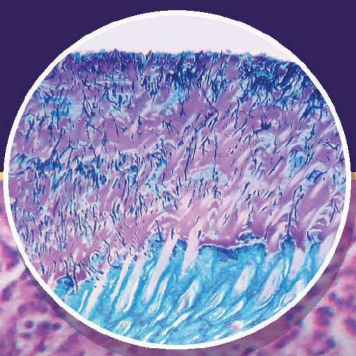
Third Edition

Pathology of Pet and Aviary Birds

Edited by Robert E. Schmidt
Jason D. Struthers
David N. Phalen



WILEY Blackwell

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This book is dedicated to Dr. Drury R. Reavill. Dr. Reavill was one of the original authors for the first and second editions. During her career, she authored or co-authored 189 publications, posters, and professional meeting proceedings, both in the USA and internationally. These publications helped pave the way for many novel treatments and procedures that benefit the lives of so many animals. She inspired colleagues to push the limits for exotic animal medicine and surgery with her contagious enthusiasm and dedication to a rigorous scientific approach. So many of her colleagues entered the world of scientific publication for the first time under her guidance and encouragement.

To those who knew Drury personally, she was a kind and generous soul. She lived life with gusto and had a remarkable sense of humor. She was a good friend to so many. Also, like so many of her generation, her passion for wildlife, exotic animal, avian, and zoo medicine was driven by the belief that these wonderful creatures deserved as much care and attention as any other animal. She will be greatly missed.

Drury Robb Reavill finished her journey on earth on October 30, 2021, after a 4-year battle with ovarian cancer. She was born Drury Robb on March 17, 1958. Drury aspired to become a bird veterinarian since the age of 7. In veterinary school, her professors told her there was no future in avian medicine and to forget this career path.

Drury was an outstanding asset to exotic and non-traditional animal medicine. She was proficient in the pathology of every zoo and pet exotic species, including exotic mammals, birds, reptiles, and fish.

She owned Zoo and Exotic Pathology Services in Sacramento, CA, USA for more than 15 years.

In 2020, Drury received some of the highest honors conferred to an exotic animal veterinarian, including the Oxbow Quest award, the Reptile and Amphibian Veterinary Excellence award, the ZooMed Laboratories, Inc. award, and a Lifetime Achievement award for Outstanding Contributions to Exotic Animal Veterinary Medicine.

The Drury Reavill Research Grant funded by the Association of Exotic Mammal Veterinarians will continue its mission to encourage research that improves our understanding of disease in exotic pets in hopes of developing better treatment options.

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About the Editors

Robert E. Schmidt, DVM, PhD, is a veterinary pathologist and independent Veterinary Pathology Consultant specializing in diagnostic pathology of birds, reptiles, fish, and non-domestic mammals. He received his BS and DVM degrees from the University of California, Davis; his MS in veterinary pathology from Michigan State University; and, his PhD in veterinary comparative pathology from Oklahoma State University. He is a diplomate of the American College of Veterinary Pathologists and has been involved in diagnostic pathology of pet and exotic birds for more than 50 years. His professional affiliations include the Association of Avian Veterinarians, Exotic Mammal Veterinarians, the Association of Reptile and Amphibian Veterinarians, the American Veterinary Medical Association, and the American Association for the Advancement of Science. He is a recipient of the Avian Pathology Award from the Association of Avian Veterinarians.

Jason D. Struthers, DVM, MVetSc, obtained his DVM in 2011 from the University of Montreal and then completed an MVetSc in anatomic pathology at the University of Saskatchewan. He finished his anatomic pathology residency at the University of Florida, followed by a year as an anatomic pathology clinical instructor at Walt Disney World's Animal Kingdom in Bay Lake, FL. He is a diplomate of the American College of Veterinary Pathologists and a tenured associate professor at Midwestern University's College of Veterinary Medicine in Glendale, AZ, USA. Dr. Struthers instructs in the veterinary curriculum, trains anatomic pathology residents, pursues opportunistic research, and provides diagnostic pathology service to veterinarians, researchers, government, and non-profit organizations. He is currently the Education Chair of the Maricopa Audubon Society. His scholarly endeavors are diverse and include peer-reviewed publications, frequent conference presentations, and research mentorship of veterinary students and anatomic pathology residents.

David N. Phalen, DVM, PhD, earned his BA at the University of Chicago, his DVM from Cornell University, and his PhD from Texas A&M University. He has been an avian practitioner for 40 years and is a diplomate of the American Board of Veterinary Practitioners in avian practice. Dr. Phalen has spent the last 30 years studying the epizootiology, diagnosis, and control of diseases of aviary, companion, and wild birds and has published extensively in this field. He recently retired as a Professor of Wildlife Health and Conservation in the School of Veterinary Science at the University of Sydney. He has received the Excellence in Avian Research Award from the American Veterinary Medical Foundation and was awarded the TJ Lafeber Practitioner of the Year in 2009. This year, he was awarded the Goldened Leaf Award for excellence in wildlife medicine. He plans to continue to contribute to the field as a Professor Emeritus in the faculty of the Sydney School of Veterinary Science and as an adjunct professor at Texas A&M University.

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Preface to the First Edition

The number of birds in captivity, as pets and breeders, and in ornamental and zoological collections has increased dramatically in the past 30 years. In many cases, wild populations of some of these species are threatened or have disappeared entirely, leaving the survival of the species to captive-bird breeding programs. With the growth in the bird-owning public has come a commensurate growth in the number of veterinarians providing care for birds and an enormous increase in the knowledge of the husbandry and diseases of these birds, including several comprehensive textbooks of avian medicine and surgery. Since birds are now common mainstream pets, there is also a need for diagnostic veterinary pathologists to be familiar with the diseases of these species.

The necropsy and related diagnostic services are an integral part of avian medicine. Both private and public collections are often large and closely housed. The death of a bird may be the first indication of a serious infectious disease, nutritional disease, or other management-related problem. Avian veterinarians and bird owners depend on pathologists to make an accurate diagnosis and provide advice on the significance of their findings.

Diseases of pet and aviary birds differ significantly from those of poultry. They also differ from many of the common diseases seen in wild birds, even wild birds of the same species. Much of the literature on the disease of pet and aviary birds is widely scattered in individual articles and in proceedings that most pathologists would not routinely review. Additionally, much information has never been published in any form. The goals of this book are to bring together in one volume a comprehensive review of the gross and histologic features of the diseases of pet and aviary birds and to provide a guide to ancillary diagnostics and a context in which to interpret the pathologic findings. While we feel this book will be a valuable reference for practitioners and students of avian medicine, helping them to understand the pathogenesis of the clinical manifestations of disease.

We have organized this material in a systemic format so that pathologists faced with a diagnostic challenge involving a particular organ can hopefully go to the appropriate chapter rather than having to search through extraneous listings under etiology or by bird species.

For the most part, this book deals with diseases of common, and a few uncommon, pet birds. However, the authors have also included material relating to other avian species that private practitioners and pathologists might occasionally be expected to encounter.

Preface to the Second Edition

Eleven years have passed since the first edition of this book was published. During that time there have been many exciting advances in the fields of avian pathology and the medicine of pet and aviary birds. Additionally, the nature of avian medicine has changed. Veterinarians are now likely to be treating pigeons, backyard chickens, and other species of poultry, as well as traditionally kept pet bird species. Veterinarians are also more likely to be treating birds with diseases associated with aging. The role and importance of the veterinarian in regard to aviculture continues. In general, the avian species that we now have in captivity cannot be replaced by birds from the wild so that maintaining their health and maximizing their breeding success is essential. Increasingly, captive breeding is also the last line of defense against extinction requiring significant veterinary input to maintain the health of small numbers of vulnerable birds.

Tissue biopsies and postmortem examination are an integral part of avian medicine. Biopsies inform treatment options and prognosis. Gross and microscopic postmortem assessments are essential if the impact of disease and inappropriate management practices are to be minimized. The second edition of *Pathology of Pet and Aviary Birds* is designed to assist the modern avian veterinarian and the avian pathologist so that they can maximize the information that they obtain from tissue biopsies and postmortem examinations. To this end, the number of illustrations is increased and the figures are in color. The written content is also greatly expanded. These changes will allow practicing veterinarians and avian pathologists to identify the common and not-so-common diseases in the case material presented to them and understand the pathogenesis and epizootiology of the diseases they identify across a wide range of species.

Preface to the Third Edition

This edition of *Pathology of Pet and Aviary Birds* presented anticipated and several unforeseen challenges that nearly jeopardized the project's completion. Due to the increasing breadth of avian disease literature and research, we expanded the preexisting system chapters and included three additional chapters on the diseases of passerines, raptors, doves, and pigeons. We also added an anatomy chapter that describes the avian postmortem examination, an avian cytology chapter replete with useful images, and a chapter on diagnostic modalities other than gross and histological examination. Unlike the first two editions, we invited veterinarians with experience and knowledge in avian medicine and pathology to contribute a new chapter or improve a system pathology chapter. This was a winning idea. The contributors added a wealth of information, and their efforts were paramount to ensuring the project's success. Wherever possible we strived to improve the number and quality of images and purposefully included multiple examples of sparsely photographed conditions and lesions. To ensure clarity, we annotated many of the images; where possible we identified the bird species photographed; and, bird names, common and Latin, used throughout the text were capitalized and referenced version 13.1 of the IOC World Bird List.

While this book focuses on captive and pet birds, we incorporated select conditions and diseases of poultry and free-ranging birds into all chapters, given that many veterinary practitioners and pathologists are liable to interact with a spectrum of avian patients. We also desired to illumine conditions that are threatening *our* global sustainable bird populations, and, unfortunately, these are principally anthropogenic threats. Most chapters, but especially Chapter 15, include images and discussion of window collisions, which indiscriminately kill 0.5–1 billion birds per year in the United States. Chapter 4 details the first report of plastic debris causing proventricular pathology in seabirds, aptly coined plasticosis. Chapters 6 and 17 discuss NSAIDs, particularly the association between diclofenac and the precipitous and disturbing decline of Indian vultures. Chapter 11 exposes bromide pollution as the instigator of vacuolar myelinopathy, and selenium toxicity as a culprit for congenital defects in shorebirds. Chapter 17, in addition to the relevant system chapters, reminds us of the deadly consequences of anti-coagulant rodenticides, electrocution, and lead shot on the health of avian apex predators and scavengers.

We hope that the content of this expanded third edition benefits veterinary pathologists, clinicians, and students and that the text meets the user's principal objective: to study avian diseases, to support diagnostic activities, or to serve as a reliable and comprehensive reference of avian diseases.

Acknowledgments

The editors thank the many individuals who contributed material (tissue and photographs) for use in this book. Their contributions have made this book possible.

Cover photographs are courtesy of Robert E. Schmidt and Alyson Fryer.

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Anatomy and Postmortem Examination

Dale Smith

Avian Anatomy

Integumentary System

Feathers

Feathers are the most unique feature of birds, but feather density, distribution, and morphology vary tremendously among species. The integument of birds can be divided into feathered and unfeathered (glabrous) regions. Feathered areas have a thin epidermis with a thin superficial stratum corneum. The dermis is also thin, comprised of a loose superficial layer containing smooth muscle and a deeper stratum compactum, with dermal papillae only at feather follicles. Cutaneous nerves, including sensory Herbst corpuscles, are associated with feather follicles, which also have smooth muscle attachments (arrector pili) that provide for independent movement of individual feathers or groups of feathers. Excluding the uropygial gland (present only in some species) and auricular glands, birds lack cutaneous glands; the epithelium itself functions as a holocrine sebaceous gland. Some species also have skin tubular vent glands. The subcutis is mobile and has localized aggregations of adipocytes. In some species (e.g., chickens and turkeys), there is a subcutaneous sternal bursa. Under the influence of estrogen and prolactin, a brood patch (incubation patch) develops in the ventral breast and coelomic skin of many species, including psittacine birds, raptors, and Passeriformes (Fig. 1.1). This patch corresponds to a region of thickened, edematous, hyperemic, and temporarily featherless skin that provides heat to and tactile information from incubating eggs. In unfeathered areas, the epithelium can be thickened with a leathery or even hard keratinized surface. These areas include the beak, cere, facial or other decorations (e.g., comb, wattles), scales of the legs, footpads, interdigital webs, and nails.

Mature feathers are composed entirely of keratin and are divided into six basic types. Contour feathers are the "classic" feather types and refer to those covering the body (coverts), the flight feathers (remiges), and the tail feathers (rectrices). Covert feathers are distributed over the body in distinct tracts (pterylae) separated by unfeathered areas (apteria). Feathers are seated in follicles; a small dermal papilla extends into the base of the hollow quill (calamus) through a small ostium known as the proximal (inferior) umbilicus (Fig. 1.2).

For additional strength, the follicles of the remiges and rectrices are attached to the underlying bones of the wing and pygostyle, respectively, by syndesmoses. The central shaft of the feather continues outwards as the more rigid rachis. Two vanes, which emanate from opposite sides of the rachis, are composed of long slender barbs and small hooklike barbules that project from the leading and trailing edges of the barbs. The barbules of the leading edge interlock with the barbules of the trailing edge of its adjacent barb, causing the vane of the feather to act as a single flexible membrane. A small secondary feather (hypoptile) may emerge at the base of the rachis.

In the remainder of feather types (semiplume, down, filoplume, bristle, powder down) and at the base of contour feathers, the barbs and barbules do not interlink, and the feather is known as plumulaceous (versus pennaceous). Semiplume and the rachis-less down feathers provide a layer of insulation below the contour feathers. Specialized powder down feathers are found in dense tracts in a band cranial and dorsal to the legs in species including cockatoos, Cockatiels (*Nymphicus hollandicus*), and some Columbiformes. These feathers grow continuously and degrade to produce a white powder of fine keratin granules. Filoplumes are long feathers with a bare rachis and terminal barbs; they provide sensory input via adjacent dermal corpuscles, particularly from the flight feathers. Hairlike bristles are most numerous around the eyes, nostrils, and mouth.

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Figure 1.1 Brood patch (incubation patch) in a female Cedar Waxwing (*Bombycilla cedrorum*). Courtesy of Jared B. Clarke.

Figure 1.2 Normal wing feather (remex—plural remiges). Proximal umbilicus (A), calamus (B), distal umbilicus (C), rachis (D), and vane (E).

Feather color derives from two primary sources: pigments and feather structure. Pigments include melanin, carotenoids, porphyrins, and Psittaciforme plumage pigments called psittacofulvins. Melanin, of which there is an entire family, is produced by melanocytes in the skin and in the feather. Carotenoid pigments or their precursors are obtained from dietary items and produce yellow to red to orange feather colors; however, in psittacine birds, these colors result from psittacofulvin pigments that are presumed synthesized in the developing feather. Porphyrins are produced in the liver by the breakdown of hemoglobin. Structural colors, generally white, blue, and violet, are the result of refraction and reflection of incident light by the feather. Combinations of structural and pigmentary colors are common; for example, iridescence results from melanin and structural color.

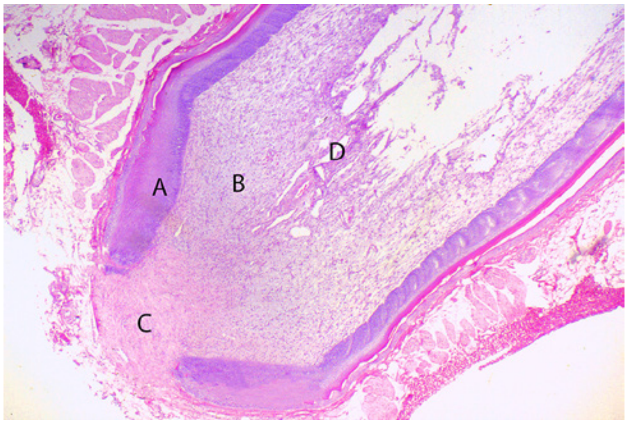

Figure 1.3 Base of normal developing feather. Feather sheath (A), pulp (B), dermal papilla (C), and central blood vessel (D).

New feather growth occurs in the embryo and chick, after feather loss, and at times of molt. Birds typically molt once or twice a year; frequency and pattern of feather loss vary with species and, in some cases, sex. The growing feather develops in and emerges from the feather follicle, an invagination of the superficial epithelium (Fig. 1.3). The dermal papilla, containing a central axial artery, projects into the base of the growing feather and at its apical end proliferates to produce the loose vascular mesenchymal reticulum (pulp) that fills the developing calamus. At the base of the follicle, the epithelium reflects upwards as the epidermal (germinal) collar. The stratum corneum will form the thin outer feather sheath, and the intermediate layers will proliferate as a complex three-dimensional combination of proliferation and apoptosis to form the calamus, rachis, and vanes (with barbs and barbules). The inner (basal) layer forms the lining of the pulp cavity. As the growing feather (pin feather) emerges from the skin surface, the bird breaks off the outer sheath, exposing the underlying feather structure. A central vascular pulp cavity remains until the feather is fully formed; its gradual recession leaves a series of air-filled chambers or pulp caps.

Beak and Cere

The avian beak has tremendous variation in morphology across species, including the position of the nostrils, to suit its myriad of functions. A dense cornified epidermis, the rhamphotheca, covers the upper jaw (rhinotheca) and lower jaw (gnathotheca) and is continuous with the soft epithelium of the surrounding skin and the oral mucosa. A thin dermal layer attaches to the periosteum; there is no subcutis. The beak is an important sensory organ, with mechanoreceptors, including Herbst corpuscles (Fig. 1.4) and, in waterfowl, Grandry corpuscles in the subepithelium or in pits in the underlying bone, particularly in the region of the bill tip.

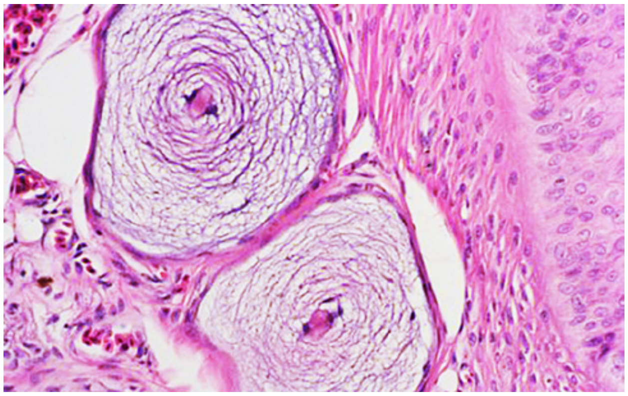

Figure 1.4 Herbst corpuscles beneath the epidermis of the beak.

In some species (e.g., Falconiformes), the tomia, the edges of the upper and lower jaws, form cutting or grasping surfaces (Chapter 17). The beaks of psittacine birds are rigid and hooked for holding and cracking foodstuffs and other objects. The upper jaw of many avian groups, including psittacine birds, articulates independently with the skull. In embryos of some species, a keratinized projection known as the "egg tooth" develops on the dorsal surface of the beak (the culmen); this is shed post-hatching.

The cere is the thickened portion of integument that straddles the base of the nasal region. It may be feathered or bare, and it may or may not contain the nares (nostrils). In psittacine birds, the nares are located dorsally within the cere, while kiwi nares are at the tip of the upper beak. Cockatiels and Budgerigars (*Melopsittacus undulatus*) have a well-developed cere compared to Amazon parrots. The cere of an Amazon parrot is covered with tiny feather bristles (setae) (Fig. 1.5). Columbiformes usually have well-developed ceres above the horn (rhinotheca) of their bills and behind the nares. Many species of parrots, raptors, and

Figure 1.5 *Amazona* sp. parrot with setae (bristles) covering the cere.

Figure 1.6 Operculum or bony tubercle in the left nare of a Turquoise-fronted Amazon (*Amazona aestiva*). Courtesy of William Aqeel.

Galliformes have an operculum or bony tubercle just inside the nares (Fig. 1.6). It is a rounded or plate-like keratinized structure that may act as a baffle to deflect and prevent inhalation of foreign material.

Uropygial Gland

The uropygial gland (preen gland) is at the base of the tail, dorsal to the levator muscles, and is bilobed and pear-shaped (Fig. 1.7A and B). It is a holocrine tubuloalveolar gland with an oily secretion that has several functions, including acting as a lubricant during preening. Excretory ducts from the gland exit from the caudally directed nipple-like apex, which has a tuft of short wick-like down feathers. The number of orifices depends on species. The uropygial gland is present in most birds and is largest in aquatic species. It is absent in most Psittaciformes, ratites, and select Columbiformes.

Bone, Appendicular/Axial Skeleton, and Skeletal Muscle

There are several unique aspects to the avian skeleton that provide rigidity and strength for flight while minimizing weight. Bone cortices are thin, and there are multiple internal "struts" for support. Extracellular bone has a high proportion of inorganic substances, primarily hydroxyapatite crystals; this varies with the skeletal site reflecting the differing functions of bone. Avian bones are brittle and tend to splinter. The marrow of many bones is replaced by extensions of air sacs, such that the air sac membrane will line the endosteum. The degree of pneumatization is species-specific. In most birds, the femur, humerus, sternum, skull, and at least some of the vertebrae are pneumatized.

Birds have the unique ability to deposit and remove calcium from what is known as medullary bone, a meshwork

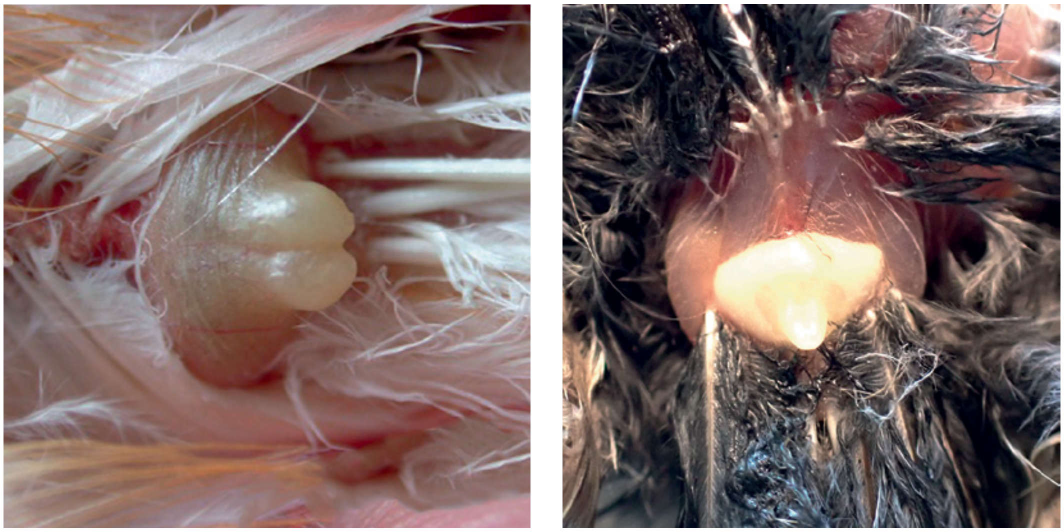

Figure 1.7 Normal uropygial (preen) gland above the base of the rectrices. The gland morphology varies among species. The left is from an unknown species and the right is from a male House Finch (*Haemorhous mexicanus*). Courtesy of Jason D. Struthers (Book Author).

Figure 1.8 Avian long bone illustrating the interconnecting spicules in the marrow cavity.

of interconnecting bone spicules that fills the marrow cavity of long bones, particularly the humerus, femur, and tibiotarsus (Fig. 1.8). Medullary bone is deposited in female birds prior to the period of lay under the influence of ovarian estrogen to act as a reservoir of calcium for eggshell formation.

The proportions of the axial skeleton vary tremendously among species based on the type of locomotion: flight and style of flight, ability to swim, or flightlessness. The skeletal structure of the avian pectoral girdle is more complex than that of mammals, whereas that of the wing is simplified. The humerus articulates distally with the radius and ulna; the ulna is the larger bone, unlike in mammals. The humerus is pneumatized by the clavicular air sac through a foramen grossly visible below the ventral tubercle. There are only two carpal bones: the radial and the ulnar. The carpometacarpus consists of the fused major (digit 2), minor (digit 3), and alular (digit 1) metacarpal bones. From these extend the phalangeal bones of the major and minor digits and the short alula or "thumb."

The large ventral flight muscles that connect the sternum, pectoral girdle, and humerus, and the pelvic limb muscles are located close to the core of the body below the center of gravity for stability in flight. The cervical muscles are complex to manipulate the flexible neck, while the rigidity of the remainder of the vertebral column and pelvis reduces the need for muscular strength in these regions. Hind limb biarticular muscles, which span two articulations between their origin and insertion, comprise important and strong muscles of birds and, in Passeriformes at least, are critical for the take-off leap. Ossification of tendons in the leg is common.

The bones of the avian pelvis (ilium, ischium, and pubis) are fused and with the vertebral synsacrum create a large rigid area for muscular attachment and protection of the coelomic contents. The femur articulates proximally at the ilial acetabulum, and distally with the tibiotarsus, which refers to the fused tibia and the proximal tarsal bones. There is a patella and a greatly reduced fibula. The distal tarsal bones are fused with a single metatarsal bone as the tarsometatarsus.

The number of toes, the number of phalanges, and their orientation vary among species. Most birds have four toes, but several species have three, and the ostrich (*Struthio* spp.) has two. Psittacine birds have digits 1 and 4 facing backwards, and 2 and 3 facing forwards (zygodactyl).

Histologically, avian skeletal muscle resembles that of mammals. Although myofibers are commonly thought of as red or white based on myoglobin content, this is a vast simplification. The majority of fibers of the flight muscles of most birds are fast-twitch oxidative glycolytic (FOG) with high aerobic capacity.

Skull

The avian skull is extensively pneumatized via the nasopharynx (paranasal sinuses) and middle ear (paratympanic sinuses), and the thin cranial bones are fused and thus without sutures. The orbits are large and incomplete, except in parrots, and there is a single occipital condyle. The shape of the facial bones, including those of the upper and lower beaks, varies tremendously with species to support the varied shape and functions of the beak, position of the nares, and any specialized structures, such as a casque (Fig. 1.9). Upward movement of the upper beak is provided by the maxillopalatine apparatus, a combination of complex articulations and regions of flexibility in the quadrate, pterygoid, and palatine bones. In large parrots, the main point of flexion, the craniofacial hinge, is a synovial articulation. The main articulation of the lower jaw occurs on each side between the mandible and the quadrate bone; however, in some species, additional articulations and regions of osseous flexibility exist.

Axial Skeleton

The vertebral column of birds is substantially modified to support flight. The number of vertebrae in each segment varies considerably among species, and varying portions of the column are fused to provide stability. The cervical spine is S-shaped and mobile; C1 and C2 are known as the atlas and axis as in mammals. The last few cervical vertebrae may have small free ribs. Vertebrae carrying the full fixed and free ribs are considered to be thoracic vertebrae. The majority of these are fused to form the notarium in many species. A varying number of unfused thoracic vertebrae provide some flexibility caudal to the notarium. One or more caudal thoracic vertebrae may fuse with the lumbar, sacral, and proximal caudal vertebrae to form the synsacrum, which is in turn ankylosed with the os coxae; the fused ilium, ischium, and pubis. There is no pubic symphysis; the pelvis is open ventrally. There are five to eight free caudal vertebrae to which attach the muscles of the tail. In carinate (keeled) birds, the terminal caudal (coccygeal) vertebrae are fused to form the pygostyle, which supports the feathers of the tail (rectrices). In most birds, at least some of the vertebrae are pneumatized.

The pectoral girdle consists of the scapula, the clavicle (furcula refers to the fused paired clavicles or "wishbone"), and the coracoid (Fig. 1.10), all of which articulate with the

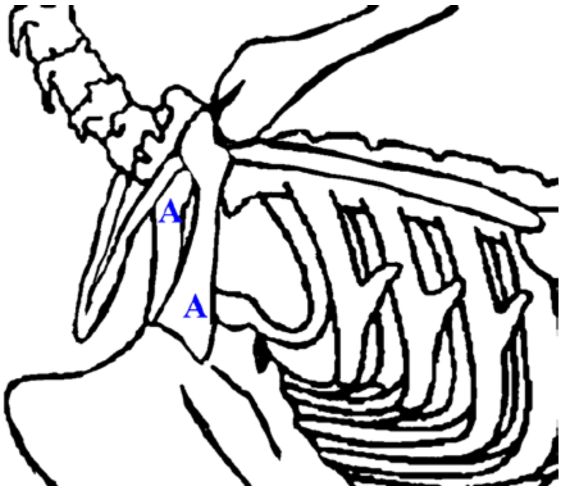

Figure 1.10 Pectoral girdle. The coracoids (A) articulate and extend between the sternum and the shoulder.

Figure 1.9 Lateral view and cross-section of the casque from a Rhinoceros Hornbill (*Buceros rhinoceros*). Courtesy of Jason D. Struthers (Book Author).

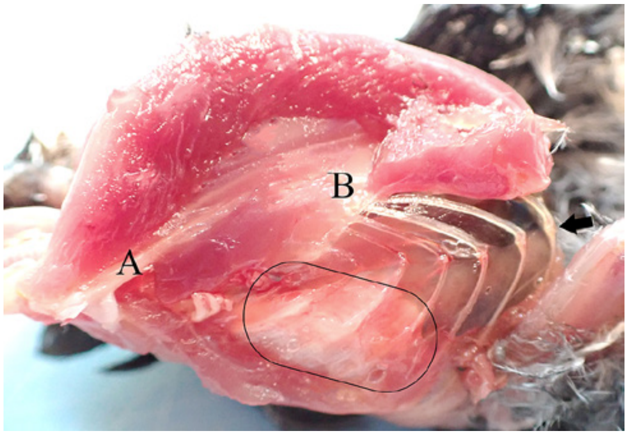

Figure 1.11 Six sternal ribs with intercostal joints (arrow) that articulate between the vertebral column (at the bottom of image) and the sternum (B) of this male House Finch (*Haemorhous mexicanus*). The coracoid (A) articulates between the sternum and the humerus to form the shoulder. The salmon pink lung (circle) is visible through the intercostal muscles at the dorsal aspect of the cranial coelom. Courtesy of Jason D. Struthers (Book Author).

Figure 1.12 Pituitary gland (star) in the sella turcica of the pneumatized skull (PS) with olfactory lobe (OL) and caudal nasal cavity (dot) in a House Finch (*Haemorhous mexicanus*). Courtesy of Jason D. Struthers (Book Author).

head of the humerus to form the shoulder joint. The tendon of the supracoracoideus muscle passes through the associated triosseal canal. The coracoid, which in mammals is simply a small process on the scapula, in birds is a strong supporting pillar connecting the shoulder joint to the sternum. In psittacine birds the clavicles are small.

The bird's sternum is a broad, pneumatized, bony plate that covers most of the ventrum, leaving only a small caudal region of unprotected coelomic cavity. A prominent keel or carina that projects perpendicularly from the sternum acts as an attachment for the major flight muscles: the pectoralis major and supracoracoideus muscles, which are responsible for the down- and up-strokes, respectively. Sternal movement is the mechanical driver of respiration through a bellows mechanism in conjunction with the air sacs. The keel (carina) is absent in ratites (i.e., ostriches, rheas, emus, cassowaries, and kiwis) and much flattened in some other flightless species (e.g., penguins). Birds have free (asternal) and sternal ribs that articulate with the sternum (Fig. 1.11). There is a cartilaginous intercostal joint. Prominent uncinate processes, caudally oriented bony extensions of the ribs, are a feature shared with reptiles.

Endocrine System

Pituitary Gland

The pituitary gland or hypophysis is encased by the dura mater and located in the sella turcica beneath the diencephalon caudal to the optic chiasm (Fig. 1.12). It is composed of the adenohypophysis (anterior pituitary) and the neurohypophysis (posterior pituitary), which are adjacent to each other but separated by a layer of connective tissue. The adenohypophysis consists of the pars tuberalis and pars distalis; in contrast to mammals, birds lack a pars intermedia. The neurohypophysis sits caudodorsal to the adenohypophysis and comprises the median eminence (a portion of the floor of the third ventricle), the infundibular stem, and the neural lobe. The pars tuberalis of the adenohyphophysis covers the median eminence and surrounds the infundibular stem, and the two together comprise the stalk of the pituitary. The third ventricle extends though the infundibular stem into the neural lobe. The pituitary has complex capillary networks and a venous portal system.

Secretory cells of the pars tuberalis form a thin layer of flattened cords covering the base of the brain, form long cords parallel to blood vessels in the portal zone of the pituitary stalk, and pass laterally over the pars distalis. Cells of the pars tuberalis are round or elongated, finely granular, and faintly basophilic with round to oval vesicular nuclei. The pars distalis consists of secretory cells organized into cords or follicles containing basophilic colloid; the latter being more frequent in mature birds. Cysts containing mucus and lined by ciliated epithelial cells are also commonly present. Secretory cell types are classified as acidophils, basophils, and chromophobes. The pars distalis is divided into cephalic and caudal zones according to cellular staining characteristics: the acidophils of the cephalic zone stain lightly giving the tissue an overall basophilic appearance, while those of the caudal zone stain more deeply making it more intensely eosinophilic.

All three segments of the neurohypophysis possess a three-layered wall: an inner ependymal layer that is in contact with