for the cranial cruciate ligament is farther distal, in the intercondylar sulcus (see Fig. 4.16 and *Arthr.* Fig. 5.7).

(264) **Crista supracondylaris medialis.** Synonymy: *Adductor crest*. This sharp crest extends proximally from the medial condyle of the femur, and is continuous with the caudal intermuscular line of the *Corpus femoris* (see Fig. 4.16).

(265) **Patella.** Sesamoid bone in the common tendon of the *Mm. femorotibiales* and *M. ilirotibialis*. Barnett and Lewis (1958) contend that the elongated patellar crest of some birds (e.g., the common diving petrel *Pelecanoides urinatrix*) represents fusion of the patella with the patellar crest of the tibiotarsus to which the patellar ligament is attached in most birds (see Annot. 269).

Sulcus [Canalis] m. ambiens. Generally the tendon of *M. ambiens* perforates or grooves the patellar ligament; in a few birds it perforates or grooves the patella (see Berger, 1966).

(266) **Facies articularis medialis/lateralis** (Fig. 4.17B). Neither of these articular facets on **caput tibiae** of the proximal end of the Tibiotarsus is concave; therefore, "cotyla" or "glenoid fossa" are inappropriate; however, well developed intra-articular menisci intervene between the femur and head of the tibia, deepening the surfaces in contact with the femoral condyles (see *Arthr.* Artcc. genus). The smaller lateral facet faces laterodorsally (see Annot. 262); the larger medial facet lies in a nearly transverse plane.

(267) **Facies articularis tibialis.** Just distal to its surface for articulation with the femur, the medial surface of the *Caput fibulae* bears another surface that articulates with the lateral surface (**Facies articularis fibularis**) of the proximal tibiotarsus. See Fig. 4.17B; Annot. 262, 263; and *Arthr.* Annot. 157, 159.

(268) **Fossa retropatellaris** (Fig. 4.17). Synonymy: *Fossae synoviales* (Ballmann, 1969a); *Fossa retrocristalis* (NAA, 1979). The retropatellar fossa is situated between the *Crista patellaris* and the femoral articular facets on the proximal surface of the head of the Tibiotarsus. The *Fossa* in certain birds appears to be subdivided by a low ridge. In the intact joint the fossa contains the retropatellar fat body (*Arthr.* Annot. 158). See Ballmann, 1969a.

(269) **Crista patellaris** (Lambrecht, 1933). Synonymy: *Crista rotularis* (Milne-Edwards, 1867-71; Howard, 1929). Crest connecting the proximal ends of the two cnemial crests of the Tibiotarsus. The patellar crest varies in different birds from transverse to oblique depending on the elevation of the cranial cnemial crest above the articular plane of the head of the tibiotarsus; the *Lig. patellae* is attached to the crest. See Fig. 4.17; Annot. 265; and *Arthr.* Annot. 158.

(270) **Crista cnemialis cranialis** (Fig. 4.17). Synonymy: *Crista cnemialis anterior* (Ballmann, 1969a); *Crista cnemialis interna* or *medialis* (Cnemial, Gk. tibial). The cranial cnemial crest is elevated well above the level of the knee joint in some aquatic birds (R. W. Storer, pers. comm.) e.g., grebes, herons, flamingos, the diving petrels (*Pelecanoididae*), and shearwaters (*Puffinus*); enormously long in the loons. In foot-propelled diving birds the elongation of the crest is associated with shortening of the femur (R. W. Storer, pers. comm.)

(271) **Facies gastrocnemialis** (Ballmann, 1969a). The medial surface of *Crista cnemialis cranialis* and the area of the *Tibiotarsus* caudal to the crest (Fig. 4.17); origin of the medial head of *M. gastrocnemius*.

(272) **Sulcus intercnemialis** (Kolda and Komárek, 1958). Synonymy: *Sulcus intercrystalis* (NAA, 1979). Wide longitudinally-oriented sulcus between the cranial and lateral cnemial crests (Fig. 4.17); for origin of *M. extensor digitorum longus*.

(273) **Incisura tibialis**. (Fig. 4.17). Seen from proximal or lateral view, this is the groove between the caudal surface of the lateral cnemial process and the *Facies articularis fibularis* of the *Tibiotarsus*; for passage of the tendon of the *Caput femorale* of *M. tibialis cranialis* (Ballmann, 1969a).

(274) **Fossa flexoria** (Fig. 4.17A). Synonymy: *Fossa flexoris digitorum longi* (Ballmann, 1969a). Depression on the caudal aspect of the proximal end of the *Tibiotarsus* distal to *Facies articularis lateralis* extending to the proximal edge of the fibular crest; serves as origin for *M. flexor digitorum longus*.

Tuberositas poplitea (Fig. 4.17). Linear scar on the caudal surface of the tibial shaft just distal to *Fossa flexoria*; for attachment of *M. popliteus* (P. Ballmann, pers. comm.). The tuberosity is pronounced in larger birds, e.g., *Ardea*, *Branta*, *Phoenicopterus*.

(275) **Corpus tibiotarsi**. The proximal two-thirds of the shaft of the *Tibiotarsus* is for the most part three-sided, with cranial, medial, and caudal surfaces (Ballmann, 1969a).

(276) **Linea extensoria** (Ballmann, 1969a). The intermuscular line of the cranial surface of the *Tibiotarsus* is prolonged from *Crista cnemialis cranialis* along the length of the shaft of the bone; continuous with the medial margin of *Sulcus extensorius*.

(277) **Pons supratendineus** (Fig. 4.17D). Synonymy: *supratendinal bridge* (Howard, 1929); *Lig. transversum ossificatum* (Lambrecht, 1933). (Pons, L. bridge). The *supratendinal bridge* is located at the distal end of the cranial surface of the *Tibiotarsus* proximal to its condyles. The bridge is ligamentous in *Bubo*, *Otus* (Berger, 1966), parrots, and ratites (Martin, 1987). See below, Annot. 278.

(278) **Canalis extensorius** (Fig. 4.17D). The passage deep to the *Pons supratendineus* at the distal end of the *Tibiotarsus* that transmits the tendon of *M. extensor digitorum longus*. See *Arthr. Annot.* 164.

Tuberositas retinaculi extensoris. Scar at each margin of the *Sulcus extensorius* of the distal *tibiotarsus* just proximal to *Pons supratendineus* (Annot. 277); for attachment of the extensor *retinaculum* (*Arthr. Annot.* 187). Since the *retinaculum* is oriented obliquely the two scars are at different levels.

(279) **Trochlea cartilaginis tibialis** (Fig. 4.17A). The *trochlea* is the wide furrow on the caudal surface of the distal end of the *Tibiotarsus*, serving as the articular surface for *Cartilago tibialis*. The sharp *Cristae* on either side of the *trochlea* are continuous with the *tibiotarsal condyles* (see Annot. 280; and *Arthr. Annot.* 164).

(280) **Condylus lateralis/medialis tibiotarsi**. The surfaces of these condyles of the *Tibiotarsus* that articulate with the *Tarsometatarsus* face cranially and distally, and caudally are continuous with the crests of the *trochlea* for the tibial cartilage (see Annot. 279).

(281) **Depressio epicondylaris lateralis/medialis**. Shallow depression on both lateral and medial sides of the lower end of the *tibiotarsus* just proximal to the distal articular surfaces of its condyles.

(282) **Tuberculum retinaculi m. fibularis [peronei]**. On the cranial surface of the distal *tibiotarsus* the *Tuberculum* is separated from the proximal part of the lateral condyle by the **Sulcus m. fibularis [peronei]** (Fig. 4.17C); the *tuberculum* is the upper point of attachment of the *retinaculum* which bridges the sulcus and restrains the tendon of *M. fibularis brevis* in the *Sulcus*.

(283) **Ossa tarsi**. The proximal tarsals consist of two elements, the **Tibiale [Astragalus]** and the **Fibulare [Calcaneum]**, which fuse to each other and to the tibia, producing the condyles of the distal end of the compound bone, the *tibiotarsus*. "Tibiale" is preferred over *Astragalus* because in fetal birds there is only one condensation (*Cartilago tibiale*) that articulates medially with the tibia, whereas the *Astragalus* of other amniotes is a compound element composed of additional elements (e.g., *intermedium* and *centralia*) that have been lost in birds (Müller and Alberch, 1990). The *fibulare* does not ossify in most ratites and tinamous; in the exceptions (*Struthio* and some *Dromaius*) the *cartilaginous lateral condyle* ossifies with the *tibiale*.

The avian ankle is characterized by an additional element, "Os pretibiale", that McGowan (1985) maintains is associated with the *tibiale*, whereas Martin and Stewart (1985) associate it with both *tibiale* and *fibulare* condensations (although more so with the latter). The *pretibiale* begins ossifying before either *tibiale* or *fibulare*; as a result, it is very unlikely that the *pretibiale* is homologous to the *intermedium* of other tetrapods (G. Müller, pers. comm.).

The single distal tarsal bone (**Os tarsi distale**) fuses with the *metatarsals* forming the proximal end, including the *Hypotarsus*, (Annot. 288) of the compound bone, the *Tarsometatarsus*. Although some workers (see Romanoff, 1960) identified up to four distal tarsals in birds, most recent workers have been able to identify only one (Hinchliffe, 1977; McGowan, 1985; Müller and Alberch, 1990). See *Arthr. Annot.* 167.

(284) **Tarsometatarsus**. *Metatarsal bones* II, III, IV of modern birds ankylose extensively with one another and the distal tarsal bone, forming the definitive *Tarsometatarsus*. *Os metatarsale I* is not involved in the ankylosis; instead it has a ligamentous junction with the medial border of the *Tarsometatarsus*. See Annot. 283; **Topog.** Annot. 43; and *Arthr. Fig.* 5.9 & Annot. 167, 173, 174.

(285) **Area intercotylaris** (Fig. 4.18D). This is the relatively flat area between the plantar parts of the two cotylae of the proximal *tarsometatarsus*, in other words, the area between the *Eminentia intercotylaris* and the *Hypotarsus*. See *Arthr. Annot.* 171.

(286) **Sulcus ligamentosus**. In some birds (e.g., *Pelecanus*, and the vulture *Cathartes*) this is a transverse groove at the junction of the proximal *Hypotarsus* and *Area intercotylaris*; the ligament from the distal end of *Cartilago tibialis* is attached in the groove. See Fig. 4.18; and *Arthr. Annot.* 166.

(287) **Arcus extensorius**. In certain birds an osseous arch is found on the cranial aspect of the proximal *Tarsometatarsus* that restrains, and acts as a pulley for, the tendon of *M. extensor digitorum longus* (e.g., strigids, picids, rallids, *Fulica*, *Chaetura*, et al.) (see Berger, 1966). The arch is in fact the ossified ligamentous *Retinaculum extensorium tarsometatarsi* of most birds. See Annot. 277, 295; and *Arthr. Annot.* 188.

(288) **Hypotarsus** (Fig. 4.18). Synonymy: Calcaneus. This process on the plantar aspect of the proximal Tarsometatarsus is formed mostly by the distal tarsal element (Annot. 283) capping the proximal end of Os metatarsale III. The Hypotarsus is simple in some birds, consisting of a wide sulcus between low crests (e.g., falconiforms, strigids). In most birds it is complex, having sulci and high crests, and perforated by one or more canals (Newton, 1896). The Sulci and Canales hypotarsi conduct flexor tendons of the pedal digits; consult Berger (1966), Simpson and Craft (1981), and Strauch (1985) for details in different taxa. See Fig. 4.18; *Integ.* Annot. 68; and *Arthr.* Fig. 8.

(289) **Cristae hypotarsi** (Fig. 4.18). Synonymy: Crista externa/interna hypotarsi (Ballmann, 1969a; Crista ecto-/entogastrocnemialis, (Lambrecht, 1933); calcaneal ridges (Howard, 1929). Lateral, intermediate, and medial crests of hypotarsus.

(290) **Crista medianoplantaris** (Fig. 4.18). Synonymy: Crista plantaris (Neugebauer, 1845); Crista plantaris mediana (NAA, 1979); hypotarsal ridge. Median, curved crest that forms a buttress from the middle of the Hypotarsus, gradually merging distally into the plantar shaft of the tarsometatarsus. The tendon of the gastrocnemius muscle extends past its main attachment on the hypotarsus to blend with the superficial border of the Crista (see Annot. 294 and *Myol.* Annot. 126), creating a septum. The septum forms the medial wall of an osseo-fibrous compartment enveloping the bundle of long flexor tendons for the digits (see *Arthr.* Annot. 176, Canalis flexorius metatarsi).

(291) **Fossa infracotyliaris dorsalis** (Fig. 4.18A). Synonymy: Depressio antinterossealis (Lambrecht, 1933); Fossa anterior (Ballmann, 1969a). An excavation on the dorsum of the proximal end of the tarsometatarsus immediately distal to its cotylae. The Foramina vascularia proximalia open into the Fossa (*Art.* Annot. 79); the tuberosity for insertion of M. tibialis cranialis in some birds is situated in the distal part of the Fossa, or in the upper part of Sulcus extensorius of those birds lacking a distinct Fossa.

(292) **Facies corporis tarsometatarsi**. The surfaces of the shaft of the Tarsometatarsus vary in their configurations in different taxa. In cross section the shaft may be: (1) rectangular, laterally compressed (e.g., *Gavia*); (2) rectangular, compressed in its dorsoplantar dimension (e.g., *Coragyps*); (3) triangular, **Facies plantaris** flat (e.g., *Ardea*); (4) triangular, **Facies dorsalis** flat (e.g., *Pelecanus*); U-shaped, concave plantar surface (e.g., *Strix*) (Annot. 294).

(293) **Facies subcutanea lateralis/medialis** (Fig. 4.18A). Generally the medial and lateral surfaces (see Annot. 295) of the Tarsometatarsus are covered only with the scaly Podotheca (see *Integ.*). By contrast, the plantar and dorsal surfaces of the Tarsometatarsus have bundles of flexor and extensor tendons interposed between podotheca and bone (Ballmann, 1969a).

(294) **Sulcus flexorius** (Fig. 4.18C). Synonymy: Sulcus longitudinalis plantaris. In certain birds (e.g., *Buteo*, *Aquila*, *Strix*) the plantar (flexor) surface of the Tarsometatarsus is strongly grooved longitudinally by the Sulcus flexorius which is bounded by the prominent, sharp **Crista plantaris medialis** and **Crista plantaris lateralis** (Fig. 4.18C). The sulcus forms the floor of the Canalis flexorius metatarsi that accommodates the bundle of tendons of the flexor muscles of the digits (*Arthr.* Annot. 178).

(295) **Sulcus extensorius** (Fig. 4.18A). Synonymy: Sulcus longitudinalis dorsalis. In some taxa a shallow, longitudinal sulcus indents the dorsal (extensor) surface of the

Tarsometatarsus, and contains the intrinsic extensor muscles of the digits (see Annot. 287, 290, 294).

(296) **Proc. calcaris** (Komárek, 1979). This is the osseous core of the metatarsal spur (Calcar metatarsale). The Proc. calcaris is ankylosed to the medial or caudal aspect of the tarsometatarsus in males of some galliform birds. See *Integ.* Annot. 89.

(297) **Trochlea accessoria**. In piciform, cuculiform, and psittaciform birds the trochlea of the metatarsal bone of the fourth digit possesses an accessory trochlea (Milne-Edwards, 1867-71; Steinbacher, 1935). See Ballmann (1969a) for diagrams of atypical forms of the tarsometatarsal trochleae in several major taxa of birds including those listed above as well as colliiforms.

(298) **Canalis interosseus distalis**. Synonymy: Canalis m. add. dig. ext. (Lambrecht, 1933). Longitudinally oriented canal that conducts the tendon of M. extensor brevis digiti IV and vessels into the lateral intertrochlear incisure. The upper end of the canal (Fig. 4.18C) is continuous with the **Foramen vasculare distale** (*Art.* Annot. 79); in some birds the canal is replaced by a groove.

(299) **Ossa digitorum pedis**. The general avian phalangeal formula is: Hallux, two phalanges; Digitus secundus, three phalanges; Digitus tertius, four phalanges; Digitus quartus, five phalanges. (The hallux is lacking in most ratites).

The recommended scheme of numbering the phalanges is that of Berger (1966) and Lucas and Stettenheim (1972). This consists of designating: the most proximal phalanx of a digit as number 1, the next most distal number 2, etc.; in digit IV with five phalanges, the most distal (ungual) phalanx is number 5. The paper of Quinn and Baumel (1990), on the tendon-locking mechanism of the avian foot, follows their scheme. The scheme of Lennerstedt (1975) who designates the unguinal phalanx as number 1, the next most proximal phalanx as number 2, etc. is less satisfactory.

(300) **Phalanx unguialis**. Synonymy: Phalanx terminalis or distalis. This usually claw-shaped phalanx (flattened in grebes, R. W. Storer pers. comm.) forms the bony core of the heavily keratinized claw (Unguis). See *Arthr.* Annot. 182, 183.

Sulcus neurovascularis (new term). The curved groove on each side of the Corpus of the unguinal phalanx that carries nerves and vessels; located just beneath the podotheca of the claw.

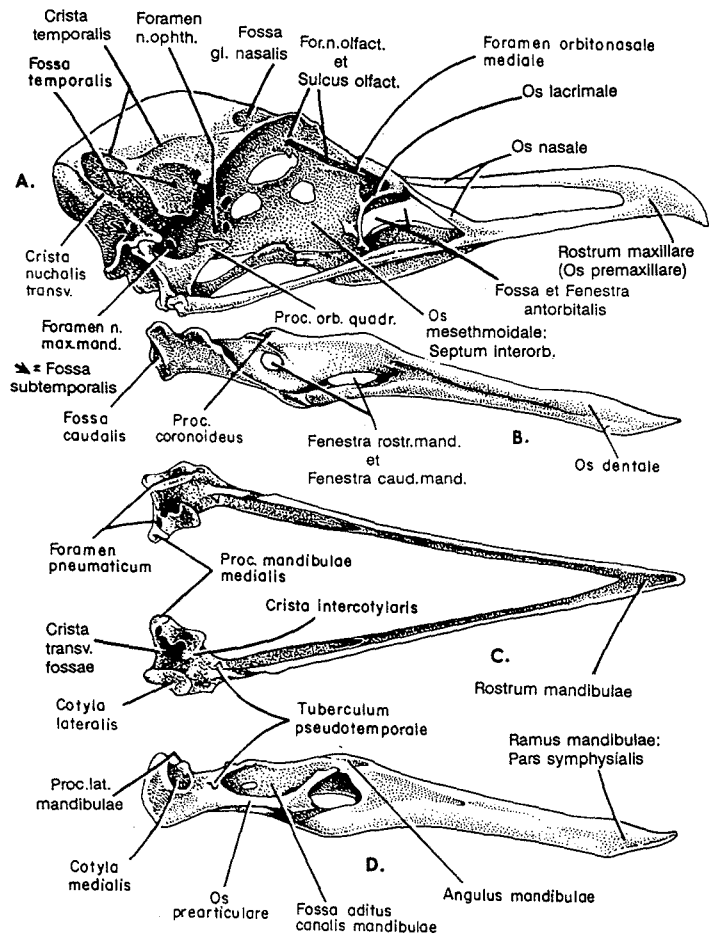


Fig. 4.1. Cranium and mandible of the gull *Larus argentatus*. Drawing by Wm. P. Hamilton. A, cranium, right lateral aspect; B, ramus of mandible, right lateral aspect; C, mandible, dorsal aspect; D, left ramus of mandible, medial aspect. Observe that: (1) the Fossa temporalis of this form is subdivided by a pronounced crest (Annot. 104); (2) in the dried skeleton of gulls the region of the Fenestra rostralis mandibulae often demonstrates several of the individual components that form the mandible (see Annot. 52, Ossa mandibulae; Arthr. Annot. 48); (3) Proc. retroarticularis is not a prominent feature in gulls (see Arthr. Fig. 5.2D, mandible of *Anas*); however the Fossa caudalis is distinct; (4) Crista transversa fossae is the partition separating the caudal fossa from the articular fossa. With permission of Academic Press.

Abbreviations: mand., mandibulae; max. mand., maxillomandibularis; ophth., ophthalmici; orb., orbitalis; quad., quadrati; transv., transversa.

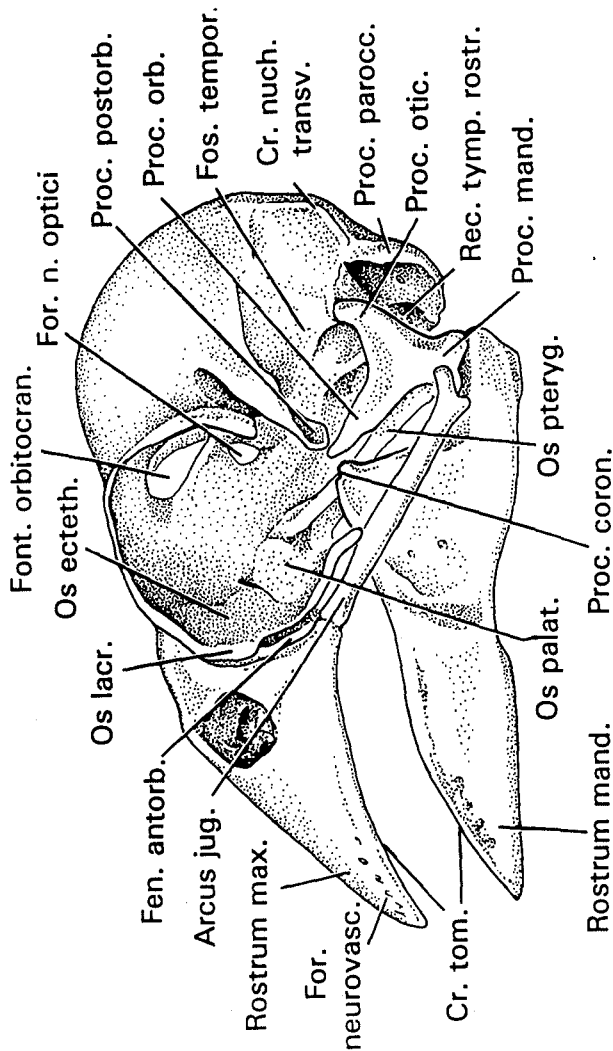


Fig. 4.2. Craniofacial skeleton and mandible of the Evening Grosbeak, *Coccythraustes vespertina*; left lateral view. Modified with permission from Witmer and Rose (1991).

Abbreviations: coron., coronoideus; Cr. nuch. transv., Crista nuchalis transversa; Cr. tom., Crista tomialis; Fen. antorb., Fenestra antorbitalis; For., foramen; lacri., lacrimale; parocc., paroccipitalis; Rec., Recessus.

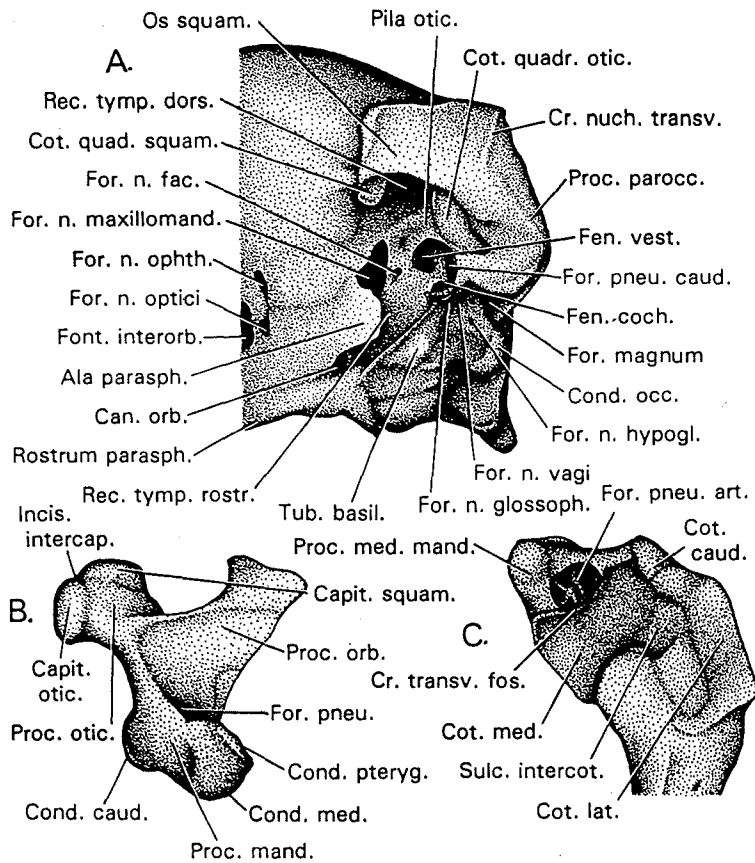


Fig. 4.3. Closeups of parts of the skull of a Greater Frigatebird, *Fregata minor*. A, Ear region and adjacent base of the cranium; left ventrolateral view. B, Quadratum, left side, medial view. C, Pars caudalis of left ramus of the mandible, dorsal view. Modified with permission from Witmer (1990).

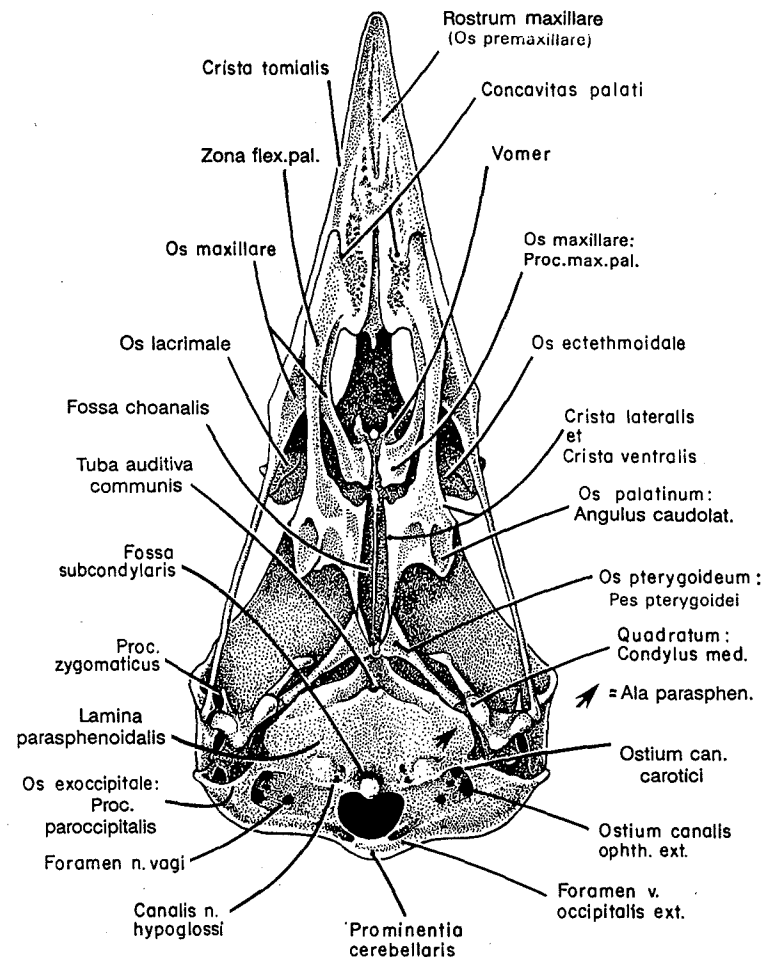


Fig. 4.4. Base of the skull, palate, and maxillary jaw of the Crow, *Corvus brachyrhynchos*; ventral aspect. Redrawn from Bock (1964). The leader for Lamina parasphenoidalis crosses the Proc. oticus of the quadrate bone. The depression in which the openings for the A. carotis cerebialis and A. ophthalmica externa are located is the Fossa parabasalis. The Foramen n. glossopharyngealis is just caudomedial to the Ostium canalis carotici. Tip of arrow rests on Ala parasphenoidalis.

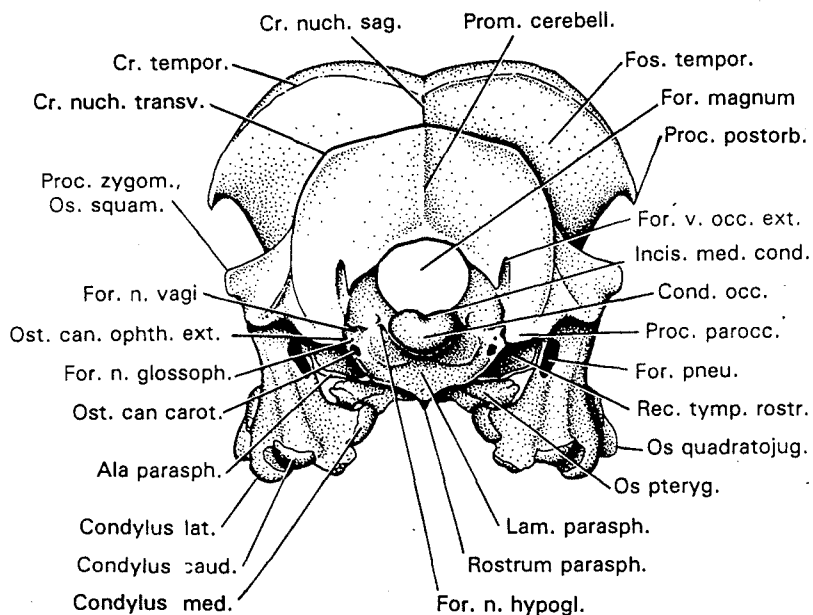


Fig. 4.5. Occipital region of skull of the Great Blue Heron, *Ardea herodias*; caudal (occipital) view. Original drawing of L. M. Witmer.

Abbreviations: Cond. occ., Condylus occipitalis; Cr. nuc. sag./transv., Crista nuchalis sagittalis/transversus; For. n. hypogl./vagi, Foramen n. hypoglossi/vagi; For. pneu., Foramen pneumaticum; Incis. med. cond., Incisura mediana condyli; Lam., Lamina; Ost. can. carot., Ostium canalis carotici; Prom., Prominentia; Rec., Recessus.

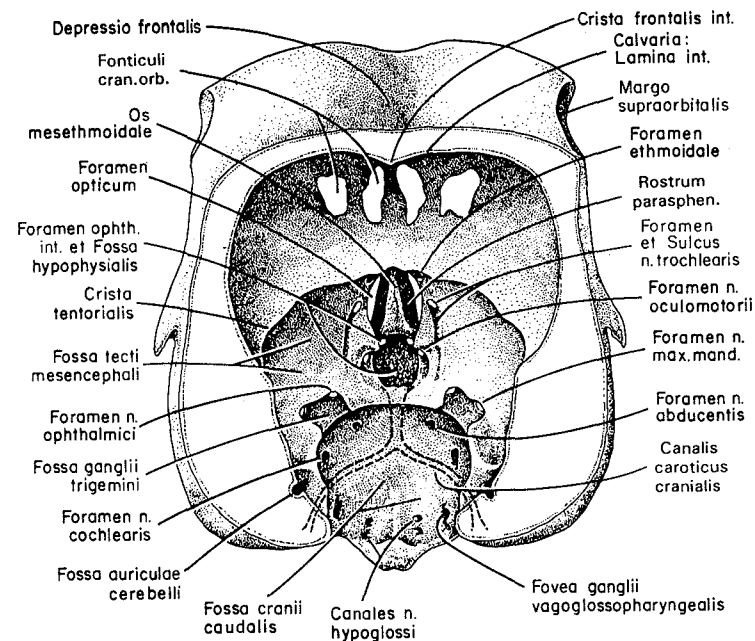
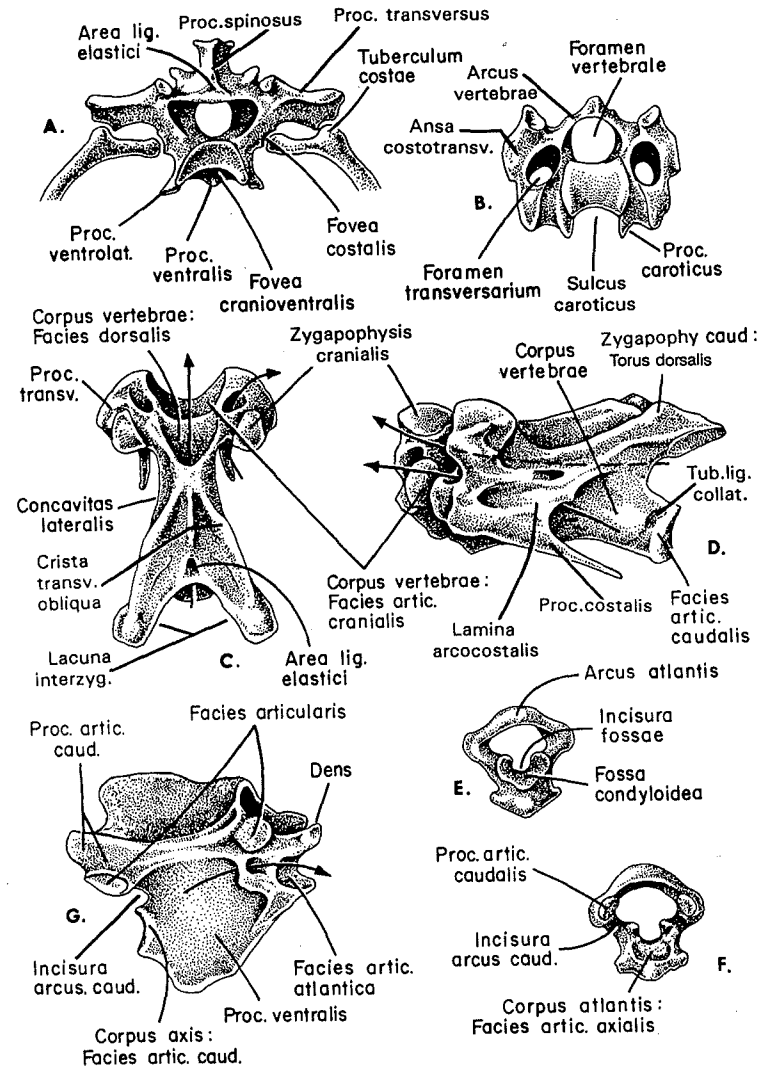
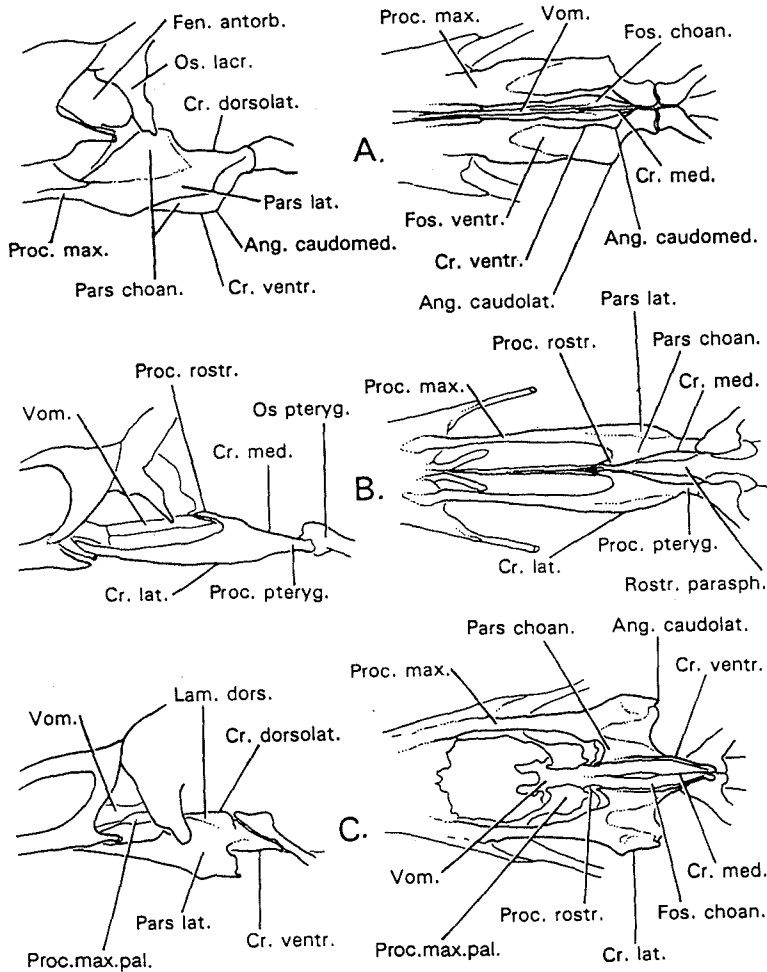


Fig. 4.6. Cranial cavity of the pigeon, *Columba livia*. Caudal view; transverse section through the Foramen magnum, plane of section inclined rostrally. Redrawn from Baumel (1968). Observe: (1) the Fossa cranii rostralis (perforated by Fonticuli cranio-orbitales) houses the telencephalic hemispheres; (2) at its ventral end the carotid canal opens into Fossa parabasalis on the base of the skull and at its rostral end into Fossa hypophysialis (Annot. 99); (3) the proximal ganglia of cranial nerves X and IX occupy a common depression, Fovea ganglii vagoglossopharyngealis, in the floor of Fossa cranii caudalis (Annot. 39). With permission of Academic Press.



Area lig. elastici Proc. spinosus Proc. transversus
 Tuberculum costae Arcus vertebrae Foramen vertebrae
 Ansa costotransv. Fovea costalis Proc. caroticus
 Proc. ventrolat. Proc. ventralis Fovea cranioventralis Foramen transversarium Sulcus caroticus
 Corpus vertebrae: Facies dorsalis Zygapophysis cranialis Corpus vertebrae Zygapophysis caud. Torus dorsalis
 Proc. transv. Concavitas lateralis Crista transv. obliqua Lacuna interzyg. Area lig. elastici
 Proc. costalis Facies art. cranialis Lamina arcocostalis Proc. costalis Facies art. caudalis
 Facies art. caud. Arcus atlantis
 Incisura fossae Fossa condyloidea
 Proc. artic. caudalis Incisura arcus caud.
 Corpus axis: Facies art. atlantica Proc. ventralis Facies art. axiali

Fig. 4.8. (cont.)

- C, Cervical vertebra 9, *Meleagris*, dorsal aspect; redrawn from Ghetie, et al. (1976).
 D, Generalized cervical vertebra, craniolateral oblique view, left side. Redrawn from Ghetie, et al. (1976).
 E, Atlas, *Meleagris*; cranial aspect; redrawn from Harvey, et al. (1968).
 F, Atlas, *Meleagris*; caudal aspect; redrawn from Harvey, et al. (1968).
 G, Axis, *Meleagris*; right lateral aspect; redrawn from Ghetie, et al. (1979). Arrows in C, D and G traverse the vertebral and transverse foramina. With permission of Academic Press.

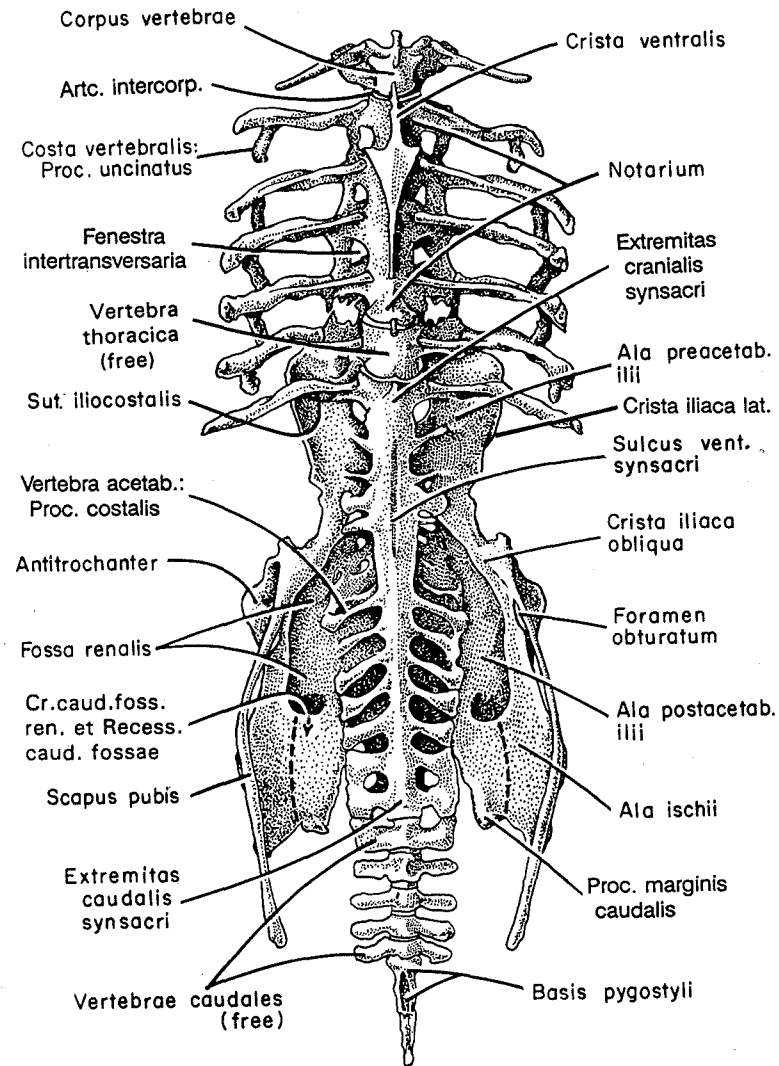


Fig. 4.9. Notarium, Synsacrum, and Os coxae of the turkey, *Meleagris gallapavo*; ventral view. Redrawn from Harvey, et al. (1968). The dashed lines represent the Sync. ilioischiastica (see Fig. 4.15). On the left side of the figure the arrow inserted into Recessus caudalis fossae passes dorsal to the ledge of bone, Pila postrenalis (Annot. 241). With permission of Academic Press.

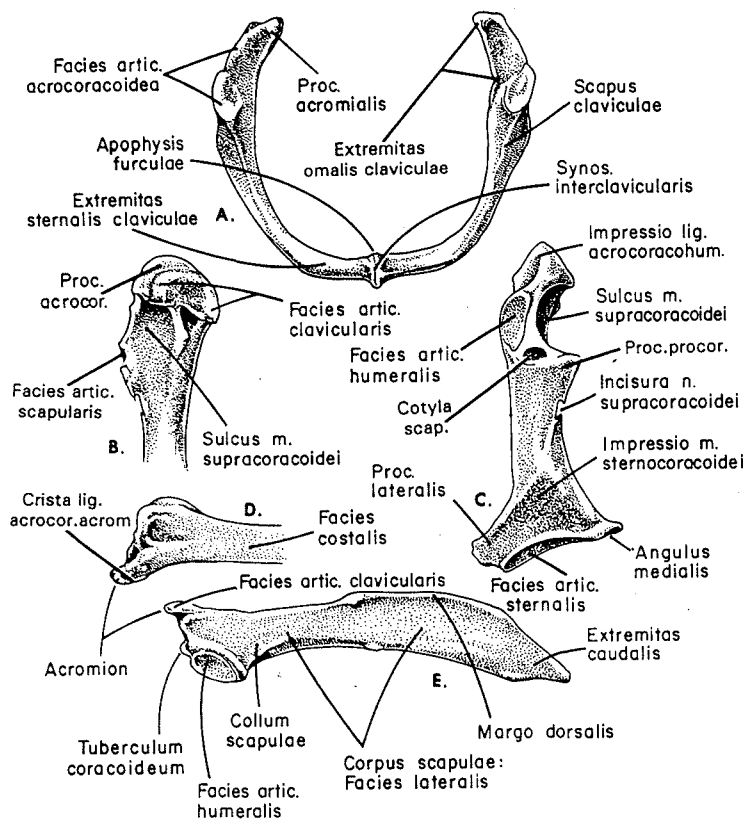


Fig. 4.10. Bones of the girdle of the thoracic limb of the eagle, *Aquila chrysaetos*. Redrawn from Howard (1929). A, Clavicle, caudal aspect; B, Coracoideum, left shoulder extremity, medial aspect. C, Coracoideum, left dorsal surface; D, Scapula, left cranial extremity, medial (costal) surface; E, Scapula, left lateral surface. The ankylosed left and right clavicles form the Furcula (see Annot. 162). With permission of Academic Press.

Abbreviations: acrocor., acrocoracoideus; acrocoracoehum., acrocoracoehumeralis; acrocor. acrom., acrocoracoacromialis; artic., articularis; glen. scap., glenoidalis scapulae; procor., procoracoideus.

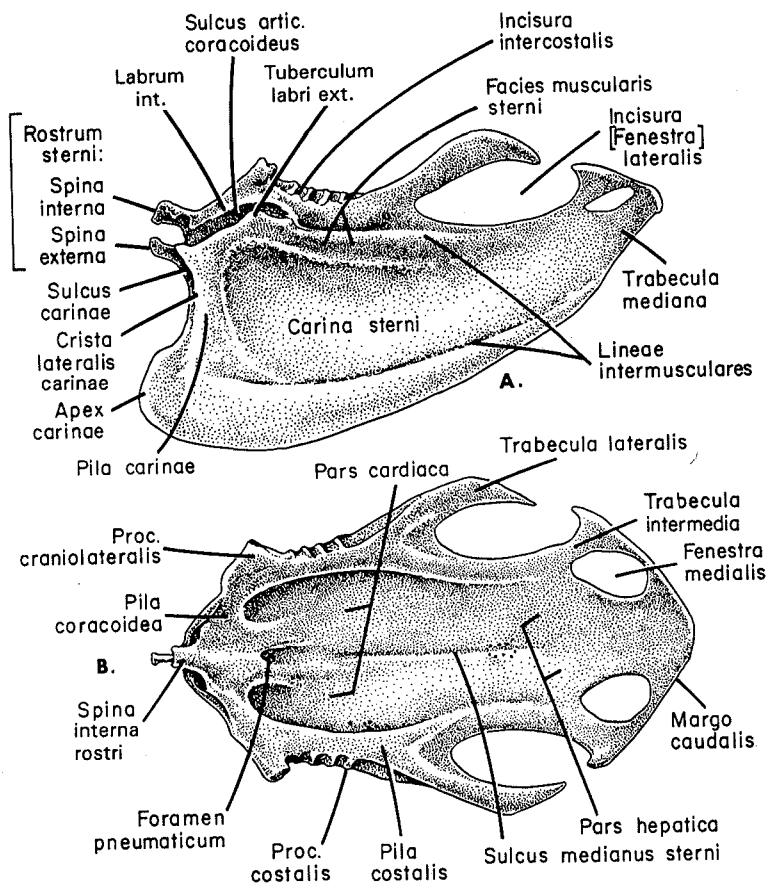


Fig. 4.11. Sternum of the pigeon, *Columba livia*. Redrawn from original of J. J. Baumel. A, left lateral aspect; B, visceral (dorsal) aspect. Abbreviation: artic., articularis. With permission of Academic Press.

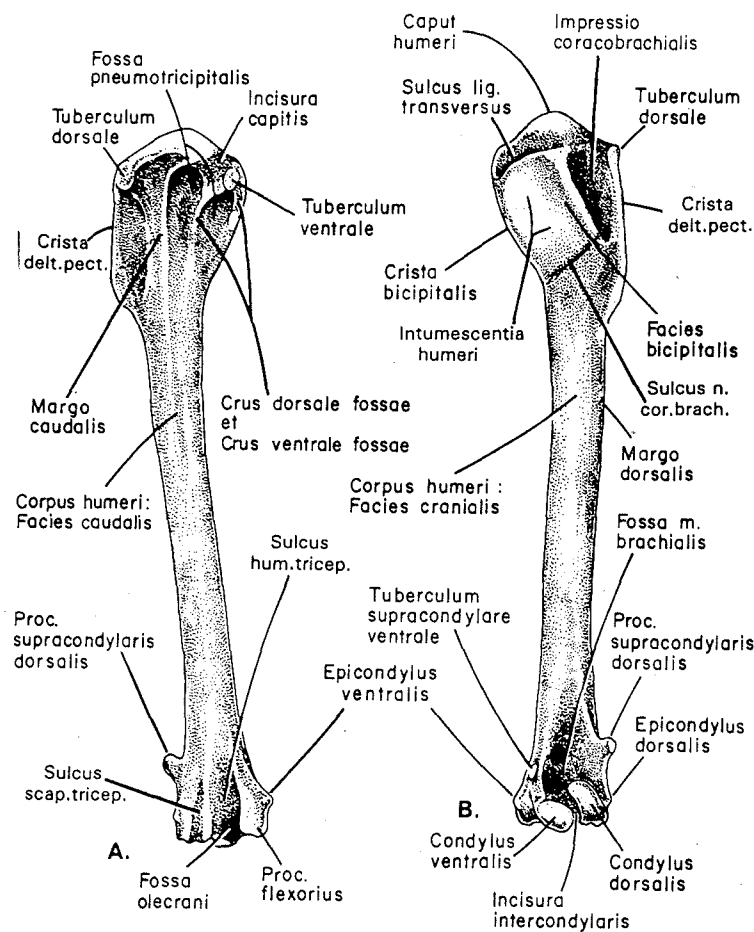


Fig. 4.12. Humerus of the gull, *Larus argentatus*. Original drawing of Wm. P. Hamilton. A. caudal surface; B. cranial surface. In *Larus* the impression for M. coracobrachialis cranialis is strongly etched and the pneumotricipital fossa is the dual type, non-pneumatic (see Annot. 188, 189).

Abbreviations: cor. brach., coracobrachialis; delt. pect., deltopectoralis; hum. tricep., humerotricipitalis; scap. tricep., scapulotricipitalis. With permission of Academic Press.

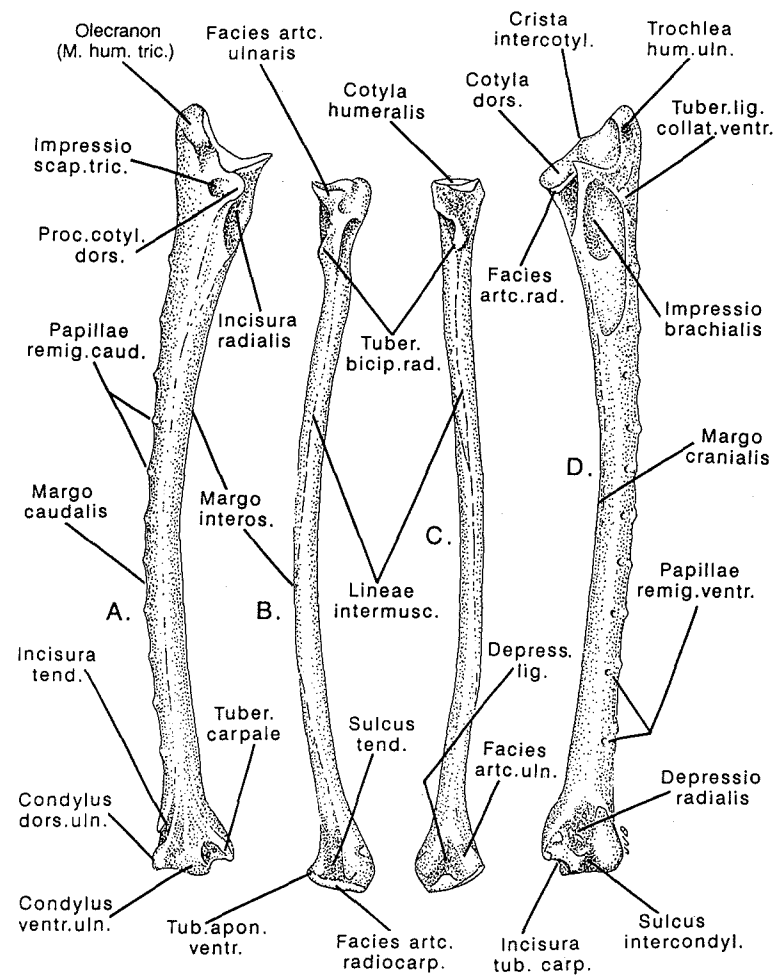


Fig. 4.13. Radius and Ulna of the vulture, *Cathartes aura*; right side. A. Ulna, dorsal aspect; B. Radius, dorsal aspect; C. Radius, ventral aspect; D. Ulna, ventral aspect. Original drawing of J. J. Baumel. Note that the terminology of these bones is based on the wing in the anatomical position (see Annot. 178 and Gen. Intro.).

Abbreviations: apon., aponeurosis; artc., articularis; bicep., bicipitale; collat., collateralis; cotyl., cotylaris; interos., interosseus; lig. ligamenti(-osa); remig., remigalis; tend., tendinosa(-us); tub. (tuber.), tuberculum(-i); uln., ulnaris.

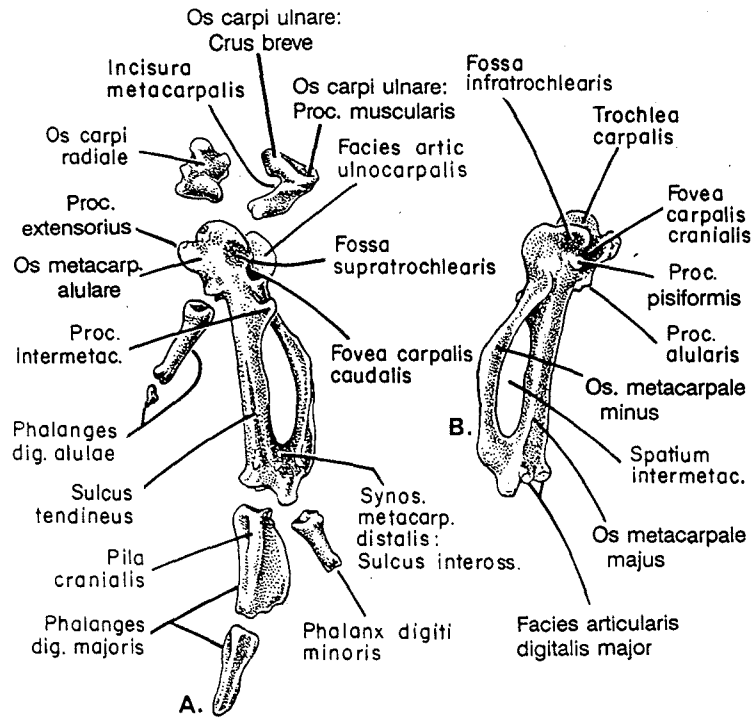


Fig. 4.14. Carpal and metacarpal bones, and phalanges of the turkey, *Meleagris gallapavo*; from left wing. Redrawn from Ghetie, et al. (1976). A. Dorsal aspect; B. ventral aspect. Note that the alular digit of the turkey has two phalanges (see Annot. 224). With permission of Academic Press.

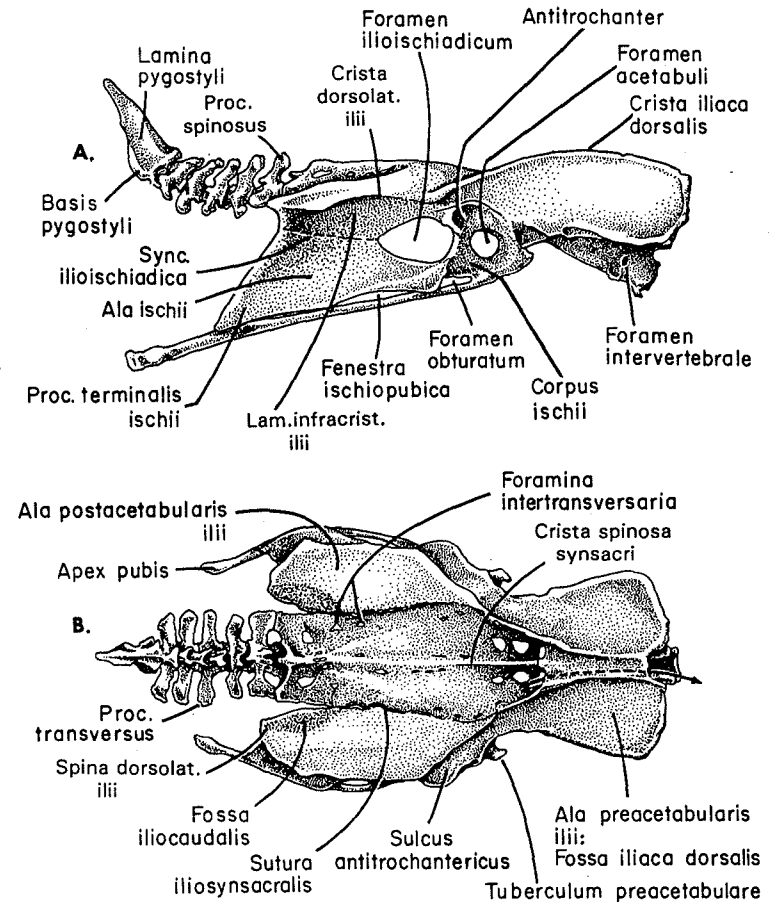


Fig. 4.15. Pelvis (Os coxae + Synsacrum) and caudal vertebrae of the turkey, *Meleagris gallapavo*. Redrawn from Harvey, et al. (1968). A. lateral aspect, right side; B. dorsal aspect. In B the arrow traverses Canalis iliosynsacralis (Annot. 234.). In A notice the dual intervertebral foramina in the synsacral part of the vertebral column (see Annot. 144). With permission of Academic Press.

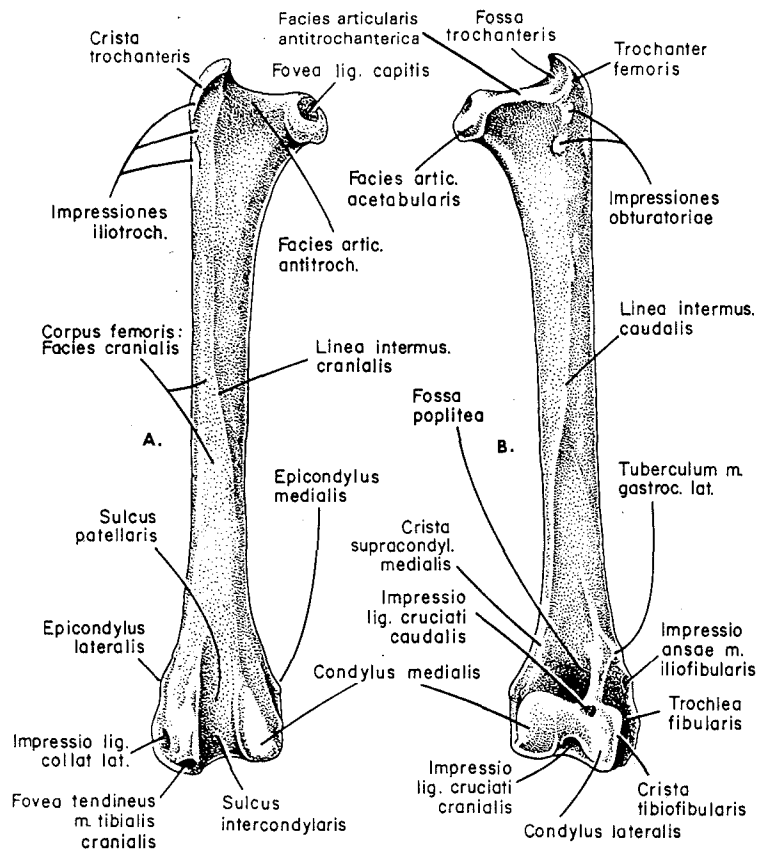


Fig. 4.16. Femur of the gull, *Larus argentatus*; right side. Original drawing of Wm. P. Hamilton. A. cranial aspect; B. caudal aspect. With permission of Academic Press.

Abbreviations: antitroch., antitrochanterica; artic., articularis; gastroc., gastrocnemialis; iliotoch., iliotochantericae; intermus., intermuscularis.

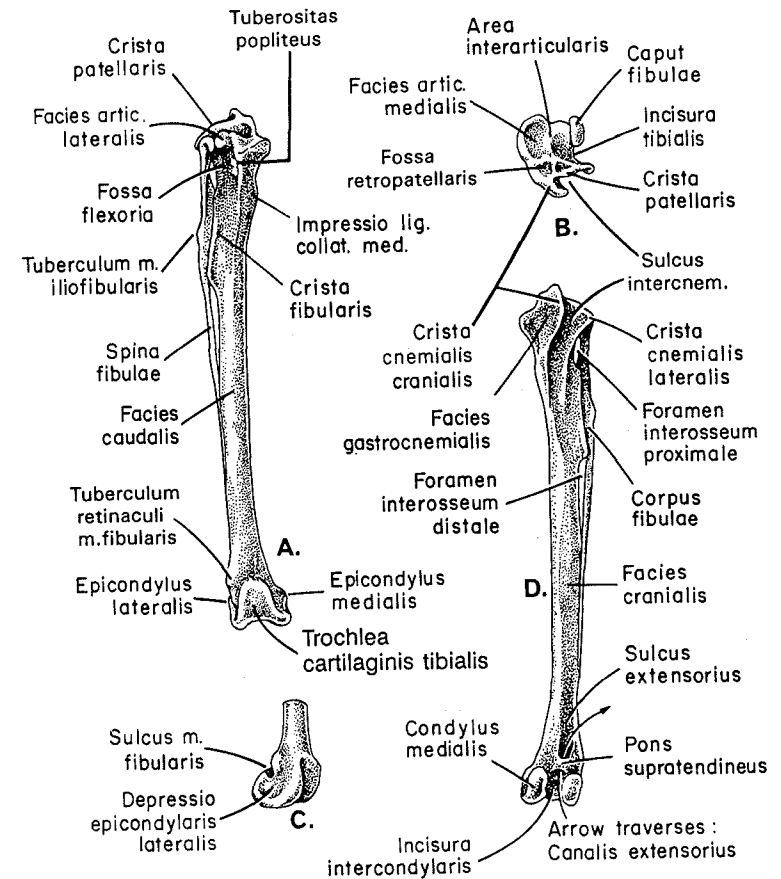


Fig. 4.17. Tibiotarsus and Fibula of the goose, *Branta canadensis*; left side. Original drawing of Wm. P. Hamilton. A. caudal aspect; B. proximal articular surfaces of both bones; C. distal extremity of tibiotarsus, lateral aspect; D. cranial aspect. With permission of Academic Press.

Abbreviations: artic., articularis; collat., collateralis.

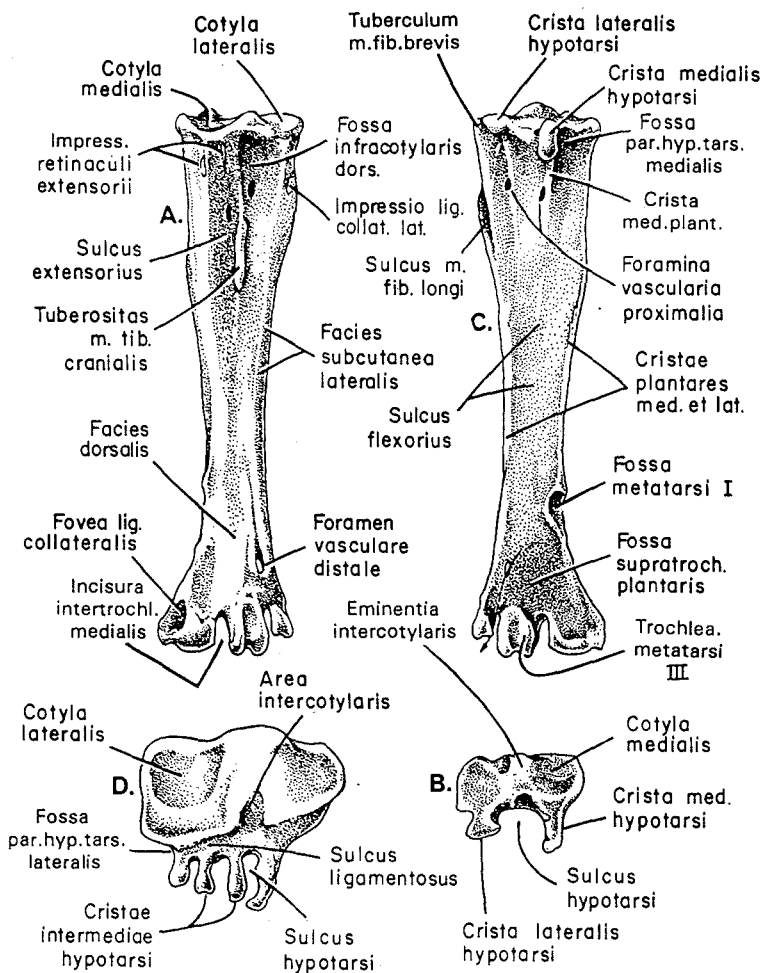


Fig. 4.18. Features of the Tarsometatarsus of the eagle, *Aquila chrysaetos* (A-C) and the goose, *Anser caerulescens* (*Chen hyperborea*) (D); all bones from the left limb. Redrawn from Howard (1929). A, dorsal aspect; B, proximal end; C, plantar aspect; D, distal end. At the distal end of C, the arrow traverses Canalis interosseus distalis (not labelled) (see Annot. 298) which conducts the tendon of *M. ext. digiti IV*. The Eminentia intercotylaris in the articulated intertarsal joint projects between the tibiotarsal condyles and is the distal attachment of *Lig. intercondylare tibiotarsale* (Arth. Annot. 171). With permission of Academic Press.

Abbreviations: impress., impressio; intertroch., intertrochlearis; med. plant., medianoplantaris; par. hyp. tars., parahypotarsalis.