

A Guided Tour of Avian Anatomy



2021 Revision of 2014 Edition

James Edgar Smallwood, DVM, MS



A Guided Tour of Avian Anatomy

2021 Revision of 2014 Edition

James Edgar Smallwood, DVM, MS
Professor Emeritus

**Department of Molecular Biomedical Sciences
North Carolina State College of Veterinary Medicine**

**Published by the Author
as Electronic Version**

Library of Congress Cataloging-in-Publication Data

Smallwood, James E.

A guided tour of avian anatomy / James E. Smallwood

ISBN 0-9702165-2-1

1. Veterinary anatomy - bird

I. Title.

SF762.S74 2014

636.089'1 --- dc20

Copyright © 2014, 2018, 2021 by James Edgar Smallwood

For information about ordering copies of this book, please contact the author at:

edandkay.smallwood@gmail.com

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the author.

Printed in the United States of America as electronic version

Revised March 24, 2021

Dedication & Notes

This book is dedicated to my students, who over the years have endured my lectures, laboratories, stories, and jokes, and who, in spite of that, have gone on to become (for the most part) competent and successful veterinarians. This book was written for my students, but if others find it useful, I am delighted to be of assistance.

About the Author

James Edgar Smallwood was born in Dallas, Texas and grew up on a small farm near Fort Worth. He attended Burleson High School, Sam Houston State University, San Antonio College, and Texas A & M University, from which he received the DVM in 1969. Upon graduation, Dr. Smallwood was offered an instructorship in the Department of Veterinary Anatomy, which *in lieu of* finding a real job, he accepted. Thus he began teaching veterinary students in 1969. While serving as an instructor, he completed his MS degree in veterinary anatomy in 1972, at which time it became obvious he had been educated well beyond his intelligence.

In 1975, Dr. Smallwood left academia and tried working for a living as an associate in a small animal practice in San Antonio. The university was gracious enough to extend a one-year leave of absence, during which time the opportunity arose for Dr. Smallwood to return to Texas A & M University in a "split appointment" in veterinary anatomy and radiology. From 1976 to 1981, he spent approximately 50% of his time teaching anatomy and 50% doing a residency in veterinary radiology.

In 1981 Dr. Smallwood was offered the unique opportunity to become one of the initial faculty members of a new veterinary college being established at North Carolina

State University. He became Professor of Anatomy and began teaching the first class of that college, which graduated in 1985. In 1989 he was named Alumni Distinguished Professor of Anatomy, and continued to harass first-year veterinary students as their "tour guide" in learning veterinary anatomy through the spring of 2013. Dr. Smallwood retired on July 1, 2013 to pursue his "bucket list" and drive his wife crazy.



James E. Smallwood, DVM, MS
1945 - ?

Dr. Smallwood has received numerous teaching awards including the Texas Veterinary Medical Association Faculty Achievement Award for Teaching, Texas A & M University Faculty Distinguished Achievement Award for Teaching, Norden Distinguished Teacher Award, North Carolina State University Outstanding Teacher Award, NCSU Alumni Distinguished Professor Award, UNC System Board of Governors' Award for Excellence in Teaching, and Second Place

Winner of the Student AVMA National Teaching Excellence Awards in Basic Sciences. He has served as President of the American Association of Veterinary Anatomists (1988-89) and the World Association of Veterinary Anatomists (1995-99). In 2002, Dr. Smallwood received the Distinguished Veterinarian Award from the North Carolina Veterinary Medical Association.

About the Book

A Guided Tour of Avian Anatomy emerged from the expansion of notes, which had been used for a number of years in teaching a one-week "selective" in avian anatomy to first-year veterinary students. I call it a "guided tour" because I often compare what I do, in terms of teaching anatomy, with the role of a "tour guide." Consequently, this guided tour is intended to serve as a sort of *gubernaculum*^{1*} for first-year veterinary students in their comparative anatomic study of the bird. An attempt has been made to emphasize applied anatomy as it relates to physiology, pathology, radiology, medicine, and surgery. In fact, much of the information contained in this guide is related to the application of anatomy to veterinary medicine.

As is already evident from the above, this guide is written in rather plain language, with a liberal interjection of comments that are (at least) slightly humorous. Some of my colleagues will undoubtedly view these notations as out of place, and I accept this criticism constructively. *Thank you.* I really don't see any reason why anatomy can't be fun as well as educational.

Acknowledgements The author is greatly appreciative of the dedicated efforts of Ms.

Monica Wilson of Millennium Print Group. Without her perseverance and patience, this book would never have been completed.

My lovely and exciting wife, Kay, has helped in many ways with the production of this book. Special thanks to Dr. Martje Fentener van Vlissingen for providing many of the line drawings that I have modified to be included in this book. Mr. William A. Wise has kindly provided me with many of the photographs of skeletal material and bird feet that are included in the book.

The author gratefully acknowledges the significant improvement in this book provided through the careful critique of the following individuals: Dr. Laurel Degernes, Associate Professor of Avian Medicine, NC State University College of Veterinary Medicine, and Dr. Lauren Powers, Service Head, Avian and Exotic Pet Service, Carolina Veterinary Specialists, Huntersville, North Carolina.

2014 ("First") Edition

Although I have used a much reduced version of this book for a number of years in teaching the avian selective, the 2014 Edition is my first attempt to "go public," with the book. I have greatly expanded the book to include introductory chapters on comparative anatomy of birds and on the evolution of birds, as we currently understand it. As in any "first" edition, there are undoubtedly many, yet-to-be-discovered, errors in this edition. With your help, we shall attempt to remove these as soon as they are identified. *Comments and suggestions relative to the improvement of this guided tour are always welcomed and appreciated.*



* gubernaculum- "helm"; "rudder"; something that guides.

Contents

Chapter 1 • Introduction and Comparative Anatomy of Birds	1
Chapter 2 • Terminology, Osteology, and Arthrology	57
Chapter 3 • Evolution of Birds and Integument	74
Chapter 4 • Myology	88
Chapter 5 • Digestive System	94
Chapter 6 • Respiratory System	105
Chapter 7 • Urogenital System	115
Chapter 8 • Cardiovascular System	128
Chapter 9 • Nervous System	134
References	149
Index Removed • Use Keyword Search on PDF Version	

Chapter 1 • Introduction and Comparative Anatomy of Birds

INTRODUCTION

A working knowledge of avian anatomy is a necessity for any veterinarian involved with either disease control in commercial poultry production units or with the treatment of individual patients in a pet-bird practice. Because of the great diversity among avian species, it should be intuitively obvious that the material contained in this book is merely a basic introduction to avian anatomy. **Disclaimer:** Birds represent such a diverse group that almost any statement of “bird anatomy” should be construed as a **general rule**. Undoubtedly, there is some bird out there somewhere who didn’t get the e-mail when this or that “bird rule” was enacted, and thus represents an exception to the basic bird pattern.

COMPARATIVE ANATOMY: How the domestic species we study relate to one another and fit into the larger scheme of birds on the planet

Birds represent a highly diverse group of animals, with more than 10,000 recognized species as compared with less than 5000 known species of mammals. Birds can be found in almost every known habitat- from the arctic to the desert and from the tropics to the open sea.

Birds are considered by some to be more primitive phylogenetically than mammals, and share certain characteristics (*viz.*, scales) with reptiles, from which birds are thought to have evolved. Table 1-1 gives the scientific names for some of the more common species of birds.

Before we get too carried away with focusing our attention on the relatively few species of poultry and pet birds, let’s step back a moment and take a broader look at how those species relate to one another and how they fit into the larger scheme of birds on the planet. This information is helpful as we try to gain an understanding of why certain species share more common anatomic features with their closer relatives and differ more from their more distant ones. Figure 1-1 shows how the Class Aves can be divided into its various subclasses, and superorders. You might ask—Isn’t what you call “comparative anatomy” really taxonomy? To which I humbly reply—just what is taxonomy primarily based on if not **comparative anatomy**?

Table. 1-1. Scientific Names of Some Birds

Common Name	Scientific Name
chicken	<i>Gallus gallus</i>
turkey	<i>Meleagris gallopavo</i>
mallard duck	<i>Anas platyrhynchos</i>
Muscovy duck	<i>Cairina moschata</i>
greylag goose	<i>Anser anser</i>
ring-necked pheasant	<i>Phasianus colchicus</i>
pigeon	<i>Columba livia</i>
helmented guineafowl	<i>Numida meleagris</i>
Indian peafowl	<i>Pavo cristatus</i>
budgerigar*	<i>Melopsittacus undulatus</i>
cockatiel	<i>Nymphicus hollandicus</i>
cockatoo	<i>Cacatua leadbeateri</i>
African grey parrot	<i>Psittacus erithacus</i>
hyacinth macaw	<i>Anodorhynchus hyacinthinus</i>
blue & gold macaw	<i>Ara ararauna</i>
canary	<i>Serinus canarius</i>
rosy-faced lovebird	<i>Agapornis roseicollis</i>
bobwhite quail	<i>Colinus virginianus</i>
ostrich	<i>Struthio camelus</i>
emu	<i>Dromaius novaehollandiae</i>
greater rhea	<i>Rhea americana</i>

* parakeet (Although all budgies are “parakeets,” there are numerous “parakeets” that are not budgies.)

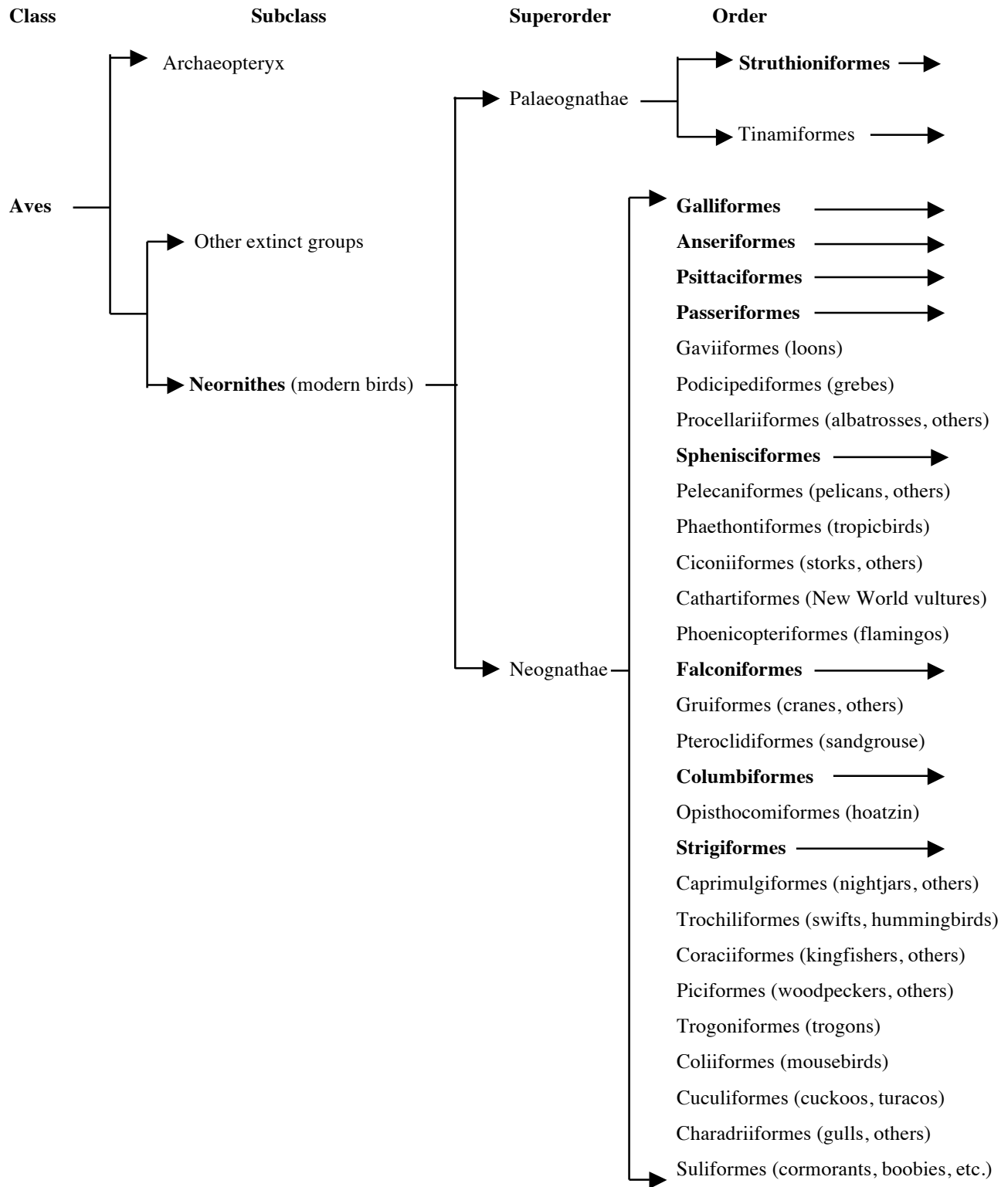


Figure 1-1. Class Aves: Modern-day Order Struthionioformes is continued in figure 1-2. Modern-day Orders Anseriformes, Galliformes, Psittaciformes, Passeriformes, Sphenisciformes, Falconiformes, and Strigiformes are continued in subsequent figures.

Since the eighteenth century, humans have made numerous attempts to classify birds correctly, and it is unlikely that ornithologists will ever completely agree on the taxonomy. Therefore, the taxonomic outline proposed in this chapter is admittedly imperfect. At best, it represents an honest attempt on my part to put birds into some useful groupings for veterinarians, even if it doesn't make all ornithologists happy.

The Subclass **Neornithes** includes two superorders of modern birds. **Paleognathae** (old jaw) consists of only two orders-Struthioniformes and Tinamiformes (Figs. 1-1 & 1-2). In the paleognathae, the sphenoids and other bones of the palate do not fuse. The entire superorder contains only about 52 living species. From the perspective of a veterinarian, the order

Struthioniformes or **ratites** is much more important than the tinamiformes.

Tinamous are one of the most ancient groups of living birds. They are ground dwellers, ranging in size from a few ounces to about 5 pounds, and are found in Central and South America.

Most birds in the order **Struthioniformes**, including the elephant bird, are now extinct, but the surviving species of ratites form a rather diverse group of flightless birds, which can found on three continents. How these few remaining species ended up in Africa, South America and Australia/New Zealand apparently stems from the break-up of the prehistoric landmass, *Gondwana*. **Ratites** get their name because they have no keel on their flat, scoop-like sternum, which makes it resemble a raft, or in Latin "ratis."

Order	Family	Name	Genus Species	Native To
Struthioniformes (Ratites)	Struthionidae	ostrich	<i>Struthio camelus</i>	Africa
	Rheidae	rhea	<i>Rhea</i> (2 species)	South America
	Casuariidae	cassowary	<i>Casuaris</i> (3 species)	New Guinea/Australia
	Dromaiidae	emu	<i>Dromaius novaehollandiae</i>	Australia
	Apterygidae	kiwi	<i>Apteryx</i> (5 species)	New Zealand
Tinamiformes	Tinamidae	tinamous	9 genera, 47 species	Central & South America

Figure 1-2. Modern-day Struthionioformes (Ratites). Extinct families are not included.

The African **ostrich** (*Struthio camelus*) is the largest living bird, with some adult males weighing in at over 300 lbs. and standing more than 9 feet tall (Fig. 1-3). Ostriches, which may live to be 40-45 years old, are also the fastest running birds, being able to reach speeds greater than 40 miles per hour. The ostrich is important to veterinarians because of its **commercial value** in terms of meat, skin, and feathers. Adult males are easily distinguished from

females by their mostly black feathers with white feathers on the wings and tail. Females and immature males are grayish-brown and white.

Unlike most birds, the urates and fecal material of the ostrich do not mix in the cloaca. The fecal matter is retained in the coprodeum and does not mix with the urates, which enter the urodeum. Ostriches retain two claws on their wings, one on the alula

(digit 1) and another on the major digit (digit 2). The foot of the ostrich is also unique in that it has only two digits (Fig. 1-4). The larger digit (digit 3) has a claw, while the smaller digit (digit 4) does not.



Figure 1-3. Male ostrich. (Photo courtesy: animals.howstuffworks.com).



Figure 1-4. Ostrich foot. (Photo courtesy: http://en.wikipedia.org/wiki/File:Ostrich_foot).

The second tallest, but not heaviest, living bird is the Australian **emu** (*Dromaius*

novaeollandiae), which may reach a height of over 6 feet, and may weigh more than 100 lbs. (Fig. 1-5). Although not as fast as ostriches, emus can travel great distances at a fast trot and can reach speeds of about 30 miles an hour.



Figure 1-5. Adult emu. (Photo courtesy: <http://en.wikipedia.org/wiki/Emu>)

Males and females look alike, but the two can be distinguished by differences in the sounds they produce. Emus can alter these sounds by manipulating an inflatable sac associated with their cervical trachea. This **tracheal sac** is of importance when using gas anesthesia in the emu. Emus can live to be about 20 years old in the wild. Although not as extensively farmed as the ostrich, emus are **raised commercially** for their meat, oil, and leather. The emu is a cultural icon in Australia.

The South American **rhea** is slightly smaller than the emu and there are two recognized species- the lesser or Darwin's rhea and the greater or **American rhea** (Fig. 1-6). Adult male greater rheas may be up to 5.5 ft. tall and weigh in at about 85 lbs.



Figure 1-6. Adult American rhea (*Rhea americana*). (Photo courtesy: <http://en.wikipedia.org/wiki/Rhea>)

Rheas have 3 pelvic digits and large wings for a ratite. When running, they spread their wings, which may help with some “lift.” Like the ostrich, the rhea does not mix the urates and fecal matter in their cloaca. They do not have as much commercial value as the ostrich or emu; however, their meat and feathers are used.

Another large ratite is the **cassowary**, of which there are 3 species, all native to the tropical forests of New Guinea, nearby islands, and northeastern Australia. The cassowary is second only to the ostrich in terms of body weight, with females being larger and more brightly colored than males.

An adult female **southern cassowary** may weigh in at more than 125 lbs (Fig. 1-7). Cassowaries do not have rectrices (tail feathers) and lack a uropygial (preen) gland. Like the ostrich, the cassowary retains a claw on the primary digit of the wing. Cassowaries have heavy, powerful legs with 3 digits and sharp claws. The claw of digit 2 is dagger-like and about 5 inches long (Fig. 1-8).

Caution to zoo veterinarians: Cassowaries are **very dangerous birds**, capable of inflicting serious bodily injury. Cassowaries can run about 30 mph and can jump almost 5 ft. high. They can live up to 50 years.



Figure 1-7. Adult southern cassowary (*Casuarius casuarius*). (Photo courtesy: <http://en.wikipedia.org/wiki/Cassowary>)



Figure 1-8. Adult southern cassowary (*Casuarius casuarius*): arrows indicate dagger-like claw of digit 2. (Photo courtesy: <http://en.wikipedia.org/wiki/Cassowary>).

The smallest of the living ratites is the **kiwi**, which is the national symbol of New Zealand (Fig. 1-9). The kiwi is about the size of a domestic chicken and there are 5 recognized species. Kiwis are mostly nocturnal, and their single egg per season is the largest relative to body size of any bird (about 5 times the size of a chicken egg). It takes the female about 30 days of hard work

to produce a single egg. Unlike most birds, kiwis have two functional ovaries, a **keen sense of smell**, and their nostrils are at the tip of their upper beak.



Figure 1-9. Adult southern brown kiwi (*Apteryx australis*). (Photo courtesy: <http://en.wikipedia.org/wiki/Kiwi>)

Neognathae (new jaw) is where most of our modern birds are found. Neognathae is divided into 27 orders and about 10,000 species. Although other orders are of some interest, as veterinarians, our primary attention will be focused on the orders **Anseriformes** (ducks, geese, and swans), **Galliformes** (chicken, turkey, pheasants, quails, etc.), **Psittaciformes** (parrots), **Passeriformes** (sparrows, canaries, finches, and a total of about 5000 species), **Sphenisciformes** (penguins), **Falconiformes** (falcons, eagles, hawks, etc.), **Columbiformes** (pigeons and doves), and **Strigiformes** (owls).

The order **Anseriformes** contains about 150 living species of birds in three families (Fig. 1-12). By far the largest family is **Anatidae**, which includes 40 genera and over 140 species of ducks, geese, and swans. Anatidae can be found on every continent except Antarctica and on practically every island on the planet. Anatidae vary in size from the tiny cotton pigmy goose (≈ 6 oz) to the trumpeter swan, weighing in at up to 38 lbs.

The genus *Cygnus* includes 6 or 7 species of swans, which are the largest members of Anatidae. The trumpeter swan (*Cygnus buccinator*) is the largest living species of waterfowl (Fig. 1-10).



Figure 1-10. Adult trumpeter swan (*Cygnus buccinator*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Tumpeter>)

The genus *Anser* includes the grey geese and some white geese. Wild species of geese have been domesticated, primarily for meat or their fattened liver (*foie gras*), which is a popular food in some European countries. There are many breeds of domestic geese (Fig. 1-11), and some breeds (viz., pilgrim goose) can be sexed by their color, with ganders being white and females being grey.



Figure 1-11. Domesticated greylag goose (*Anser anser*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Domesticated_greylag_goose)

Order	Family	Name	Genus Species
Anseriformes	Anhimidae	screamers	2 genera; 3 species
		magpie goose	<i>Anseranas semipalmata</i>
	Anseranatidae	whistling ducks	<i>Dendrocygna</i> (8 species)
		white-backed duck	<i>Thalassornis leuconotus</i>
		swans	<i>Cygnus</i> (6 species)
		grey geese	<i>Anser</i> (10 species)
		white geese	<i>Chen</i> (3 species)
		black geese	<i>Branta</i> (7 species including Canadas)
		freckled duck	<i>Stictonetta naevosa</i>
		spur-winged goose	<i>Plectropterus gambensis</i>
		Egyptian goose	<i>Alopochen aegyptiacus</i>
		shelducks	<i>Tadorna</i> (7 species)
		Salvadori's duck	<i>Salvadorina waigiensis</i>
		Cape Barren goose	<i>Cereopsis novaehollandiae</i>
		Orinoco goose	<i>Neochen jubata</i>
		sheldgeese	<i>Chloephaga</i> (5 species)
		blue duck	<i>Hymenolaimus malacorhynchos</i>
		torrent duck	<i>Merganetta armata</i>
		dabbling ducks	<i>Anas</i> (40+ species including mallards)
		crested duck	<i>Lophonetta specularioides</i>
		bronze-winged duck	<i>Specularia specularis</i>
		Brazilian duck	<i>Amazonetta brasiliensis</i>
		some pochards	<i>Netta</i> (3 species)
		some pochards, scaups	<i>Aythya</i> (12 species)
	Anatidae	Steller's eider	<i>Polysticta steller</i>
		other eiders	<i>Somateria</i> (3 species)
		harlequin duck	<i>Histrionicus histrionicus</i>
		scoters	<i>Melanitta</i> (5 species)
		long-tailed duck	<i>Clangula hyemalis</i>
		goldeneyes	<i>Bucephala</i> (3 species)
		smew	<i>Mergellus albellus</i>
		hooded merganser	<i>Lophodytes cucullatus</i>
		typical mergansers	<i>Mergus</i> (4 species)
		stiff-tailed ducks	<i>Oxyura</i> (5 species)
		masked duck	<i>Nomonyx dominicus</i>
		Australian musk duck	<i>Biziura lobata</i>
		black-headed duck	<i>Heteronetta atricapilla</i>
		Coscoroba swan	<i>Coscoroba coscoroba</i>
		pink-eared duck	<i>Malacorhynchus membranaceus</i>
		knob-billed duck	<i>Sarkidiornis melanotos</i>
		steamer ducks	<i>Tachyeres</i> (4 species)
		blue-winged goose	<i>Cyanochen cyanoptera</i>
		pygmy geese	<i>Nettapus</i> (3 species)
		Hartlaub's duck	<i>Pteronetta hartlaubii</i>
		Muscovy duck	<i>Cairina moschata</i>
		wood & Mandarin ducks	<i>Aix</i> (2 species)
		ringed teal	<i>Callonetta leucophrys</i>
		Australian wood duck	<i>Chenonetta jubata</i>
		marbled duck	<i>Marmaronetta angustirostris</i>

Figure 1-12. Modern-day Anseriformes. By far the largest family is Anatidae, which contains more than 140 species of ducks, geese, and swans. Extinct families are not included.

Order	Family	Name	Genus Species
Galliformes	Megapodiidae (mound builders)	maleo Moluccan megapode scrubfowl malleefowl brushturkeys	<i>Macrocephalon maleo</i> <i>Eulipoa wallacei</i> <i>Megapodius</i> (13 species) <i>Leipoa ocellata</i> 3 genera; 6 species
		highland guan sickle-winged & black guans typical guans wattled guan piping guans chachalacas horned guan nocturnal curassow curassows curassows helmeted & horned curassows	<i>Penelopina nigra</i> <i>Chamaepetes</i> (2 species) <i>Penelope</i> (15 species) <i>Aburria aburri</i> <i>Pipile</i> (4 species) <i>Ortalis</i> (13 species) <i>Oreophasis derbianus</i> <i>Nothocrax urumutum</i> <i>Crax</i> (7 species) <i>Mitu</i> (4 species) <i>Pauxi</i> (2 species)
	Cracidae	various partridge species mountain quail quail banded quail bobwhite quail wood quail singing quail Montezuma & ocellated quail tawny-faced quail	<i>Dendrortyx</i> (3 species) <i>Oreortyx pictus</i> <i>Callipepla</i> (4 species) <i>Philortyx fasciatus</i> <i>Colinus</i> (4 species) <i>Odontophorus</i> (15 species) <i>Dactylortyx thoracicus</i> <i>Cyrtonyx</i> (2 species) <i>Rhynchortyx cinctus</i>
		Odontophoridae (new world quail)	
	Numididae (guineafowl)	white-breasted & black guineafowl helmeted guineafowl plumed & crested guineafowl vulturine guineafowl	<i>Agelastes</i> (2 species) <i>Numida meleagris</i> <i>Guttera</i> (2 species) <i>Acryllium vulturinum</i>
		Numididae (guineafowl)	
Galliformes	Phasianidae	wild & domestic turkey ocellated turkey stone & Nahan's partridges various partridge species see-see & sand partridges snow mountains quail various partridge species bamboo partridges ferruginous partridge various quail species crested francolin various francolin species spurfowl crimson-headed partridge snow partridge Madagascar partridge black partridge various francolin species bush quail various partridge species various francolins & spurfowl long-billed & Hose's partridges crested partridge	<i>Meleagris gallopavo</i> <i>Meleagris ocellata</i> <i>Ptilopachus</i> (2 species) <i>Alectoris</i> (7 species) <i>Ammoperdix</i> (2 species) <i>Anurophasis monorthonyx</i> <i>Arborophila</i> (21 species) <i>Bambusicola</i> (2 species) <i>Caloperdix oculeus</i> <i>Coturnix</i> (8 species) <i>Dendroperdix sephaena</i> <i>Francolinus</i> (5 species) <i>Galloperdix</i> (3 species) <i>Haematortyx sanguiniceps</i> <i>Lerwa lerwa</i> <i>Margaroperdix madagascariensis</i> <i>Melanoperdix niger</i> <i>Peliperdix</i> (4 species) <i>Perdicula</i> (4 species) <i>Perdix</i> (3 species) <i>Pternistis</i> (23 species) <i>Rhizothera</i> <i>Rollulus rouloul</i>
		Phasianidae	

Figure 1-13. Modern-day Galliformes (continued on next page). Extinct families are not included.

Order	Family	Name	Genus Species
Galliformes (continued)		various francolin species	<i>Scleroptila</i> (7 species)
		forest partridges	<i>Xenoperdix</i> (2 species)
	Phasianidae (continued)	snowcocks	<i>Tetraogallus</i> (5 species)
		monal-partridges	<i>Tetraophasis</i> (2 species)
		Koklass pheasant	<i>Pucrasia macrolopha</i>
		blood pheasant	<i>Ithaginis cruentus</i>
		tragopans	<i>Tragopan</i> (5 species)
		monals	<i>Lophophorus</i> (3 species)
		junglefowl (domestic chicken)	<i>Gallus</i> (4 species)
		gallopheasants	<i>Lophura</i> (12 species)
		eared pheasants	<i>Crossoptilon</i> (4 species)
		cheer pheasant	<i>Catreus wallichi</i>
		long-tailed pheasants	<i>Syrmaticus</i> (5 species)
		common & green pheasants	<i>Phasianus</i> (2 species)
		ruffed pheasants	<i>Chrysolophus</i> (2 species)
		peacock pheasants	<i>Polyplectron</i> (8 species)
		crested argus	<i>Rheinartia ocellata</i>
		great & double-banded argus	<i>Argusianus</i> (2 species)
		Indian & green peafowl	<i>Pavo</i> (2 species)
		Congo peafowl	<i>Afropavo congensis</i>

Figure 1-13. Modern-day Galliformes (continued from previous page). Extinct families are not included.

The genus *Branta* consists of 7 species of black geese, including the **Canada goose** (*Branta canadensis*). These geese have black bills and mostly black feet and legs. Canada geese are native to North America, and although they typically migrate, many flocks have now become “permanent” residents in various areas of the United States, including the triangle area of North Carolina. These populations have grown so large that they are now considered pests because of their droppings (Fig. 1-14).

There are only 3 species of wild white geese in the genus *Chen*. White geese are native to North America, breeding in the subarctic and migrating south in the winter. The most familiar of these is the **snow goose**, *Chen caerulescens* (Fig. 1-15). You should know that not all snow geese are white because there are two versions— the white (snow) version and a grayish-blue variant. The blue variant has bluish-grey feathers replacing the white ones, except on their head and tip of their tail. Both types

have reddish feet and legs, and pink bills except for the cutting edges or tomia, which are black. The two variants flock and migrate together, and will interbreed with one another.



Figure 1-14. Canada geese (*Branta canadensis*) grazing and pooping in my backyard.

What about those white farm geese we see? Well, there is no doubt that these geese are white, and that they are a common type of domestic goose. However, these domestic geese are actually grey geese,

which have been derived from either the greylag goose (Fig. 1-11) or the swan goose. One domesticated descendent of the greylag goose is the **Embden goose** (Fig. 1-16). This is a fast growing breed of European domestic goose, with geese reaching 20 lbs. and ganders reaching 30 lbs. by about 2 years of age.



Figure 1-15. Snow geese (*Chen caerulescens*). This is the more familiar white variant, but there is also a blue variant. (Photo courtesy: http://en.wikipedia.org/wiki/File:Anser_caerulescens).



Figure 1-16. Embden goose (*Anser anser domesticus*). (Photo courtesy: http://en.wikipedia.org/wiki/Domestic_geese).

Another common breed of farm goose is the **Chinese goose** (Fig. 1-17), which is a descendent of the wild swan goose (*Anser cygnoides*). These geese can be easily distinguished from the European geese by the large, knob-like protuberance over their bill, which is typically larger in the gander (Fig. 1-18).

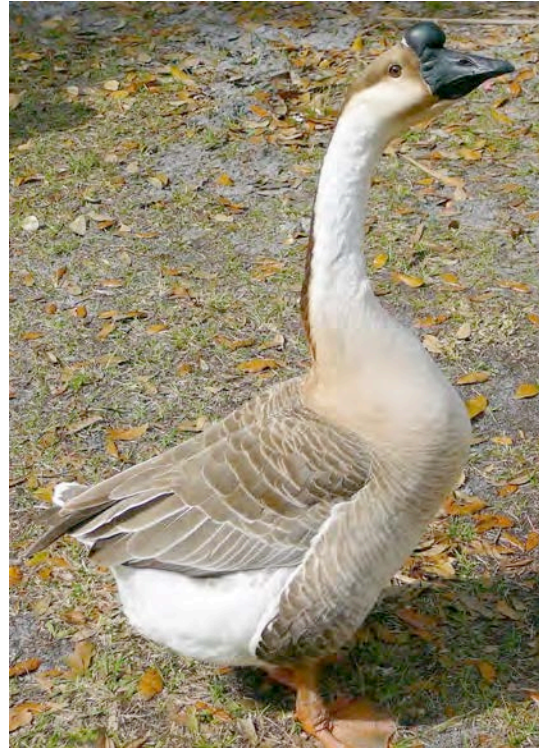


Figure 1-17. Chinese goose (*Anser cygnoides*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Anser_cygnoides).



Figure 1-18. Head of white Chinese gander (*Anser cygnoides*). (Photo courtesy: http://en.wikipedia.org/wiki/Domestic_geese).

The genus *Anas* consists of more than 40 species of “dabbling ducks,” including mallards, wigeons, teals, pintails, and shovelers. **Mallards** (*Anas platyrhynchos*) are a common species in the United States (Fig. 1-19). Most domestic duck breeds, of which there are many, have been derived from the mallard. One of these mallard-descent breeds is the **Pekin** or Long Island **duck**, which was originally domesticated in China—thus the name “Pekin” (Fig. 1-20).

From just nine ducks originally imported from China to Long Island, NY in 1873, the Pekin duck has become by far the most popular commercial duck in the US. Pekin ducks account for more than 90% of all ducks raised for meat and eggs. Male and female Peking hatchlings look alike, but can be distinguished by “vent-sexing.” As the hatchlings mature, the drakes acquire a curled tail feather and their quack becomes softer; the females lack this curled “drake feather,” and their quack becomes stronger. This vocal change is typical of many duck species, and there may be an anatomic reason why the quack of the mature male is softened or muted. More on this when we examine the respiratory system of ducks.



Figure 1-19. Adult mallard drake (top) and hen (bottom). Photos made in Raleigh, NC.

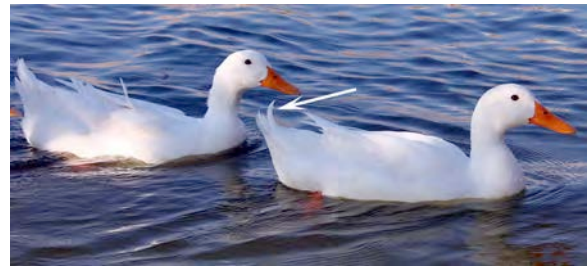


Figure 1-20. Pekin or Long Island ducks (*Anas platyrhynchos domestica*). The drake (right) can be distinguished from the hen (left) by his “drake feather” (arrow). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Barvas>).

There is one type of common domestic duck that is not a member of the genus *Anas* and that is the **Muscovy duck** (*Cairina moschata*). Although the term “Muscovy” suggests some connection to Moscow, this large duck is native to Mexico, and South and Central America, and a feral population still exists along the Rio Grande and in other locations. These ducks have been kept and bred by Native Americans since before Columbus arrived in the Americas, and even though they were later imported to Europe, there is some debate as to how they became known as “Muscovies.”

Males, which may weigh up to 15 lbs., are twice the size of females (≈ 7 lbs). Both sexes have reddish caruncles forming a sort of “facial mask” around their eyes and the base of their bill. The facial mask of the male is more colorful and prominent (Fig. 1-21).

Although this is the only species in the genus *Cairina*, there are two subspecies. *Cairina moschata sylvestris* is used for the wild form and *Cairina moschata domestica* is used to describe the domesticated version, which is also known by several common names—the “creole duck” or the “mute duck.” The latter designation comes from the fact that these ducks don’t really “quack.” Females are more vocal and make

a sort of “thrill” sound, while males make more of a “hissing” sound, often accompanied by “tail-wagging.” Their relative silence might be one reason why Muscovies are often kept as “backyard” ducks. These ducks are raised for meat, and in the culinary sense are referred to as “Barbary duck.”



Figure 1-21. Muscovy ducks (*Cairina moschata domestica*). The male (left) is much larger than the female (right), and these domestic ducks are heavier than their closely related wild cousins. (Photo courtesy: http://en.wikipedia.org/wiki/File:Cairina_moschata).

The order **Galliformes** consists of about 290 species, which are distributed across most continents except for deserts, oceanic islands, and extremely cold regions. Galliformes contains five families of which **Phasianidae** (chicken, quail, partridges, pheasants, turkeys, and grouse) is the largest (Fig. 1-13).

Members of **Megapodiidae** are known as “mound builders” and are heavy-bodied, chicken-like birds with small heads and big feet. There are about 20 species distributed in and around Australia, including Fiji. Rather than incubating their eggs with their own body heat, they construct large nesting mounds of decaying vegetation (Fig. 1-22). This method of incubation is similar to that of the alligator, and in at least some megapodes, temperature has been shown to affect the sex ratio of the hatchlings.



Figure 1-22. Australian brushturkey (*Alectura lathami*) on incubation mound of decaying vegetation. (Photo courtesy: <http://en.wikipedia.org/wiki/Megapode>).

The family **Cracidae** contains chachalacas, guans, and curassows. Cracids are typically large turkey-like birds. The guans and curassows live in trees, while the smaller chachalacas prefer more open scrubby areas. Cracids are found primarily in Central and South America.

Odontophoridae consist of 9 genera and some 32 species of New World quail ranging from Canada through southern Brazil. There are 22 subspecies of the northern **bobwhite quail** (Fig. 1-23), which is a popular game species in the US.



Figure 1-23. Northern bobwhite quail male (*Colinus virginianus*). (Photo courtesy: http://en.wikipedia.org/wiki/Northern_Bobwhite).

Bobwhites are raised in captivity in the US for purposes of future release for hunting. In the wild they travel, mostly on the ground, in groups known as “coveys.” Here is where a good pointer or setter comes in to “point” or locate the covey prior to “flushing” them. When the covey flushes, you have a good example of an *auditory reflex* in that it is almost impossible not to be startled and jump when they take off. **Hint for hunters-** wait until they level off before you shoot.

Numididae is the family of galliformes known as guineafowl or guineahens. Guinea fowl are native to Africa, but the **helmeted guineafowl** (Fig. 1-24) has been domesticated and distributed to many areas including the US. Domestic variants of the wild guineafowl come in two colors-speckled and white, and are commonly kept as barnyard birds for meat. Guineas are really good “watchdogs” in that they make a lot of racket when any intruder (fox, coyote, raccoon) comes around the barnyard. They are also good at finding and eating a large number of ticks, which otherwise would be available to spread diseases such as Lyme disease.



Figure 1-24. Helmeted guineafowl (*Numida meleagris*). This is the speckled or more native variant, but we also have white domestic guineas. (Photo courtesy: http://en.wikipedia.org/wiki/File:Numida_meleagris).

By far the largest family of galliformes is **Phasianidae**, containing more than 150

species, including the red junglefowl, turkeys, grouse, pheasants, partridges, Old World quail, and peafowl.

The **red junglefowl** (*Gallus gallus*) is the principal (if not the only) ancestor of the domestic chicken, and was originally domesticated in Asia more than 5000 years ago. The cock (rooster) is much larger than the hen, and is brightly colored (Fig. 1-25). The hen is much less impressive (Fig. 1-26), with a more muted color for camouflage, especially when she is on the nest.



Figure 1-25. Red junglefowl cock (*Gallus gallus*). (Photo by Wameng Chue).



Figure 1-26. Red junglefowl hen (*Gallus gallus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Gallus_gallus).

The **domestic chicken** has been selectively bred for many years, and hundreds of breeds have been developed and crossed with other breeds. We will consider just a few of the many breeds raised in the United States.

Some of the more popular breeds raised in the US are the white leghorn, the Cornish, the Plymouth Rock, the buff orpington, the Rhode Island Red, the cochin, the Wyandotte, the Australorp, the silkie, and the Dominique. Some of these breeds are considered dual-purpose breeds, which means they are raised for both eggs and meat, but almost all commercial chickens are highly-specialized and consist of hybridized lines of birds that are bred exclusively for one purpose or the other.

Nearly all the eggs you find in American grocery stores come from genetically selected **commercial layers**. The foundation breed for modern layers is the **leghorn**, which originated in the Tuscany region of Italy, and was imported into the US in 1828. In fact, the English word “leghorn” is a translation of the Italian “Livorno,” which was the port city from which the original birds were exported to the US.

Although there are numerous variants of the leghorn breed, the **white leghorn** (Fig. 1-27) has been selected as the most prolific layer. These hens can produce more than 300 eggs per year, and have an excellent feed-to-egg production ratio. Major poultry companies, both for layers and broilers, are continually experimenting with the genetics in these birds, and they employ nutritionists to develop the most efficient diets.

Commercial broiler production is equally, if not more, specialized. The foundation breeds for the now highly

selected broiler birds are the Cornish (Fig. 1-28) and Plymouth Rock (Fig. 1-29) breeds. This “cornish-rock” crossbreeding was initiated in the 1930s, and initially was plagued with problems of low fertility, slow growth-rates, and disease susceptibility. However, through diligence selective breeding and improvements in husbandry and nutrition, the modern meat bird (Fig 1-30) is a far cry from those early hybrids.



Figure 1-27. White leghorn hen (*Gallus gallus domesticus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:ARS-White_Leghorn_hen).

In fact, modern-day broiler production is one of the most efficient operations I can think of for any industry. It is truly amazing how they can produce such high-quality protein in the form of chicken for such a relatively low price. And this didn’t happen by accident. It was the result of industry

specialists collaborating with faculty at major research universities like NC State, and the implementation of vertical integration into the broiler production industry. Due to their high feed conversion ratio, today's broilers can reach a dressed slaughter weight of 4-5 lbs. in less than 5 weeks. Truly remarkable!!



Figure 1-28. Dark cornish hen (*Gallus gallus domesticus*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:DkCornishHen>).



Figure 1-29. White Plymouth rock pullet. (*Gallus gallus domesticus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:First_Root_Farm_chicken).



Figure 1-30. Modern-day broiler (*Gallus gallus domesticus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Poultry_Classes_Blog_photo_-_Flickr_-_USDAgov).

One of the more popular “backyard” chicken breeds is the **buff orpington** (Fig. 1-31). This English breed is popular because it is both an excellent layer, and is a good-quality meat bird. There is also a bantam variety of the buff orpington, and there are several other colors of the orpington.

Another of these “dual purpose” breeds is the **Rhode Island Red** (Fig. 1-32). This breed was developed in Rhode Island and Massachusetts, and these hardy birds are good layers. There are at least 3 varieties: Asiatics, Game, and Mediterranean. Although usually friendly, these birds can be quite aggressive toward people, and especially toward other breeds when kept together in the same coup.



Figure 1-31. Buff orpington hen (*Gallus gallus domesticus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Buff_Orpington).



Figure 1-32. Rhode Island Red rooster (*Gallus gallus domesticus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Rhode_Island_Red_rooster).

The **cochin** breed of chicken became very popular in the US after its importation from China in about 1845. Cochins are large birds, with roosters commonly weighing 11 lbs. (Fig. 1-33) and hens weighing about 7 lbs. There are numerous color patterns of cochins, including buff, black, silver-laced, blue, golden-laced, and white. These birds have fully feathered legs, and there is a bantam variety of this breed.



Figure 1-33. Cochin rooster (*Gallus gallus domesticus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Imposing_chicken).

The **Wyandotte** is another dual-purpose breed known for their pale brown or tan eggs. This breed, which originated in the US, comes in 17 colors, with the silver-laced being the original pattern (Fig. 1-34). They typically have white feathers on their neck, with a rose comb and no feathers on their legs. There is also a bantam variety.

Originating in Australia, the **Australorp** is a large, hardy breed with black legs and beak, but with white claws (nails). They have a single comb with 5 distinct points. Australorps come in both standard and bantam varieties, and two or three colors including black and blue. The black Australorp (Fig. 1-35) is the most common, having glossy black feathers with a greenish sheen.

One of the more unusual backyard breeds is the **silkie** (Fig. 1-36). Silkies have a very fluffy plumage, dark flesh and bones, blue earlobes, and 5 pelvic digits rather than 4. They have feathers all the way down to

their feet, and silkies come in several colors. Although generally considered to have come from China, there seems to be some debate that they may have originated in Southeast Asia.

Most US strains are of the bantam size, but in Europe the somewhat larger version is common. Even the large version, however, is not very large with roosters weighing about 4 lbs. and hens about 3. The fluffy nature of the silkie is due to the lack of barbules on their feathers. And without the barbules to stiffen their feathers, silkies are essentially unable to fly.

Silkies are one of the most popular “ornamental” breeds of chicken, and because of their docile nature are often kept as pets. And, because they are so “broody,” silkies have been used to incubate the eggs of waterfowl and other game fowl such as quails and pheasants.



Figure 1-34. Silver-laced Wyandotte hens (*Gallus gallus domesticus*). Note the rose comb and small wattles. (Photo courtesy: http://en.wikipedia.org/wiki/File:Silver_Laced_trio).



Figure 1-35. Black Australorp rooster (*Gallus gallus domesticus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Australorp_Rooster).



Figure 1-36. Bantam white silkie hen (*Gallus gallus domesticus*). Note the blue earlobe (arrow); some silkies lay blue-tinted eggs. (Photo courtesy: http://en.wikipedia.org/wiki/File:Silky_bantam).

Also among the many so-called “heritage breeds” of chickens is the **Dominique** (Fig. 1-37). This breed is thought to be the oldest of the American breeds, and is likely the descendent of chickens brought over from England by the

American pilgrims. In fact, it is sometimes referred to as the “Pilgrim fowl” and by the name “dominicker,” which is what we called them when I was growing up on the farm. In colonial times, their feathers were used as stuffing for pillows and mattresses.



Figure 1-37. Young Dominique (*Gallus gallus domesticus*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:DominiqueCockZeus>).

Dominiques have quite a distinctive look with their rose comb and black-and-white “barred” feathers. These are very hardy, fast-maturing birds that begin to lay at about six months of age. We could go on and on with many more heritage breeds of farmyard chickens, but let’s stop here and get back to other galliformes.

The wild turkey is native to North America, and the domestic turkey is a descendent of a south Mexican subspecies of the **wild turkey**, *Meleagris gallopavo* (Fig. 1-38), which was originally domesticated by the Aztecs. These “tame” turkeys were brought back to Spain in the mid-16th century, and from there the bird was imported to France and Britain. By 1620, the “domestic turkey” was brought back to the US by the pilgrims, not knowing that it had a larger cousin already plentiful in the forests of Massachusetts.

As you may know, Benjamin Franklin wanted the wild turkey to become our nation’s national symbol rather than the bald eagle. Although he never made a public issue of it, Franklin considered the bald eagle to be “*a bird of bad moral character*” because it often stole fish from the hard-working osprey. The wild turkey played a major role in the culture of the Eastern tribes of Native Americans. They prized the bird for both its meat and eggs, and even cleared some forests to make meadows for them (and to provide for a better shot of course).



Figure 1-38. Wild turkey gobbler (*Meleagris gallopavo*). The beard (arrow) of the gobbler is the trophy of the turkey hunter. (Photo courtesy: <http://en.wikipedia.org/wiki/File:Gall-dindi>).

The wild turkey is an example of how game management can be successful. By the 1940s, due to excessive hunting and loss of habitat, the wild turkey had virtually disappeared from Canada, and was reduced to as low as 30,000 birds in the US. Thanks to efforts by game officials and hunters, birds were bred in protected areas. By the 1970s, numbers had rebounded to about 1.3

million, and today's (2012) estimates place the US wild turkey population at about 7 million.

Male turkeys are known as “gobblers” or “toms,” while females are called hens, and young turkeys are called poults. The tom has a more elaborate decoration on its head, including the snood, the dewlap, and caruncles (Fig. 1-39). The “prize” of today's turkey hunter is the “beard,” a tuft of coarse hair-like feathers growing from the center of the breast of the gobbler (Fig. 1-38). Some hens also have a beard, but it is smaller and thinner than that of the gobbler.

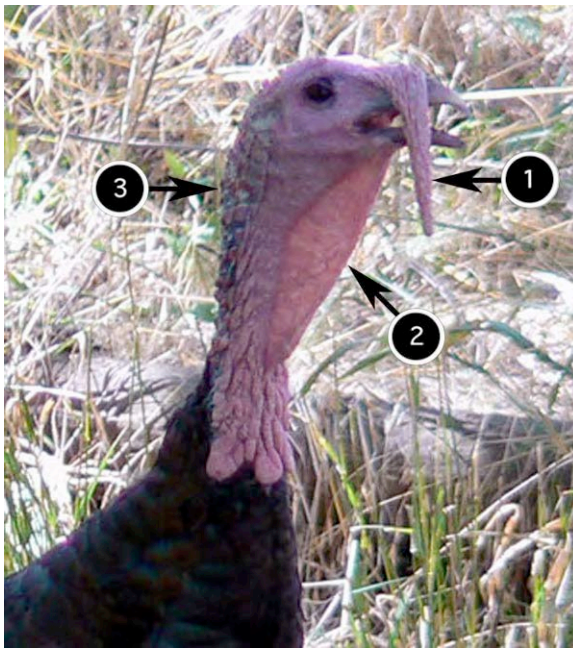


Figure 1-39. Wild turkey gobbler (*Meleagris gallopavo*): (1) snood; (2) dewlap; (3) caruncles. (Photo courtesy: http://en.wikipedia.org/wiki/File:Meleagris_gallopavo_Wild_Turkey).

The native color of the wild turkey is bronze (Fig. 1-38), and gobblers are more colorful than hens. Wild gobblers can reach a weight of nearly 25 lbs; hens are much smaller and only grow to about 10-12 lbs. So how does the modern domestic turkey differ from its wild ancestor?

Much like the situation with our modern broiler chickens, the modern meat-turkey has resulted from many generations of careful selection (genetics) for rapid and efficient weight gain. Although some bronze turkeys are still raised, most **commercially produced turkeys** are now white because their small pinfeathers (new replacement feathers) are less visible on the dressed carcass (Fig. 1-40).



Figure 1-40. A commercial flock of broad-breasted white turkeys (*Meleagris gallopavo*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Turkeys>).

Although numerous heritage breeds are still raised for meat, almost all commercially produced turkeys in the US are **broad-breasted whites** (Figs. 1-40 & 41). The broad-breasted white is not really a breed of turkey, but much like the cornish-rock of the broiler world, is a **hybrid** resulting from crossing the White Holland and the broad-breasted bronze.

These hybrids have very large breasts, and the toms can weigh in excess of 50 lbs. Because they are so large, with short, widely spaced legs, they are not able to breed the hens naturally. Most hens are **inseminated artificially**. Remarkably, breast meat makes up about 73% of the carcass yield, with only 1% fat. The broad-breasted white hybrid was developed to grow faster than pure varieties and to have an excellent feed-meat conversion ratio. With nutritionists focusing

on the best diets, and geneticists focusing on the best bird, the broad-breasted white may reach 13 lbs. by 10 weeks of age.



Figure 1-41. Head & neck of a broad-breasted white tom (*Meleagris gallopavo*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Large_White_turkey_male).

Most **pheasants** originated in Asia. Although there are many types of pheasants, the one we are most familiar with is the common or **ring-necked pheasant**, which is in the genus *Phasianus*. There are, however, numerous subspecies, and there has been substantial **hybridization** since introduction to Europe and the US, where it has become a popular game bird (Figs. 1-42 & 43).

In fact, many hybrids are crosses between the common pheasant and the green pheasant from Japan. Originally introduced to the US in 1881, these birds are now bred to be hunted, especially in the Great Plains states. South Dakota alone has an annual harvest of over a million birds a year.

Pheasant farms have some 10 million birds in the US and 35 million in the UK.



Figure 1-42. Male (cock) ring-necked pheasant hybrid (*Phasianus colchicus*). (Photo courtesy: [http://en.wikipedia.org/wiki/File:Phasianus_colchicus_2_tom_\(Lukasz_Lukasik\)](http://en.wikipedia.org/wiki/File:Phasianus_colchicus_2_tom_(Lukasz_Lukasik))).



Figure 1-43. Female (hen) ring-necked pheasant hybrid (*Phasianus colchicus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Phasianus_colchicus_-_Rutland_Water_-female-8).

Peafowl, originally from Asia, are also in the pheasant family. There are two species in the genus, *Pavo*— the Indian peafowl (*Pavo cristatus*) (Fig. 1-44) and the green peafowl (*Pavo muticus*) (Fig. 1-45). There is also a Congo peafowl, but it is not common in the US. The male is known as a peacock, while the female is called a peahen. Contrary to what you might think, the elongated fan feathers of the peacock are not the retrices (primary flight feathers of tail), but are highly-modified covert feathers.



Figure 1-44. Male (cock) Indian peafowl (*Pavo cristatus*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Paonroue>).



Figure 1-45. Male (cock) green peafowl (*Pavo muticus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Siamese_Dragon).

When the peacock fans its tail, the “eyes” of the specialized tail feathers are displayed, and the fan actually helps direct sound to its ears. There are several color mutations of Indian peafowl, which have been produced by selective breeding in captivity.

One mutant variety of the Indian peafowl is the white peafowl (Fig. 1-46). These birds are not albinos, but represent an example of **leucism**. Unlike *albinism*, where only the melanin-producing cells are affected, leucism affects all pigment-producing-cells. In leucistic phenotypes, the eyes are not typically affected so the animal does not have the characteristic “red” eye of the albino (Fig. 1-46).



Figure 1-46. Male (cock) white mutation of Indian peafowl (*Pavo cristatus*). Note dark eyes. (Photo courtesy: http://en.wikipedia.org/wiki/File:Indian_peafowl_white_mutation).

Peafowl are commonly kept as back yard or farm yard birds, and like guineafowl; peafowl can serve as “watchdogs.” Both cocks and hens vocalize with several different “alarm calls.”

The order **psittaciformes** consists of more than 370 species of parrots (Fig. 1-52). The so-called true parrots are in the family **psittacidae**, the cockatoos are in the family **cacatuidae**, and the New Zealand parrots are in the families **Nestoridae** and **Strigopidae**. One of the anatomical features of parrots is that they have **zygodactyl feet** (2 toes forward & 2 toes back). This design, which is an adaptation for clinging to a vertical surface, is not unique to parrots, and is also seen in woodpeckers, cuckoos, and some owls. Most parrot species show little to no sexual dimorphism, but there are exceptions. Parrots are found mostly in tropical or subtropical regions, but some have explored into more temperate zones.

The family **cacatuidae** consists of 21 species of cockatoos, most of which originate in and around Australia, including the Philippines, Solomon Islands, and New Guinea. The most characteristic feature of a cockatoo is the crest, and with the exception

of the cockatiel, most cockatoos are rather large parrots. The genus, *Calyptorhynchus* contains 5 species of black cockatoos, including the red tailed cockatoo (Fig. 1-47).



Figure 1-47. Red-tailed black cockatoo (*Calyptorhynchus banksii*). (Photo courtesy: [http://en.wikipedia.org/wiki/File:RedTailedBlackCockatoo_\(Redphoenix\).](http://en.wikipedia.org/wiki/File:RedTailedBlackCockatoo_(Redphoenix).))

Within the genus, *Cacatua*, are 11 species of mostly white-feathered cockatoos, with a few variations toward pink and grey. There is even one grayish-black cockatoo in this genus. One of the favorite members of this group is the white (umbrella) cockatoo (Fig. 1-48), which originated in Indonesia. Although mostly white, these birds have some yellow on the ventral surface of their primary and secondary flight feathers.

One reason these parrots are favored as pets is because they are quite affectionate, appear to really like people, and even “cuddle” with people they know. Cockatoos are a bit noisier than most parrots, but not particularly good talkers. One should keep in mind that a white cockatoo is capable of living 100 years, and that they can crush a

walnut with their beak; your finger would not present much of a challenge.



Figure 1-48. White or umbrella cockatoo (*Cacatua alba*) displaying its crest. (Photo courtesy: [http://en.wikipedia.org/wiki/File:Umbrella_Cockatoo_\(Cacatua_alba\)_-Free_Flight_Aviary_-San_Diego](http://en.wikipedia.org/wiki/File:Umbrella_Cockatoo_(Cacatua_alba)_-Free_Flight_Aviary_-San_Diego)).

The family **psittacidae** (true parrots) contains most of the psittacines, which includes the typical parrots, the conures, the parakeets, the parrotlets, the lorries, and the lorikeets. There are two genera of **African parrots**- the African grey and 9 species in the genus *Poicephalus*. There are two subspecies of African greys- the Congo (Fig. 1-49) and the Timneh. An African grey parrot may live to be more than 50 years old.

The **neotropical parrots** belong to the subfamily Arinae, which are divided into short-tailed and long-tailed groups. Examples of the long-tailed group are the

macaws, which are typically colorful birds in six genera native to Mexico, and Central and South America. Examples of macaws are the blue and gold (yellow) macaw (Fig. 1-50) and the Hyacinth macaw (Fig. 1-51).



Figure 1-49. Congo African grey parrot (*Psittacus erithacus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Psittacus_erithacus_perching_on_tray-8d).

One now-**extinct** species of interest is the **Carolina parakeet** (*Conuropsis carolinensis*) (Fig. 1-53), which once explored the more temperate zone of the eastern US up to New York and Wisconsin. Apparently, the last wild bird was killed in Florida in 1904, and the last captive bird died in 1918. Although many of these birds were killed as pests or for their feathers, it is even thought by some that introduction of the honeybee may have contributed to the extinction by taking many of its nesting sites.

Examples of short-tailed parrots are the **Amazon parrots**. One species that is often kept as a pet is the red-crowned Amazon (*Amazona viridigenalis*), which is also known as the green-cheeked Amazon or the Mexican red-headed parrot (Fig. 1-54). Wild red-crowned Amazons range as far north as southern California, Florida, and along the Rio Grande. They are also found on the island of Oahu. Like most parrots, these birds nest in tree cavities, and feed on seeds, fruits, flowers, and nectar. They are great mimickers, and some are excellent talkers.



Figure 1-50. Blue and gold (yellow) macaw (*Ara ararauna*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Blue-and-Yellow-Macaw>).



Figure 1-51. Hyacinth macaw (*Anodorhynchus hyacinthinus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Anodorhynchus_hyacinthinus-Australia_Zoo_-8-2c).

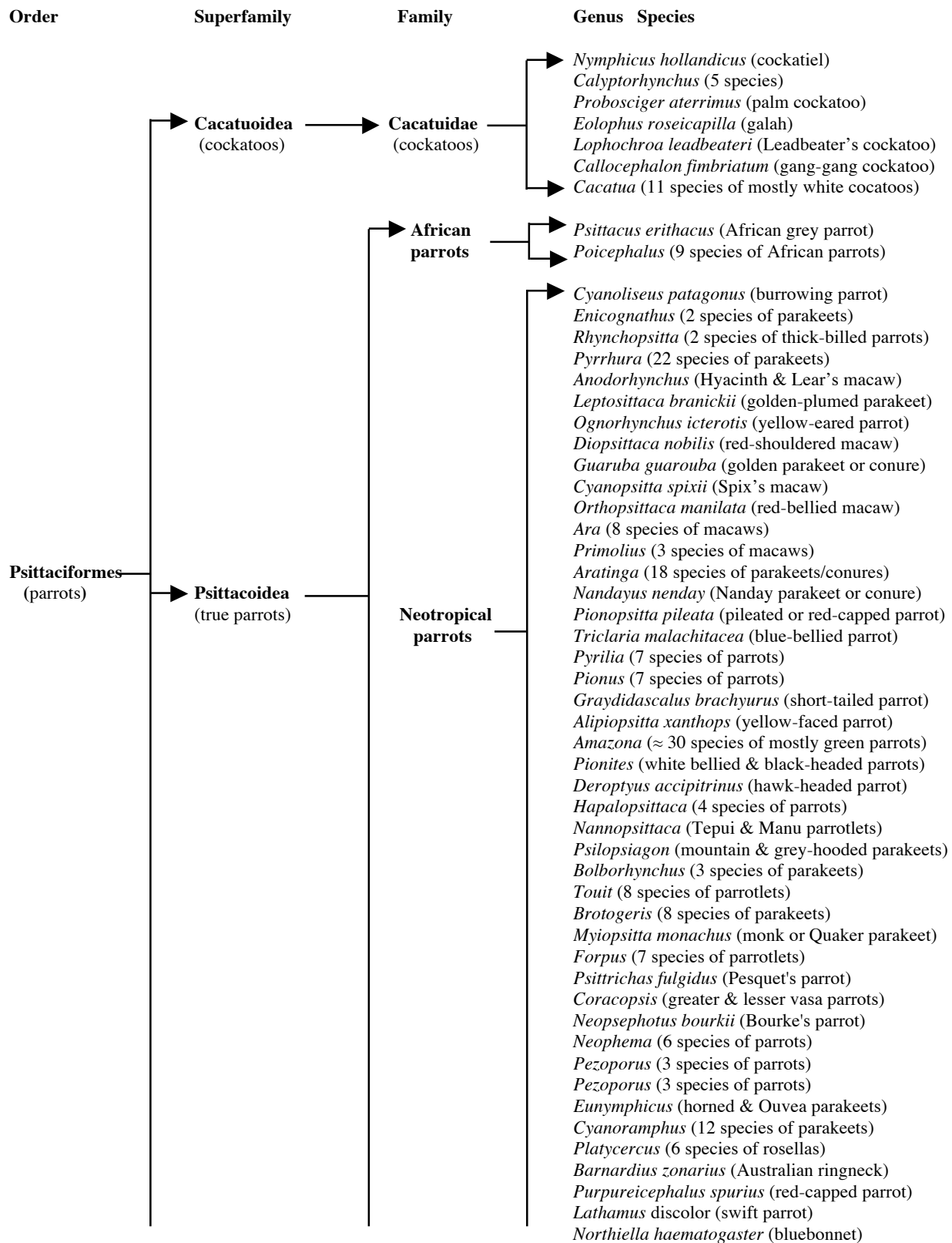


Figure 1-52. Modern-day Psittacines. There are more than 370 recognized species in the order Psittaciformes (continued on next page).

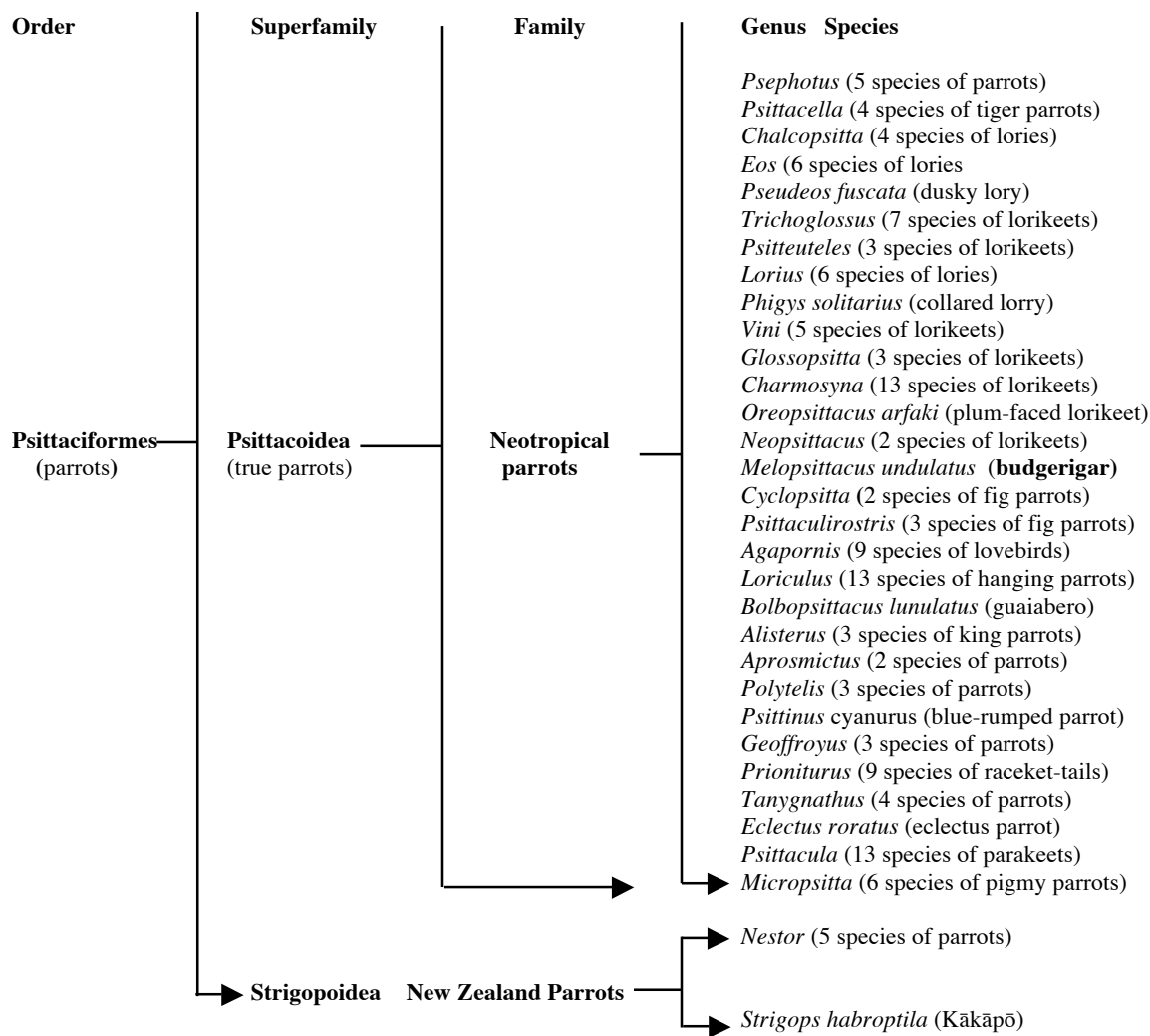


Figure 1-52. Modern-day Psittacines. There are more than 370 recognized species in the order Psittaciformes (continued from previous page).



Figure 1-53. Mounted specimen of a Carolina parakeet (*Conuropsis carolinensis*); now extinct. These birds once inhabited the eastern US as far north as New York and Wisconsin (Photo courtesy: http://en.wikipedia.org/wiki/File:Karolinasittich_01).

So what's the difference between a parrot, a parrotlet, a parakeet, a conure, a lorie, a lorikeet, a pigmy parrot, a rosella, a lovebird, and a racket-tail? It gets confusing doesn't it? Well here's my explanation of the terminology. A **parrot** is any member of the order Psittaciformes (Fig. 1-52), including the cockatoos, African parrots,

Neotropical parrots, and two genera of New Zealand parrots. However, within the Neotropical parrots, there are some birds that carry other names.



Figure 1-54. Red-crowned Amazon parrot (*Amazona viridigenalis*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Red_Crowned_Amazon).

A **parrotlet** is a small New World (Central & South America) parrot in one of three genera- *Forpus*, *Nannopsittaca*, and *Touit*. These birds typically have a stocky build and a broad tail, which is demonstrated by the Pacific parrotlet (Fig. 1-55).

A **parakeet** is any one of a large number of unrelated small to medium-sized parrots that typically have long tail feathers. The most familiar example of a parakeet is the popular pet bird, the **budgerigar** or “**budgie**” (Fig. 1-56). This bird is also referred to as the common parakeet or shell parakeet. All budgies are parakeets, but this term is also applied to many small parrots with long flat tails.

The native color of the budgerigar is green and yellow with black, scalloped markings on the nape, back, and wings (Fig.

1-56). These small parrots have survived the dry, harsh climate of inland Australia for at least several million years. Once they became popular as pet birds, they have been selectively bred to produce the additional colors of blue, white, yellow, and grey. Although there are several ideas as to how the budgerigar got that name, the one I like the best is that it is derived from the Australian slang words “budgery” meaning “good” and “gar” meaning “cockatoo.”



Figure 1-55. Pacific parrotlet (*Forpus coelestis*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Forpus_coelestis_-_male_pet).

The term **conure** is used to describe a loosely defined group of small to medium-sized parrots that belong to several genera within the long-tailed group of New World parrots. The American Ornithologists’ Union refers to all conures as parakeets, and in fact, the same bird is often called a parakeet in the wild, but becomes a “conure” when raised in captivity.

One example is the **mitred conure** or mitred parakeet (Fig. 1-57). Although native to the forests of the Andes from Peru to Argentina, these birds have been introduced to the wild in California, Florida,

and Hawaii. In fact, these little birds are not too welcome in Maui, and the Invasive Species Committee has been trying to get rid of them. From about 200 birds in 2003, they have killed almost all of them, and it is anticipated that they will soon be totally removed from Maui. Last note- the now extinct **Carolina parakeet** was considered a conure, thus the name *Conuropsis carolinensis*).



Figure 1-56. Male Australian budgerigar (*Melopsittacus undulatus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Melopsittacus_undulatus-Fort_Worth_Zoo-8a-4c).

The terms, **lories** and **lorikeets**, are used to describe certain small to medium-sized arboreal parrots with unique brush-tipped tongues for feeding on the nectar of various blossoms and berries. The names are derived from their tribe, Lorini, and they are closely related to the budgerigar and the fig parrots. An example of this group is the rainbow lorikeet (Fig. 1-58). You can appreciate the specialized tongue of the lorikeet in figure 1-59.

Pigmy parrots are the smallest members of psittaciformes, and all six

species belong to the genus, *Micropsitta*, which means small parrot. Pigmy parrots are native to New Guinea and nearby islands. These are very small birds, and the smallest is the buff-faced pigmy parrot (Fig. 1-60). This tiny parrot weighs less than ½ ounce, and measures less than 3½ inches.



Figure 1-57. Mitred conure or parakeet (*Aratinga mitrata*) (Photo courtesy: http://en.wikipedia.org/wiki/File:Mitred_Parakeet,_Inka_Trail,_Peru).



Figure 1-58. Rainbow lorikeet (*Trichoglossus haematodus*). Photo courtesy: [http://en.wikipedia.org/wiki/File:Rainbow_Lorikeet_\(Trichoglossus_haematodus\)_-Nelson_Bay_-NSW](http://en.wikipedia.org/wiki/File:Rainbow_Lorikeet_(Trichoglossus_haematodus)_-Nelson_Bay_-NSW)). I guess this bird slept through camouflage classes.



Figure 1-59. Rainbow lorikeet (*Trichoglossus haematodus*) drinking water. (Photo courtesy: [http://en.wikipedia.org/wiki/File:Rainbow_Lorikeet_\(Trichoglossus_haematodus\)_-drinking](http://en.wikipedia.org/wiki/File:Rainbow_Lorikeet_(Trichoglossus_haematodus)_-drinking)).



Figure 1-60. Buff-faced pigmy parrot (*Micropsitta pusio*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:NasiternaPusioWolf>).

A **rosella** is one of about 6 species of broad-tailed Australian parrots in the genus *Platycercus*, meaning flat tail. When Europeans first came upon these parrots, they called them Rosehill parakeets, which was later shortened to “rosellas.” An example of this small group of parrots is the crimson rosella (Fig. 1-61).



Figure 1-61. Crimson rosella (*Platycercus elegans*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Platycercus_elegans_Wilsons_Prom). Talk about a “fashion statement.”

A **lovebird** is one of 9 species in the genus, *Agapornis*. They get their common name because they are very affectionate birds. Lovebirds are native to Africa and Madagascar (one species). One of the more common pet species is the rosy-faced lovebird (Fig. 1-62). Actually, their species name means rose-colored neck. This bird is often kept in pairs, but it can be aggressive toward one another or toward people. They have a tendency to bond with one person and not get along with others.



Figure 1-62. Rosy or peach faced lovebird (*Agapornis roseicollis*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Agapornis_roseicollis_-Namibia-8).

Racket-tails consist of 9 species of parrots in the genus *Prioniturus*. These birds, which are native to the Philippines and Indonesia, can be easily distinguished

by elongated central tail feathers (Fig. 1-63). These feathers have bare shafts with “little spatulas” on the ends. Side note- there is also a “racket-tail” humming bird found in parts of South America.

Did you know that more than half of the 10,000 species of birds belong to the order **Passeriformes**? There are more species of passerines than there are species of mammals on the planet. Needless to say, they have been a most successful group. Passerines get their name from the single genus *Passer*, which contains the Old World sparrows, including the house sparrow (*Passer domesticus*). This order contains 110 families, which means we will not be going down to the genus level in our “diagram” of Passeriformes (Fig. 1-72).



Figure 1-63. Blue-crowned racket-tail parrot (*Prioniturus discurus*). (Photo courtesy: <http://en.wikipedia.org/wiki/Racket-tail>)

The largest passerine is the thick-billed raven, which may be 25 inches long and weigh in at over 3 lbs., while the smallest is the **short-tailed pygmy tyrant** (Fig. 1-64),

which is only about 2½ inches long and weighs about 0.15 ounce.



Figure 1-64. Short-tailed pygmy tyrant (*Myiornis ecaudatus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Myiornis_ecaudatus_1847).

There are 3 suborders in passeriformes. **Ancanthistti** contains a single family of so-called New Zealand “wrens.” These birds, which are limited to New Zealand, are from an ancient lineage, and there are only two living species. Although they are called “wrens” because of their size, they are not true wrens. The two species, the “rifleman” and the New Zealand rock wren (Fig. 1-65) represent 2 of the 3 species of **flightless** passerines.



Figure 1-65. New Zealand rock wren (*Xenicus gilviventris*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Rock_wren).

The suborder Tyranni is a *clade* of passerines that includes about **1000 species**, most of which are found in South America. Of the 15 families, **Tyrannidae** is the largest family of birds on the planet, containing more than **400 species** of tyrant flycatchers. An example of a tyrant flycatcher is the **scissor-tailed flycatcher** (Fig. 1-66), which is found in North and Central America. These were very common where I grew up in north central Texas near Fort Worth. In fact, it is even known as the Texas bird-of-paradise, although I never heard it called that when I was a kid. It is also in a group of insectivorous birds known as “kingbirds.”

By far the largest suborder of passeriformes is **Passeri**, which contains some **4000 species**. This group is also known as the “**songbirds**” or in Latin, the “**oscines**.” The passeri have a more complex musculature to their syrinx than the Tyranni, allowing them to produce more elaborate bird songs— thus the name songbirds.



Figure 1-66. Scissor-tailed flycatcher (*Tyrannus forficatus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Tyrannus_forficatus_on_branch).

One of the best known families of **passerines** is the **finch family** or Fringillidae. Members of this family are mostly native to the northern hemisphere; however, some species inhabit the

neotropics, and Hawaiian Islands. There are many types of finches in the US, including the **Eastern (American) goldfinch** (Fig. 1-67), which is incorrectly called the “wild canary.” Bird feeder note-- these beautiful little finches appear to like thistle seeds.



Figure 1-67. Eastern (American) goldfinch (*Spinus tristis*). The more brightly colored male is on the left, and this photo shows their summer plumage. (Photo courtesy: http://en.wikipedia.org/wiki/File:American_Goldfinch-27527).

As noted above, the Eastern goldfinch is not really a “wild canary,” but there are wild canaries. The **Atlantic canary** (Fig. 1-68) is a true wild canary, which is native to the Canary Islands, the Azores, and the Portuguese archipelago known as Madeira. This small bird is in fact one of the national symbols of the Canary Islands. The wild version is mostly yellow-green with brown on its back, but since it has been bred in captivity, several other color patterns have appeared.



Figure 1-68. Male Atlantic canary (*Serinus canaria*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Serinus_canaria_Parque_Rural_del_Nublo_Gran_Canaria_Spain_male-8a).

This is a common species of pet bird, and is often called the **domestic canary**. Through selective breeding, many color varieties have been developed, including yellow, orange, brown, and white (Fig. 1-69). Domestic males are called “singers” and the females are known as hens. Unlike the situation with ducks, male canaries are by far the more vocal of the sexes. Sexing of canaries can be difficult in the young birds, but the males typically begin to sing, and the hens do not sing much at all.

Other physical differences appear as the “breeding season” approaches. The abdomen of the hen becomes more rounded, and that of the male enlarges and protrudes. The latter is due to a gigantic enlargement of the terminal parts of the ducti deferentes. Not surprisingly, singers (cocks) are often ready to breed long before the hens get in the mood.



Figure 1-69. Domestic canary hen (*Serinus canaria domestica*) on nest. (Photo courtesy: http://en.wikipedia.org/wiki/File:Canary_nesting).

Although you are probably familiar with the “canary in a coal mine” usage to warn miners of the build-up of toxic gases, you may not know that canaries are also used in research, particularly in the area of neurogenesis and regeneration of brain cells.

Another passerine bird kept as a pet bird is the **zebra finch**, (*Taeniopygia guttata*).

Originating primarily in central Australia, this beautiful little bird (Fig. 1-70) has been exported to numerous countries, including the US. These birds are also used in genetic research, and many domestic variants have been developed through selective breeding. Although the life expectancy in the wild is only about 5 years, under optimal conditions, these birds may live up to 14 years in captivity. Male zebra finches are lively singers, and each male’s song is slightly different. Another popular pet finch is the society finch (Fig. 1-71). This bird is not found in the wild.



Figure 1-70. Wild zebra finch male (*Taeniopygia guttata*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Taeniopygia_guttata_Karratha_Pilbara_Western_Australia_Australia-male-8_2).



Figure 1-71. Society (Bengalese) finches (*Lonchura striata domestica*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Rbruni>).

Order	Suborder	Family	Name
Passeriformes	→ Acanthisitti	Acanthisittidae	New Zealand “wrens”
	→ Tyranni	→ Eurylaimidae	broadbills
		Philepittidae	asities
		Sapayoidae	broad-billed sapayoa
		Pittidae	pittas
		Tyrannidae	tyrant flycatchers
		Tityridae	tityras and allies
		Cotingidae	cotingas
		Pipridae	manakins
		Furnariidae	ovenbirds & woodcreepers
		Thamnophilidae	antbirds
		Formicariidae	antthrushes
		Grallariidae	antpittas
		Rhinocryptidae	typical tapaculos
		Conopophagidae	gnateaters and gnatpittas
		Melanopareidae	crescent-chests
		→ Menuridae	lyrebirds
		Atrichornithidae	scrub-birds
		Maluridae	fairywrens, emu-wrens & grasswrens
		Dasyornithidae	bristlebirds
		Acanthizidae	scrubwrens, thornbills, & gerygones
		Meliphagidae	honeyeaters, pardalotes, spinebills
		Melanocharitidae	berrypeckers and longbills
		Callaeidae	New Zealand wattletails
		Cnemophilidae	satinbirds
		Neosittidae	sittellas
		Vireonidae	vireos
		Campephagidae	cuckoo-shrikes and trillers
		Pachycephalidae	whistlers & allies
		Oriolidae	orioles and figbird
		Paramythiidae	tit berrypecker and crested berrypecker
		Artamidae	woodswallows, butcherbirds, currawongs & Australian magpie
			puffback shrikes, bush shrikes, tchagras & boubous
		Malaconotidae	
	→ Passeri	Platysteiridae	wattle-eyes
		Aegithinidae	ioras
		Pityriaseidae	Bornean bristlehead
		Prionopidae	helmetshrikes & woodshrikes
		Vangidae	vangas
		Dicruridae	drongos
		Monarchidae	monarch flycatchers
		Rhipiduridae	fantails
		Paradisaeidae	birds of paradise
		Corcoracidae	white-winged chough & apostlebird
		Laniidae	shrikes
		Corvidae	crows, ravens & jays
		Colluricinclidae	shrike-thrushes
		Cinclosomatidae	whipbirds & allies
		Falcunculidae	Shrike-tit & allies
		Climacteridae	Australian treecreepers
		Ptilonorhynchidae	bowerbirds
		Orthonychidae	logrunners
		Pomatostomidae	pseudo-babblers
		Petroicidae	Australian robins

Figure 1-72. Modern-day Passeriformes (continued on next page).

Order	Suborder	Family	Name
Passeriformes	Passeri	Picathartidae	rockfowl
		Chaetopidae	rock-jumpers
		Eupetidae	Malaysian Rail-babbler
		Regulidae	kinglets
		Irenidae	fairy-bluebirds
		Chloropseidae	leafbirds
		Nicatoridae	nicators
		Panuridae	bearded reedling
		Alaudidae	larks
		Hirundinidae	swallows & martins
		Pnoepyidae	pygmy wren-babblers
		Macrosphenidae	African warblers
		Phylloscopidae	leaf-warblers & allies
		Aegithalidae	long-tailed tits or bushtits
		Cettiidae	ground-warblers & allies
		Locustellidae	grass-warblers & allies
		Donacobiidae	black-capped donacobius
		Bernieridae	Malagasy warblers
		Acrocephalidae	marsh- & tree-warblers
		Pycnonotidae	bulbuls
		Cisticolidae	cisticolas & allies
		Timaliidae	tree babblers
		Pellorneidae	ground babblers
		Leiothrichidae	laughingthrushes & allies
		Sylviidae	Sylvia warblers & allies
		Zosteropidae	white-eyes & allies
		Cinclidae	dippers
		Muscicapidae	Old World flycatchers & chats
		Turdidae	thrushes & allies
		Buphagidae	oxpeckers
		Sturnidae	starlings & possibly Philippine creepers
		Mimidae	mockingbirds & thrashers
		Sittidae	nuthatches
		Tichodromadidae	wallcreeper
		Certhiidae	treecreepers
		Salpornithidae	spotted creeper
		Troglodytidae	wrens
		Poliopitilidae	gnatcatchers
		Passeridae	true sparrows
		Prunellidae	accentors
		Motacillidae	wagtails & pipits
		Urocynchramidae	Przewalski's finch
		Estrildidae	estrildid finches (waxbills, munias, etc.)
		Ploceidae	weavers
		Viduidae	indigobirds & whydahs
Peucedramidae	olive warbler		
Fringillidae	true finches and Hawaiian honeycreepers		
Icteridae	grackles, New World blackbirds & orioles		
Parulidae	New World warblers		
Thraupidae	tanagers & allies		
Cardinalidae	cardinals		
Emberizidae	buntings & American sparrows		
Paridae	tits, chickadees & titmice		
Remizidae	penduline tits		
Stenostiridae	stenostirids ("flycatcher-tits")		
Bombicillidae	waxwings		
Nectariniidae	sunbirds		
Dicaeidae	flowerpeckers		
Promeropidae	sugarbirds		

Of the more than 10,000 species of passerines, a few of my back-yard favorites are the **eastern bluebird** (Fig. 1-73), the **northern mockingbird** (Fig. 1-74), the **white-breasted nuthatch** (Fig. 1-75), the **Carolina wren** (Fig. 1-76), the **Carolina chickadee** (Fig. 1-77), the **cardinal** (Fig. 1-78), and the **tufted titmouse** (Fig. 1-79).



Figure 1-73. Eastern bluebird (*Sialia sialis*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Sialia_sialis_-Michigan,_USA_-pair-8c).



Figure 1-74. Northern mockingbird (*Mimus polyglottos*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Mimus_polyglottos_Krendle_Woods,_Cary,_North_Carolina,_USA-8).



Figure 1-75. White-breasted nuthatch (*Sitta carolinensis*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Sitta-carolinensis-001>).



Figure 1-76. Carolina wren (*Thryothorus ludovicianus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Carolina_Wren_2).



Figure 1-77. Carolina chickadee (*Poecile carolinensis*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Carolina_Chickadee1_by_Dan_Pancamo).



Figure 1-78. Cardinal (*Cardinalis cardinalis*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Cardinal>).



Figure 1-79. Tufted titmouse (*Baeolophus bicolor*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Tufted_Titmouse-27527-2).

Although the order **sphenisciformes** has limited veterinary significance, **penguins** are one of the most remarkable of birds, and of course, **zoo veterinarians** will be called upon to treat these amazing birds. The mere fact that penguins can survive in one of the harshest environments on the planet provides

an object lesson in anatomic and physiologic adaptability. As a result of some debate among ornithologists, there are about 19 species of living penguins. All penguins are in the family **Spheniscidae**, and there are 6 genera (Fig. 1-80).

Order	Family	Name	Genus Species
Sphenisciformes (Penguins)	Spheniscidae	great penguins	<i>Aptenodytes</i> (2 species)
		brush-tailed penguins	<i>Pygoscelis</i> (3 species)
		little penguins	<i>Eudyptula</i> (2 species)
		banded penguins	<i>Spheniscus</i> (4 species)
		yellow-eyed penguin	<i>Megadyptes antipodes</i>
		crested penguins	<i>Eudyptes</i> (8 species)

Figure 1-80. Modern-day Sphenisciformes (Penguins). Extinct species are not included.

The great penguins include the **king** and **emperor penguins** (Fig. 1-81). These are the two largest species, with emperors being up to 4 ft. tall and weighing in at up to 90+ lbs. Kings are considerably smaller—standing about 3 ft. tall and weighing in at about 30 lbs. King penguins breed on the sub-Antarctic islands and northern Antarctica, while the gigantic emperors are the ones that move inland about 50 miles and breed during the harsh Antarctic winters. Their annual journey and reproductive cycle were well documented in the movie, *March of the Penguins*. Even the movie, *Happy Feet*, features the emperor penguins.

While diving, the emperor penguin's heart rate is reduced to about 20 bpm, and their hemoglobin can bind with and transport very low blood concentrations of oxygen. The emperor penguin has the highest feather density of any bird, with more than 100 feathers per square inch of body surface. These dense feathers, coupled with a thick layer of subcutaneous fat provide the insulation necessary for these birds to survive in temperatures of -40°F. It is not surprising that the largest penguins

inhabit the coldest regions because they have the lowest surface area to body mass ratio, which reduces heat loss from the body core.

The brush-tailed penguins include the Adelie, the gentoo, and the chinstrap (Fig. 1-82) penguins. **Chinstrap penguins** are about 2 ft. tall and weigh about 13 lbs. They live on barren islands of the sub-Antarctic region and the Antarctic Peninsula, and they require solid, snow-free ground for nesting.



Figure 1-81. King penguins (*Aptenodytes patagonicus*) (left) & emperor penguins (*Aptenodytes forsteri*) (right). (Photos courtesy: http://en.wikipedia.org/wiki/File:Manchot_royal_-_King_Penguin & http://en.wikipedia.org/wiki/File:Aptenodytes_forsteri_-_Snow_Hill_Island,_Antarctica_-_adults_and_juvenile-8).



Figure 1-82. Chinstrap penguins (*Pygoscelis antarctica*). (Photo courtesy: http://upload.wikimedia.org/wikipedia/commons/6/69/Manchot_01).

The genus *Eudyptula* consists of two species of small penguins that are found in southern Australia, Tasmania, New Zealand, and the Chatham islands. The white-flipped penguin and the **little blue penguin** (Fig. 1-83) make up this genus of “little penguins.” These guys are only about a foot tall and weigh in at a little more than 3 lbs. On most days, little penguins spend the entire day swimming.



Figure 1-83. Little blue penguin (*Eudyptula minor*). (Photo courtesy: http://en.wikipedia.org/wiki/Little_Penguin).

The genus *Spheniscus* consists of 4 species of banded penguins that live in the more temperate climates around South Africa, the southern coasts of Chile and Argentina, and the Galapagos Islands.

Among these is the **Magellanic penguin** (Fig. 1-84). This species grows to about 26 inches, and weighs about 10 lbs.



Figure 1-84. Magellanic penguin (*Spheniscus magellanicus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Magellanic_penguin_Valdes_Peninsula_e).

The genus *Megadyptes* has only one living species, the **yellow-eyed penguin** (Fig. 1-85), which is found around the south island of New Zealand and nearby smaller islands. This is another medium-sized penguin standing about 27 inches and weighing in at about 10-15 lbs. The weight of these birds varies a lot before and after molting.



Figure 1-85. Yellow-eyed penguin (*Megadyptes antipodes*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Yellow-eyed_Penguin_MC).

The genus *Eudyptes* contains 8 species of crested penguins. Among these are the 2 species of **rockhoppers** and the **macaroni penguins** (Fig. 1-86). The southern rockhopper lives in the sub-Antarctic waters of the western Pacific and Indian Oceans, while the macaroni penguin explores from the Falkland Islands south to the Antarctic Peninsula. The southern rockhopper is about 20 inches tall, while the macaroni penguin stands about 27 inches, with a highly variable body weight.



Figure 1-86. Southern rockhopper (*Eudyptes chrysocome*) (left) and macaroni (*Eudyptes chrysolophus*) (right) penguins. Photo courtesy: http://en.wikipedia.org/wiki/File:Gorfou_sauteur_-_Rockhopper_Penguin & [http://en.wikipedia.org/wiki/File:Macaroni_Penguins_\(js\)](http://en.wikipedia.org/wiki/File:Macaroni_Penguins_(js)).

Falconiformes (Fig. 1-89) is the order of birds that includes the diurnal birds of prey. This order contains about 290 species of diurnal raptors, which includes caracaras, falcons, falconets, hobbies, eagles, hawks, goshawks, harriers, kites, buzzards, vultures, condors, and the secretary bird.

The family **Falconidae** contains about 60 species of falcons and caracaras, and is divided into two subfamilies- Polyborinae (caracaras and forest falcons) and Falconinae (falcons, kestrels, and falconets). **Caracaras** (Fig. 1-87) are relatively slow-flyers, and are primarily indigenous to South and Central America, extending to the southern US. Like many raptors, most caracaras act frequently as scavengers.



Figure 1-87. Caracara in flight (Photo courtesy: http://en.wikipedia.org/wiki/File:Caracara_by_Dan_Pancamo).

Falcons may be defined as any member of the genus *Falco*, of which there are some 37 recognized species. Falcons are characterized by their thin, tapering wings, which allow these raptors to fly at high speed, and to change directions quickly. **Peregrine falcons** (Fig. 1-88) have been clocked at speeds up to **200 mph**, making them the fastest animal on the planet. This amazing bird is found in every part of the world except the Polar Regions, making it the most widespread raptor. They feed primarily on other birds, including ducks, and in North America, they are sometimes called the “duck hawk.”



Figure 1-88. Peregrine falcon (*Falco peregrinus*) with a kill. (Photo courtesy: http://en.wikipedia.org/wiki/File:Falco_peregrinus_-Nova_Scotia,_Canada_-eating-8).

Order	Family	Name	Genus Species
Falconiformes (diurnal raptors)	Falconidae	black caracara	<i>Daptrius ater</i>
		red-throated caracara	<i>Ibycter americanus</i>
		caracaras	<i>Phalcoboenus</i> (4 species)
		crested caracaras	<i>Caracara</i> (2 species)
		brown caracaras	<i>Milvago</i> (2 species)
		laughing falcon	<i>Herpetotheres cachinnans</i>
		forest falcons	<i>Micrastur</i> (7 species)
		spot-winged falconet	<i>Spizapteryx circumcincta</i>
		pigmy falcons	<i>Polihierax</i> (2 species)
		typical falconets	<i>Microhierax</i> (5 species)
		true falcons, hobbies, kestrels	<i>Falco</i> (37 species)
	Cathartidae	black vulture	<i>Coragyps atratus</i>
		vultures	<i>Cathartes</i> (3 species)
		California condor	<i>Gymnogyps californianus</i>
		Andean condor	<i>Vultur gryphus</i>
	Pandionidae	king vulture	<i>Sarcoramphus papa</i>
		osprey	<i>Pandion haliaetus</i>
	Accipitridae	black-winged kites	<i>Elanus</i> (4 species)
		scissor-tailed kite	<i>Chelictinia riocourii</i>
		pearl kite	<i>Gampsonyx swainsonii</i>
		swallow-tailed kite	<i>Elanoides forficatus</i>
		bazas	<i>Aviceda</i> (5 species)
		honey buzzards	<i>Henicopernis</i> (2 species)
		honey buzzards	<i>Pernis</i> (3 species)
		grey-headed & white-collared kites	<i>Leptodon</i> (2 species)
		hooked bill & Cuban kites	<i>Chondrohierax</i> (2 species)
		bat hawk	<i>Macheiramphus alcinus</i>
		red-headed vulture	<i>Sarcogyps calvus</i>
		cinereous vulture	<i>Aegypius monachus</i>
		lappet-faced vulture	<i>Torgos tracheliotus</i>
		white-headed vulture	<i>Trigonoceps occipitalis</i>
		vultures (Old World)	<i>Gyps</i> (8 species)
		hooded vulture	<i>Necrosyrtes monachus</i>
		Egyptian vulture	<i>Neophron percnopterus</i>
		palm-nut vulture	<i>Gypohierax angolensis</i>
		bearded vulture	<i>Gypaetus barbatus</i>
		Madagascar serpent eagle	<i>Eutriorchis astur</i>
		black-chested buzzard-eagle	<i>Geranoaetus melanoleucus</i>
		buteos (hawks & buzzards)	<i>Buteo</i> (29 species)
		Harris hawk	<i>Parabuteo unicinctus</i>
		hawks	<i>Pseudastur</i> (3 species)
		barred hawk	<i>Morphnarchus princeps</i>
		hawks & eagles	<i>Buteogallus</i> (9 species)
		black-collared hawk	<i>Busarellus nigricollis</i>
		hawks	<i>Leucopternis</i> (3 species)
		plumbeous hawk	<i>Cryptoleucopteryx plumbea</i>
		lizard buzzard	<i>Kaupifalco monogrammicus</i>
		buzzards	<i>Butastur</i> (4 species)

Figure 1-89. Modern-day Falconiformes. (Continued on next page.)

Order	Family	Name	Genus Species
Falconiformes (diurnal raptors)		solitary eagles	<i>Harpyhaliaetus</i> (2 species)
		crane hawk	<i>Geranospiza caerulescens</i>
		typical hawk-eagles (New World)	<i>Spizaetus</i> (4 species)
		hawk-eagles (Old World)	<i>Nisaetus</i> (9 species)
		long-crested eagle	<i>Lophaelus occipitalis</i>
		crowned eagle	<i>Stephanoetus coronatus</i>
		martial eagle	<i>Polemaetus bellicosus</i>
		hawk-eagles	<i>Hieraaetus</i> (4 species)
		rufous-bellied hawk eagle	<i>Lophotriorchis kienerii</i>
		true eagles	<i>Aquila</i> (14 species)
		black eagle	<i>Ictinaetus malayensis</i>
		harriers	<i>Circus</i> (14 species)
		African & Madagascar harriers	<i>Polyboroides</i> (2 species)
		kites (New World)	<i>Harpagus</i> (2 species)
		Mississippi & plumbeous kites	<i>Ictinia</i> (2 species)
	→ Accipitridae →	snail kite	<i>Rostrhamus sociabilis</i>
		slender-billed kite	<i>Helicolestes hamatus</i>
		Brahminy & whistling kites	<i>Haliastur</i> (2 species)
		square-tailed kite	<i>Lophoictinia isura</i>
		black-breasted buzzard	<i>Hamirostra melanosternon</i>
		goshawks & sparrow hawks	<i>Accipiter</i> (46 species)
		long-tailed hawk	<i>Urotriorchis macrourus</i>
		goshawks	<i>Erythrotriorchis</i>
		Doria's goshawk	<i>Megatriorchis doriae</i>
		bateleur eagle	<i>Terathopius ecaudatus</i>
		snake eagles	<i>Circaetus</i> (6 species)
		serpent eagles	<i>Spilornis</i> (6 species)
		Philippine eagle	<i>Pithecophaga jefferyi</i>
		sea eagles (including bald eagle)	<i>Haliaeetus</i> (8 species)
		grey-headed & lesser fish eagles	<i>Ichthyophaga</i> (2 species)
		crested eagle	<i>Morphnus guianensis</i>
		harpy eagle	<i>Harpia harpyja</i>
		Papuan eagle	<i>Harpyopsis novaeguineae</i>
		dark, pale, & eastern goshawks	<i>Melierax</i> (3 species)
	→ Sagittariidae →	secretary bird	<i>Sagittarius serpentarius</i>

Figure 1-89. Modern-day Falconiformes. (Continued from previous page.)

The terms, **falconets**, **hobbies**, and **kestrels** are used to describe small falcons, with some being about the size of a sparrow. One example of these smaller falcons is the **American kestrel** (Fig. 1-90), which is the only New World kestrel and is sometimes called the “sparrow hawk.” This is also the smallest falcon in North America, measuring only 7-8 inches long, with females being

slightly larger than males. Kestrels are known for their “hovering” technique while hunting. From this hovering position, they can quickly swoop in on insects, lizards, mice, or small birds. The American kestrel shows more **sexual dimorphism** in plumage than most falcons. Males have blue-grey and black wings with black and white spots (Fig. 1-91), while females are reddish-brown with

dark brown barring on their back and dorsal wings (Fig. 1-90).



Figure 1-90. Female American kestrel (*Falco sparverius*) with a kill. (Photo courtesy: http://en.wikipedia.org/wiki/File:Falco_sparverius-San_Luis_Obispo,_California,_USA_-female-8).



Figure 1-91. Male American kestrel (*Falco sparverius*) showing dorsal feather coloration. (Photo courtesy: http://en.wikipedia.org/wiki/File:Male_American_Kestrel).

Another example of a small falcon is the **Australian hobby** (Fig. 1-92). There are four species called hobbies, none of which is found in the Americas. These birds resemble the peregrine falcon, and they take most of their prey “on the wing.”



Figure 1-92. Australian hobby (*Falco longipennis*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Australian_Hobby_Pikedale_Jul02).

So what’s a kite? Kites are a group of soaring falcons, characterized by long wings and weak legs. All kites belong to the family Accipitridae, and there are about 20 species belonging to 12 genera. Some kites are scavengers, feeding primarily on carrion, while other species take live prey. One example is the **swallow-tailed kite** (Fig. 1-93), which is found in the southeastern US. This bird feeds mainly on snakes, lizards, frogs, large insects, and on small birds and mammals.



Figure 1-93. Swallow-tailed kite (*Elanoides forficatus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Elanoides_forficatus02).

The term “hawk” has different meanings in different parts of the world. In North America, the term has a more general meaning and describes various birds including falcons, any of the 46 species within the genus *Accipiter* as well as some *buteos*. Some of the more common hawks in the US include the **Cooper’s hawk** (Fig. 1-94), the **red-tailed hawk** (Fig. 1-95), and the **red-shouldered hawk** (Fig. 1-96). Both the red-tailed and red-shouldered hawks are *buteos*. **Buteos** have broad wings compared with the long, slender wings of accipiters. Buteos tend also to be more opportunistic than accipiters, feeding on whatever is available. The preferred prey of *buteo* hawks are small mammals, primarily rodents, but they will also feed on birds, snakes, fish, and large insects.



Figure 1-94. Cooper's hawk (*Accipiter cooperii*) with a kill. (Photo courtesy: http://en.wikipedia.org/wiki/File:Cooper's_Hawk_Eating_a_Finch).



Figure 1-95. Red-tailed hawk (*Buteo jamaicensis*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:RedTailDisplay>).

How does a **goshawk** differ from a “hawk?” The term goshawk is used to describe one of 26 species within the *Accipiter* group. Most of these birds are found in Africa, Indonesia, New Guinea, and Australia; however, the **northern goshawk** (Fig. 1-97) is found in the more temperate regions of North America, including Canada and the northern US.

The northern goshawk is the largest member of the genus *Accipiter*, with mature

females weighing as much as 2.7 lbs, and mature males reaching a weight of about 1.7 lbs. Goshawks prefer areas of dense forestation and feed primarily on small mammals and birds found in a forest habitat. In pursuit of their prey, goshawks can fly through a maze of tree branches, twisting, and turning quickly to avoid collision with these obstacles. The goshawk is a popular **falconry** species, as is the peregrine falcon.



Figure 1-96. Red-shouldered hawk (*Buteo lineatus*). (Photo by Ed Smallwood, 12-18-13, Raleigh, NC).



Figure 1-97. Northern goshawk (*Accipiter gentilis*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Northern_Goshawk_ad_M2).

A **harrier** is any one of about 18 species of accipiters, most of which are in the genus *Circus*. Like the northern goshawk, the **northern harrier** (Fig. 1-98) is found in North America, including Canada and the northern US. Unlike the northern goshawk, Harriers typically hunt by flying low over open meadows, preying on small mammals, reptiles, or birds.



Figure 1-98. Northern harrier (*Circus cyaneus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Northern_Harrier2_by_Dan_Pancamo).

Another common North American hawk is the **osprey** (Fig. 1-99), which is also known as the “sea hawk” or “fish hawk.” These amazing birds are true fisher-birds in that they have no fear of actually going into the water to retrieve their prey, and often come out with a fish so large you cannot imagine how they can even lift it out of the water, much less fly away with it. The osprey is a large hawk, weighing as much as 4.6 lbs. and having a wingspan of almost 6 feet. With its long tapering wings, you would guess the osprey must be an accipiter, but it actually belongs to its own family, **Pandionidae**. One unique feature of the osprey is its ability (like owls) to reverse its 4th digit to form a 2-forward-2-back configuration, which allows them to grasp those slippery fish.



Figure 1-99. Osprey (*Pandion haliaetus*). (Photo courtesy: <http://images.nationalgeographic.com/wpf/media-live/photos/000/006/cache/osprey>).

Like the kestrels, ospreys often hunt by hovering over the water, and then “dive-bombing” the unsuspecting fish below. This is especially true when they are hunting flounder in the shallow water of the sound. The osprey will head into the wind and hover until their keen eyesight detects the slightest movement of the well-camouflaged flounder in about 18 inches or so of water. Some speculate they do not actually see the flounder, but detect the little sand trail it leaves when it moves from one place to another. Just before the osprey hits the water, they extend their talons and go in feet-first at about a 45-degree angle of attack, smashing the surface with its “bottom.” It’s a good thing their little pubic bones are “hinged” so they do not fracture on impact. And yes, ospreys can close their nostrils when they go under water. As mentioned previously, the bald eagle will steal the osprey’s catch, which is why Benjamin Franklin described the bald eagle as “a bird of bad moral character.”

Like the term “hawk,” the name “**buzzard**” tends to have multiple meanings, depending on where you live. The term “buzzard” can be applied to numerous large raptors in several genera of accipiters, including *Buteo* and *Butastur*. For example, the **common buzzard** (Fig. 1-100) of Europe and Asia is not what most of us in

the US think of when we hear the word “buzzard.” Even though “buteo” is Latin for buzzard, we call many buteos hawks.

In the US, when the term “buzzard” is used, we typically think of a carrion-feeding bird called the **turkey vulture** (Fig. 1-101). The turkey vulture or buzzard is the most widespread of the New World vultures, ranging from Canada to the southern tip of South America. In some areas of the Caribbean it is even called the John crow. Unlike most birds, the turkey vulture uses its **sense of smell** in addition to its keen eyesight to help locate carrion. There are 5 subspecies of this bird, and it is one of 6 species of New World vultures. The turkey vulture has a wingspan of about 6 feet and it can weigh up to 5 lbs. The common name “turkey vulture” is derived from the almost featherless head, which somewhat resembles that of a turkey (Fig. 1-102).



Figure 1-100. Common buzzard (*Buteo buteo*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Buteo_buteo_-Netherlands-8).



Figure 1-101. Turkey vulture (*Cathartes aura*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Cathartes_aura_-Florida-USA_-flying-8-4c).



Figure 1-102. Head of turkey vulture (*Cathartes aura*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Cathartes_aura_-Florida-USA_-upper_body-8).

So how does a **condor** differ from a vulture? Condors represent 2 species of large New World vultures, and are the largest flying land birds in the western hemisphere. The most famous condor is the California condor, which is found in the western US and northern Mexico from the Baja peninsula to southern Utah. Unlike most birds of prey, the female is smaller than the male, and these birds can live up to 60 years. The wingspan of an adult male can reach at least 10 feet and they can weigh as much as 30 lbs.

As the only surviving member of the genus *Gymnogyps*, the **California condor** (Fig. 1-103) almost became extinct due to several causes, including DDT toxicity, low clutch size (≈ 2), slow maturation (≈ 6 years), poaching, lead poisoning, electrical power lines, and habitat destruction. By 1987, there were only 22 California condors left, all in captivity. Due to the success of the California Condor Recovery Plan, many birds have now be released back to the wild beginning in 1991. By May 2012, there were 405 living birds, with 179 in captivity.



Figure 1-103. California condor (*Gymnogyps californianus*) in flight with tracking tags. (Photo courtesy: http://en.wikipedia.org/wiki/File:Condor_in_flight).

So how does an **eagle** differ from a hawk? Eagles belong to several genera in the family Accipitridae. Most eagles are indigenous to Africa, Eurasia, Central America, and Australia. Only 2 species, the

bald eagle and the **golden eagle**, are native to North America. The bald eagle (Fig. 1-104) is the national bird of the US, and builds the largest nest of any North American bird. Its nest can be up to 13 ft. deep, over 8 ft. wide, and weigh more than a ton. Once considered endangered in the lower 48 states, it has now been removed from the US government's list of endangered species. Although an opportunistic bird, many bald eagles feed primarily on fish, which they "snatch" from the water as they swoop by (Fig. 1-105).



Figure 1-104. Adult bald eagle (*Haliaeetus leucocephalus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Haliaeetus_leucocephalus_-_Skagit_valley-8-2c).



Figure 1-105. Bald eagle (*Haliaeetus leucocephalus*) with a fish. (Photo courtesy: http://en.wikipedia.org/wiki/File:Bald_eagle_fish).

The other North American eagle is the **golden eagle**, which is also found in Eurasia and parts of Africa. These are one of the most fearsome predators, being able to take down mammals the size of young deer and goats. Like most raptors, they will also eat carrion when necessary as well as reptiles. Golden eagles (Fig. 1-106) are also used in falconry, especially in Eurasia, where they have been trained to attack unnatural prey. They are still used by the Kazakh eagle hunters (Fig. 1-107) to hunt foxes and other large prey in Mongolia. Golden eagles can have a wingspan of up to 7.7 ft., and an adult female can weigh in at close to 14 lbs. Golden eagles have also been filmed grabbing goat kids off a mountainous ledge and dropping them to their death. Then they just swoop down and enjoy their now tenderized meal.



Figure 1-106. Golden eagle (*Aquila chrysaetos*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Golden_Eagle_in_flight_-_5).

The last, but certainly not least of the Falconiformes is the **secretary bird** (Fig. 1-108). Until you have seen one of these birds up-close and personal, you have no idea just how big they are. Adults can weigh as much as 9.9 lbs., and with those “crane-like” legs, these birds stand about 50 inches tall, which

makes them the tallest raptor. Secretary birds are found mostly in the open grasslands of sub-Saharan Africa, and they are the only member of the family Sagittariidae. Although these birds can definitely fly, they prefer to hunt on foot, often hunting in pairs. One of their favorite killing strategies involves stomping their prey (especially reptiles) with their powerful legs and feet. They also feed on insects and small mammals, which they flush from the grass.



Figure 1-107. Kazakh eagle hunters with golden eagles. (Photo courtesy: <http://www.theepochtimes.com/n2/world/kazakhstan-eagle-hunting-26096>).



Figure 1-108. Secretary bird (*Sagittarius serpentarius*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Sagittarius_serpentarius_Sekretär).

The order **Columbiformes** consists of about 312 species of birds including Old World pigeons, American pigeons, bronzewings, quail-doves, American ground doves, Indopacific ground doves, crowned pigeons, and many other groups. Although the terms **pigeon** and **dove** are not scientifically distinct, the terms are used to describe similar birds, with pigeons being typically larger than doves. Pigeons and doves belong to the family **Columbidae**, which includes some 310 species. A rather unique feature of pigeons and doves is that they produce a substance known as “**crop milk**,” which consists of fat-filled epithelial cells sloughed from the lining of their crops. This highly nutritious liquid is regurgitated by both sexes to feed their young, which are known as **squabs**.

The largest members of the family Columbidae are the **crowned-pigeons** (Fig. 1-109) of New Zealand, which are almost the size of a turkey. There are 3 species of crowned pigeons. One of the more common doves we have in the US is the **mourning dove** (Fig. 1-110), which is sometimes called the “turtle dove.” This bird is one of the favorite game birds taken in the US, with more than 30 million doves shot annually.

Pigeons and doves have a wide geographic distribution, inhabiting most of the planet, except the driest areas of the Sahara desert, Antarctica, and the coldest arctic regions. The typical wild pigeon we see in the southeastern US is the **common pigeon**, *Columba livia* (Fig. 1-111), which is sometimes called the “rock dove.” The species includes the domestic pigeon, and escaped domestic pigeons have given rise to feral populations around the world. One characteristic of pigeons is their ability to drink continuously by merely dipping their bills into the water, without having to tilt their heads back to swallow. The “rock

dove” is native to Europe, North Africa, and South Asia. It was originally introduced into North America (Nova Scotia) in 1606. These pigeons live about 5 years in the wild and up to 15 years in captivity.



Figure 1-109. Victoria crowned pigeon (*Goura victoria*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Victoria_Crowned_Pigeon_Jurong).



Figure 1-110. Mourning dove (*Zenaida macroura*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Zenaida_macroura_California-8-2c).



Figure 1-111. Common feral pigeon (*Columba livia*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Rock_dove_-_natures_pics).

The last group of birds to be covered in this book is the order **Strigiformes** (Fig. 1-112), and it is quite possible I have saved the best for last. Strigiformes contains more than 200 species of mostly nocturnal predatory birds, commonly called owls. **Owls** are distributed almost world wide except for Antarctica, the arctic regions of Greenland, and some remote islands. They feed primarily on small mammals, insects, and other birds, but a few species even specialize in hunting fish. Owls are absolutely amazing hunters, having

specialized flight feathers to virtually eliminate sound as they swoop in on their prey— the original “stealth” technology. (See Chapter 3.) Not only are they recognized as “wise” birds, but they also have (like many other birds) “opposable thumbs,” which I think has been associated with the development of tool using and with the high level of intelligence attributed to primates. Strigiformes are divided into two families, Strigidae (typical owls), and Tytonidae, the barn owls.

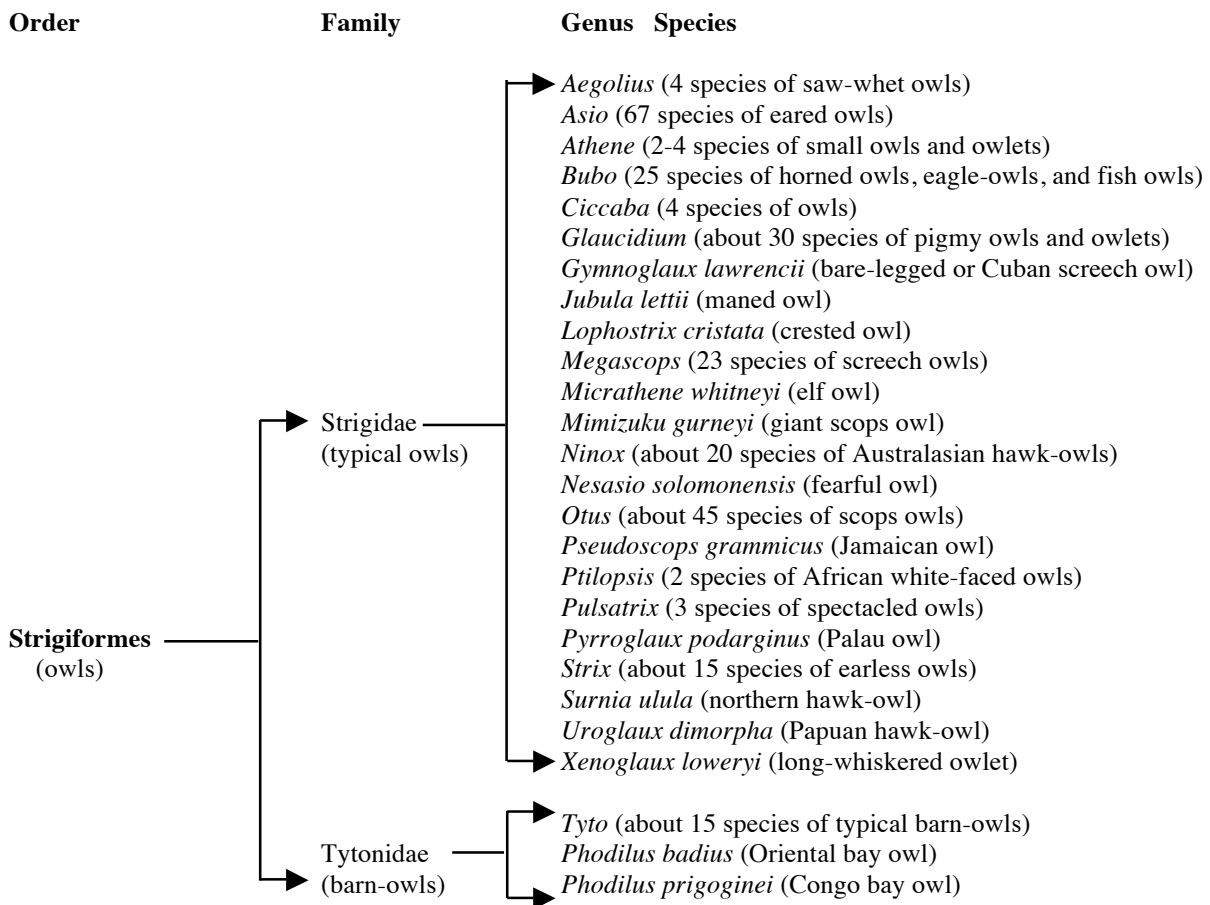


Figure 1-112. Strigiformes (owls). Extinct species are not listed.

Within the family **Strigidae** are some 23 genera of typical owls, and one of the larger genera in the family is the genus **Bubo**, which includes several familiar species.

Among these are the great-horned owl (Fig. 1-113), and the snowy owl. The **great-horned owl** is one of the largest and most widely distributed owls in the Americas,

ranging from subarctic North America to the southern tip of South America. Depending on the subspecies, great-horned owls can weigh up to 5 lbs., with females being larger than males. When spotted during their daytime roost, they will often be harassed for hours by crows. Owls are a primary predator of crows, but not when the crows gang up on them. In case you are wondering, owls have been estimated to have a crushing force with their talons (Fig. 1-114) of about **300 lbs. per square inch**.



Figure 1-113. Great-horned owl (*Bubo virginianus*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Bubo_virginianus_-Canada-6).

A close relative of the great horned owl is the **snowy owl** (Fig. 1-115), which extends the “*Bubo*” range well north of the Arctic Circle. Snowy owls, like its great-horned cousin, are large birds, and may weigh even more than the great-horned (up to 6.6 lbs.). The adult male is pure white, while the female and immature birds have some dark scalloping (Fig. 1-115).

Because snowy owls range north of the tree line in the arctic tundra, they nest on the ground. Being opportunistic hunters, their

prey species vary considerably, especially in winter. They feed on small mammals such as lemmings, but when available, they also feed on hares, ducks, and even other owl species. Snowy Owls, like many other owls, typically swallow their small prey whole. Their strong gastric enzymes digest the flesh, while the indigestible bones, teeth, fur, and feathers are compacted into oval **pellets**, which are regurgitated about 18-24 hours after their meal. (See Chapter 5.)



Figure 1-114. Talons of great-horned owl (*Bubo virginianus*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Claws1a>).



Figure 1-115. Female (left) & male (right) snowy owl (*Bubo scandiacus*). (Photos courtesy: http://en.wikipedia.org/wiki/File:Snowy_Owl_-_Schnee-Eule & http://en.wikipedia.org/wiki/File:Bubo_scandiacus_qtl3).

Although there are no fish owls indigenous to the Americas, there are 7 species of the genus *Bubo* that specialize in hunting fish. One of these is the brown fish owl (Fig. 1-116), which is found in the subtropical and tropical parts of Asia and some nearby islands. This large owl (up to 5 lbs.) feeds primarily on fish, frogs, and

aquatic crustaceans, but like most owls will resort to eating carrion if need be. The feet of this fish owl are adapted for catching fish and resemble those of the “eagle owls.”



Figure 1-116. Brown fish owl (*Bubo zeylonensis*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Brown_fishing_owl).

One of the more common owls we see in North Carolina is the **barred owl** (Fig. 1-117), which is one of about 15 species of “earless” owls in the genus *Strix*. Actually, earless owls hear very well, and this description simply means that have no “ear tufts” like those in the genus, *Bubo*. Barred owls are considerably smaller than the great-horned owl, and weigh in at about 2 lbs. They also have brown eyes rather than the typical yellow irises of the great-horned owl. Barred owls tend to prefer suburban neighbors rather than dense forest environments.

And here’s an interesting fact—the *major predator of the barred owl is the great-horned owl*. Since they compete for the same prey, the great-horned owl is not opposed to eliminating the competition. Barred owls, like many other species, typically hunt from a high perch overlooking an open, grassy area, where they can spot an unsuspecting vole or mouse, and swoop down quickly for the kill. They also feed on other birds, large insects, and will even venture into shallow water to snatch crayfish, fish, and salamanders. Humans

often spot barred owls because they tend to start hunting before dark.



Figure 1-117. Barred owl (*Strix varia*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Strix-varia-005>).

So what is an owlet, pigmy owl, an eagle owl, a hawk owl, or a screech owl? As the names imply, **owlets** and **pigmy owls** are small owls, many of which are in the genus *Glaucidium*, that feed primarily on large insects or other small prey. One such owl that is native to North and Central America is the **northern pigmy owl** (Fig. 1-118). This little owl is less than 6 inches long and can be found in southeastern Arizona. Unlike most owls, these little birds are **diurnal**, and hunt from dawn to dusk. To my knowledge, there are no “owlets” indigenous to the Americas, but this term is applied to a group of small Old World owls.

Before you get to thinking that this pigmy owl is the smallest owl alive, it is not. The smallest known owl is the tiny **elf owl** (Fig. 1-119), which can also be found in Arizona and New Mexico during the spring and summer. The average weight of these sparrow-sized owls is only about 1.4 ounces. They tend to nest in woodpecker holes made in the saguaro cactus or in hardwood trees. These tiny predators feed primarily on insects.



Figure 1-118. Northern (mountain) pigmy owl (*Glaucidium gnoma*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Northern_pygmy-owl).



Figure 1-119. Elf owl (*Micrathene whitneyi*). (Photo courtesy: http://guardiansofgahoole.wikia.com/wiki/File:Elf_owl_2).

Eagle owls are very large Old World members (≈ 15 species) of the genus *Bubo*, and some of these owls are even larger than the great-horned and snowy owls of North America. An example of this group would be the **Eurasian eagle owl** (Fig. 1-120), which is a very large owl, with some females weighing more than 9 lbs. Europeans are likely to claim that the Eurasian eagle owl is the largest owl on the planet, and there is no doubt it is the heaviest. Canadians and Americans might argue with limited justification that the longest owl is the **great grey owl** (Fig. 1-121), which is distributed all across the northern hemisphere. Although lighter than the eagle owl, great grey owls may be a little longer, measuring about 27 inches.



Figure 1-120. Eurasian eagle owl (*Bubo bubo*). (Photos courtesy: <http://en.wikipedia.org/wiki/File:Uhu-muc>).



Figure 1-121. Great grey owl (*Strix nebulosa*) coming at you. (Photo courtesy: http://en.wikipedia.org/wiki/File:Strix_nebulosa_in_flight).

Screech owls form a group of about 23 species within the genus *Megascops*, all of which are found only in the Americas. An example of this group is the **eastern screech owl** (Fig. 1-122), which is relatively common in eastern North America. Screech owls are small owls, having a wingspan of about 20 inches. They prey on insects, reptiles, small mammals, and small birds, and they tend to carry their prey back to their nests before eating it. Screech owls produce a wide variety of distinctive sounds, in addition to a high-pitched “screech.”



Figure 1-122. Eastern screech owl (*Megascops asio*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:EasternScreechOwl-Rufous>).

Although there are numerous species called “hawk-owls” in Indonesia and Australia, the only one indigenous to North America is the **northern hawk-owl** (Fig. 1-123), which is one of only a few owls that is at least partly diurnal. As the only member of the genus *Surnia*, it is found in the circumpolar regions of the northern hemisphere, including northern Canada and Alaska, but it does not extend into the snowy owl’s territory north of the tree line. Occasionally this owl ventures south into the northern US. It supposedly got its common name from its resemblance to the Cooper’s hawk.

The other family of Strigiformes is **Tytonidae**, which includes about 15 species of barn owls and 2 species called bay owls. **Barn owls** have large heads and a characteristic heart-shaped face. Different species of barn owls are referred to as sooty owls, masked owls, and grass owls. An example of this group is the **common barn owl** (Fig. 1-124), which has about 20 other common names, and there are many

subspecies. The common barn owl is widely distributed around the world, except in Polar Regions, deserts, northern Asia and most of Indonesia.



Figure 1-123. Northern hawk-owl (*Surnia ulula*). (Photo courtesy: <http://en.wikipedia.org/wiki/File:Surnia-ulula-002>).



Figure 1-124. Common barn owl (*Tyto alba*). (Photo courtesy: [http://en.wikipedia.org/wiki/File:Tyto_alba_British_Wildlife_Centre,_Surrey,_England8a_\(1\)](http://en.wikipedia.org/wiki/File:Tyto_alba_British_Wildlife_Centre,_Surrey,_England8a_(1))).

Unlike typical owls (Strigidae), **barn owls do not hoot**, but produce a scream that can be earsplitting at close range. Barn owls tend to prefer open land with only interspersed woodlands, where they can swoop in and snatch rodents. And, because they eat so many rodents, they serve a very useful purpose around farms. Barn owls are not only predators, but just as often prey. Few birds live more than 2 years in the wild, and most don't even make it to breeding age. Among their major predators are the great-horned owl in North America and the Eurasian eagle owl in Europe and Asia. Also, humans and feral cats take their share of barn owls.

Well that about does it for my attempt to take you all on a little “broader” tour of the wonderful and exciting world of birds. As is evident from my citations of photographs in this chapter, I have “leaned heavily” on **Wikipedia** for much of this information. I am genuinely grateful for this valuable resource.

There is just one thing left to do before we move on. I cannot write this chapter without mentioning two more of my favorite birds. I am personally fascinated with the **belted kingfisher** (Figs. 1-125 & 1-126) and with the ruby-throated hummingbird. Living on the river, I love to watch the belted kingfisher zooming and chirping over the water. And occasionally I get to witness one taking a plunge into the water to grab a fish. The kingfisher does not build the typical nest in a tree, but both parents dig a “nesting” tunnel into the riverbank, which typically slopes upward in case of rising water. I just love these little fisher birds!



Figure 1-125. Female belted kingfisher (*Megaceryle alcyon*) with dinner. (Photo courtesy: http://upload.wikimedia.org/wikipedia/commons/f/fb/Belted_Kingfisher_with_preys.jpg).



Figure 1-126. Male belted kingfisher (*Megaceryle alcyon*) with dinner. (Photo courtesy: http://en.wikipedia.org/wiki/File:Belted_Kingfisher.jpg).

The **Ruby-throated Hummingbird** (*Archilochus colubris*) (Figs. 1-127, 1-128) belongs to the family Trochilidae, and is the only species of hummingbird we see in NC. They are about 3 inches long and weigh in at about 3.7 grams (see figure 1-129). I used to say this was the only hummingbird in the southeastern US, but that may be changing. Some rufous hummingbirds of the western US may now be wintering along the Gulf Coast and in Florida.

The ruby-throated hummingbird is the smallest bird that breeds in the Eastern U.S, weighing in at about 3.75 grams (Fig. 1-129), with females being just slightly

larger (3.8 grams) than males (3.2 grams). Adults are metallic green above and greyish white below, with nearly black wings. Their slender bill can be 2 cm long. The adult **male** has an **iridescent ruby-red throat patch, trimmed in black**. Juvenile males resemble adult females, though usually with heavier throat markings. These tiny birds molt once a year in late summer.



Figure 1-127. Male Ruby-throated Hummingbird (*Archilochus colubris*). This photo was made in Raleigh, NC on April 16, 2015.



Figure 1-128. Female Ruby-throated Hummingbird (*Archilochus colubris*). This photo was made in Raleigh, NC on July 9, 2013.

Ruby-throated hummingbirds breed throughout most of eastern North America and Canadian prairies, which is the largest breeding range of any US hummingbird. These hummingbirds are migratory, spending most of the winter in southern Mexico and Central America, as far south as western Panama and the West Indies. During migration, these tiny birds can fly

non-stop 600 miles (20+ hours), across the Gulf of Mexico.



Figure 1-129. Ruby-throated hummingbirds weigh about 3.75 grams, which is about the weight of 1.5 US pennies.

Updated Migratory Pattern for Ruby-throated hummingbirds: Over the past several years, an interesting change in the migration pattern of these tiny birds has been documented. Researchers have noticed that some of these birds have given up their arduous trip across the Gulf of Mexico. Some have elected to forego this dangerous trip and over-winter along the US Atlantic coast, extending from Florida as far north as the outer banks of North Carolina (Fig. 1-130).



Figure 1-130. Summer-Winter and migratory pattern of ruby-throated hummingbird.

This is just one more example of the great adaptability of birds to a changing environment. Their ability to adapt is one

of the primary reasons why birds have been so successful as a group of animals.

Ruby-throated hummingbirds are solitary, except during a few minutes of courtship and breeding; only the female cares for the offspring. Both males and females are very aggressive toward other hummingbirds, and vigorously defend feeding territories (feeders).

Hummingbirds have one of the highest metabolic rates of any animal, with heart rates up to 1260 beats/minute, and a respiration rate of about 250 breaths/minute. During flight, oxygen consumption/gram of muscle is about 10 times greater than that seen in elite human athletes. They feed almost continuously during the day, and they can conserve energy by entering hypothermic torpor on cold nights (See page 30).

As you know, hummingbirds are primarily **nectarivores** that feed on ornithophilous¹ flowers. They supplement their diet with small insects and spiders, which are necessary for protein. Ornithophilous flowers typically have a lower sugar-content nectar containing more sucrose than many flowers pollinated by insects.

Ever heard the expression—eats like a bird? This would typically denote someone who is a light or picky eater. Well that's a myth. With their high metabolic rate, hummingbird can consume twice their body weight in nectar every day, meaning they must work continuously to keep from starving. Under normal circumstances, they can store just enough energy to survive the night before

they must start eating again. Unbelievably, if they survive fledging these little food machines with a heart rate of over 1000 bpm can live to be 9 years (females) old; more typically about 3-5 years (males).

If we only have one species in NC, where are other 449 species? By far the majority of hummingbird species occur in the tropical and subtropical regions of Central and South America, although there are some species that do migrate long distances to some cooler regions; *i.e.*, the ruby-throated hummingbird. If you want to go to “hummingbird haven,” travel to where their flowers bloom year-round—Mexico, Central America, Colombia, and the Caribbean. Most hummingbirds stay where their flowers are.

There are fewer than 25 species in the US. The most widespread species in western North America is the **Rufous Hummingbird** (*Selasphorus rufus*) (Figs. 1-131 & 1-132). These remarkable travelers have been known to migrate as far as 2000 miles from their wintering grounds in southwestern Mexico to their summer feeding areas in the western US.

More recently, the rufous hummingbird has been known to stray to the southeast rather than going to Mexico, some even showing up in Florida and along the Gulf Coast. This means they would have to migrate over the Rocky Mountains.

¹ ornithophilous = love for birds; these are flowers that are normally pollinated by birds.



Figure 1-131. Male Rufous Hummingbird (*Selasphorus rufus*). (Photo courtesy of: http://commons.wikimedia.org/wiki/File:Selasphorus_rufus1.jpg).



Figure 1-132. Female Rufous Hummingbird (*Selasphorus rufus*). (Photo Courtesy of: http://upload.wikimedia.org/wikipedia/commons/7/7b/Rufous_hummingbird_female.jpg).

The most common hummingbird in the southwestern US is the **Black-chinned Hummingbird** (*Archilochus alexandri*) (Figs. 1-133). These birds are known to hybridize with both the Anna's and Costa Hummingbirds.

Black-chinned hummingbirds are found in the Western US, as well as parts of British Columbia, and Mexico. Although they feed primarily on nectar, they also catch insects on the fly, using their long tongue. They are very adaptable birds and can be found in varied habitats from mountains to woodlands, to orchards and meadows. They mostly winter along the western coast of Mexico.



Figure 1-133. Male Black-chinned Hummingbird (*Archilochus alexandri*).

Some Hummingbird Myths

Myth #1: Hummingbirds hitch rides on the backs of Canada Geese during their fall migration.

Although this makes for a good story, it is just not true. Geese and hummers migrate at different times, and to different destinations.

Myth #2: You need to take your hummingbird feeders down in the fall so that the hummers will leave and migrate south.

Hummers start their southern migration after the autumnal equinox. Your hummingbird feeder has nothing to do with it. In fact, you should NOT take your feeder(s) in until at least two weeks after no hummingbirds have been seen. Leaving them in place is actually useful for hummers moving south through your area. It gives them a "pit stop" to refuel as they continue southward.

Myth #3: You should add red food-coloring or dye to your sugar water to attract hummingbirds.

While it is true that hummers are attracted to the color red, if your feeder has some red on it, there is no need to add coloring. In fact, there is a low potential that the food-coloring or dye might have an adverse effect on the hummingbirds.

Myth #4: Hummingbirds feed exclusively on nectar (sugar water).

While nectar does make up the bulk of their diet, hummers also catch small insects and spiders. These insects provide much needed protein, whereas nectar provides only energy. Female hummers feed insects to their young to provide protein necessary for development.

Myth #5: Hummingbirds feed only on red flowers.

Yes hummers are attracted to red flowers, but they will also feed on other flowers if nectar is available.

Myth #6: Humming birds suck nectar up through their bills.

Actually, hummers use their long tongue to dip into the nectar and pull it up into their mouth. Their tongue can move in and out of their bill numerous times per second when they are actively feeding. Hummers can consume nectar in one day equal to 1.5 to twice their body weight. Average body weight of a ruby-throated humming bird is about 3.75 grams—the approximate weight of 1.5 US pennies (see figure 1-129).

Chapter 2 • Terminology, Osteology, and Arthrology

DIRECTIONAL TERMINOLOGY

Most general directional terms (cranial, caudal, proximal, distal, dorsal, plantar, etc.) used in mammalian (quadrupedal) anatomy can be applied without confusion to the bipedal posture of the bird (Figs. 2-1 & 2-2).

The most notable exceptions are those terms applied to the pectoral appendage (forelimb *vs.* wing). The “top” of the wing is its **dorsal surface** and the “bottom” of the wing is its **ventral surface**. The “leading edge” of the wing is its **cranial border**, and the “trailing edge” is its **caudal border**. The term “palmar” is not used in birds; however, the terms **dorsal** and **plantar** are used on the more distal part of the pelvic limb, just as with mammals.

OSTEOLOGY & ARTHROLOGY

As an adaptation for flight, the skeleton of birds has been markedly lightened, largely through the **pneumatization** of various bones. The extent of pneumatization varies with the species, and in particular with its “flightiness,” *i.e.*, greatest in marathon fliers such as the albatross, and least in the flightless ratites. Prior to egg production, there is increased deposition of mineral in the bones of females; however, the degree of mineralization of the bones is reduced during periods of molting and egg production.

The **skull** of the bird, like that of mammals consists developmentally of numerous individual bones, many of which fuse during maturation of the animal. Unlike that of mammals, the avian skull has

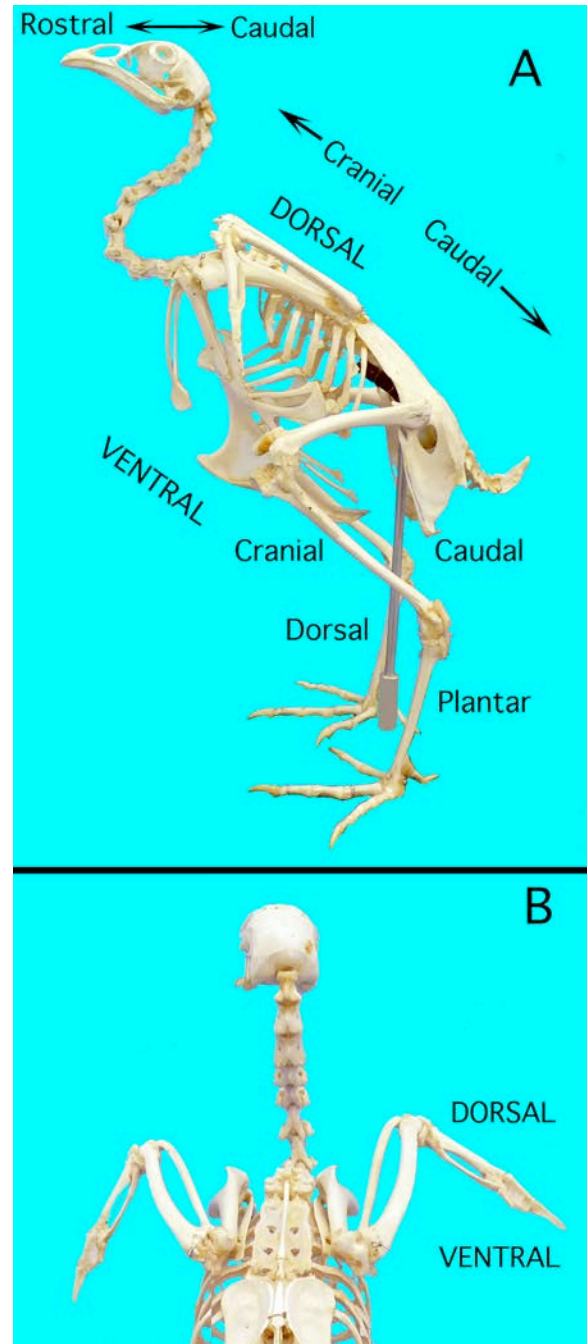


Figure 2-1. Directional terms used in avian anatomy. Chicken skeleton: (A) lateral view; (B) caudal view.

only a **single occipital condyle**, which allows the bird to rotate its head at the **atlanto-occipital articulation**. Articulation of the fused mandibles with the upper part of

the skull is quite different than in mammals. Birds retain from their reptilian ancestry a **quadrate bone**, which rotates during opening of the mouth (Fig. 2-2).

Rotation of the quadrate bone pushes rostrally on the **jugal** (zygomatic) **arch** and the interposed **pterygoid** and **palatine** bones, raising the upper beak as the lower beak is moved downward. This mechanism obviously increases the mouth-opening ability or **gape** of the bird. The skeletal basis for the upper beak is formed by the fused **premaxillae** and **nasal** bones, which are joined with the frontal bones *via* an elastic zone known as the **craniofacial hinge** (Figs. 2-2 & 2-3). This movement, **craniokinesis**, is well developed in parrots (psittacines), in which the hinge has evolved to form a synovial joint, the **nasofrontal joint**. Budgerigars in particular have a great deal of mobility in the movement of their mandibles and tongue, which comes in “handy” when they are shelling seeds.

Related to the large eyes of the bird, only a thin **interorbital septum** separates the right and left orbits. The sclera of the eye is also reinforced with a number of small bones, the **scleral ossicles**, which overlap one another to form the **sclerotic ring** (Fig. 2-2). Scleral ossicles are particularly impressive in the owl, where the sclerotic ring might be more aptly described as a sclerotic “tube” (Fig. 2-3).

Unlike the situation in mammals, the avian **hyobranchial apparatus** develops primarily from branchial components *vs.* the hyoid arches. Thus the hyoid terminology for birds is different from mammals (Fig. 2-4). The hyobranchial apparatus varies widely among avian species, and its structure is largely related to how actively the tongue participates in the prehension and the manipulation of food (Fig. 2-4).

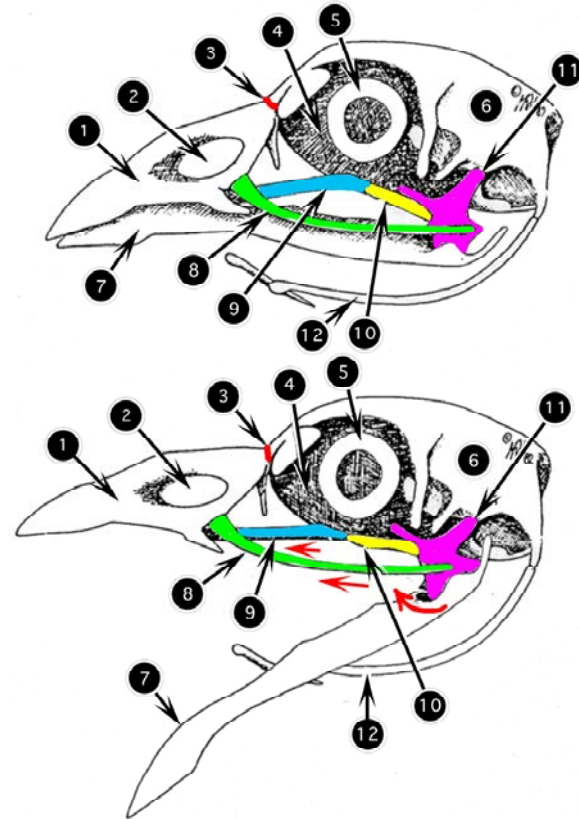


Figure 2-2. Drawing of avian skull to demonstrate craniokinesis: (1) fused premaxillae; (2) nasal aperture; (3) craniofacial hinge; (4) interorbital septum; (5) scleral ossicles forming sclerotic ring; (6) calvaria; (7) fused mandibles; (8) jugal arch; (9) palatine bone; (10) pterygoid bone; (11) quadrate bone; (12) hyobranchial apparatus.

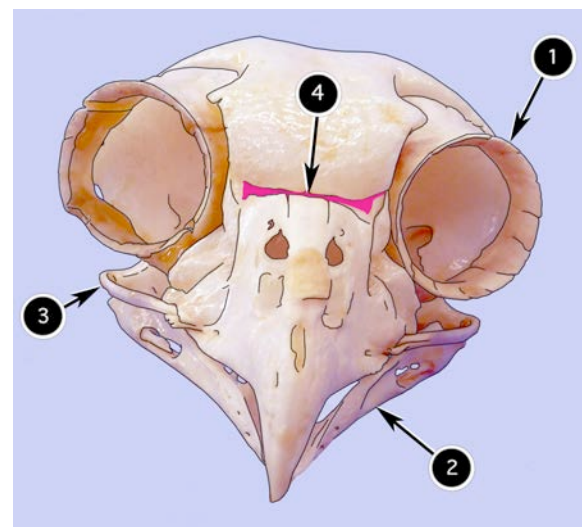


Figure 2-3. Skull of great-horned owl, rostral view: (1) tube-like scleral ossicles; (2) mandible; (3) jugal (zygomatic) arch; (4) craniofacial hinge.

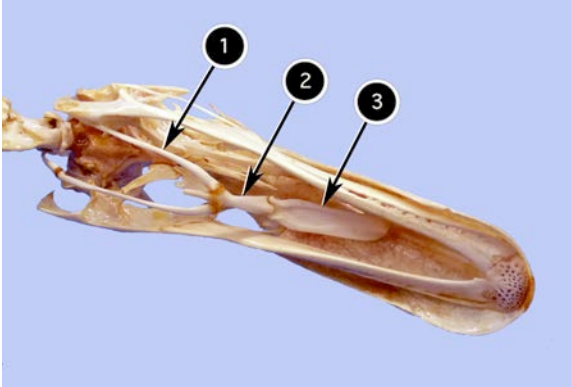


Figure 2-4. Skull of duck, ventral view showing hyobranchial apparatus: (1) ramus of hyoid; (2) os basibranchiale rostrale (basihyoid bone); (3) os entoglossum. (**Note:** Terminology for the avian hyoid apparatus is different from mammalian because avian structures are derived primarily from branchial arches, not from the hyoid arches.)

The **vertebral column** of birds is characterized by a high degree of mobility in the cervical region and a variable fusion in the thoracic, lumbar, and sacral regions. The number of **cervical vertebrae** varies greatly with the length and mobility of the neck, ranging from about 12 to 25. In the chicken, there are typically 16 cervical vertebrae, in the budgerigar 12, in ratites about 20, and in swans up to 25. The cervical vertebrae of most birds form a distinct S-shaped curve when viewed from the side (Fig. 2-5).

Because some of the more caudal cervical vertebrae bear incomplete ribs, there has been some confusion as to where the thoracic vertebrae begin. The **first thoracic vertebra** is defined as the cranial-most vertebra with a **complete rib** that articulates directly or indirectly with the sternum. In some species of birds (galliformes, columbiformes, others), 2-5 **thoracic vertebrae** fuse to form a rigid unit known as the **notarium** (os dorsale), which provides additional rigidity to this part of the vertebral column (Figs. 2-6 & 2-7). Some birds in which the thoracic vertebrae do not fuse to form a notarium include the

anseriformes and ratites. The caudal-most thoracic, lumbar, sacral, and the cranial-most caudal vertebrae of birds are fused into a rigid unit known as the **symsacrum** (Fig. 2-6).

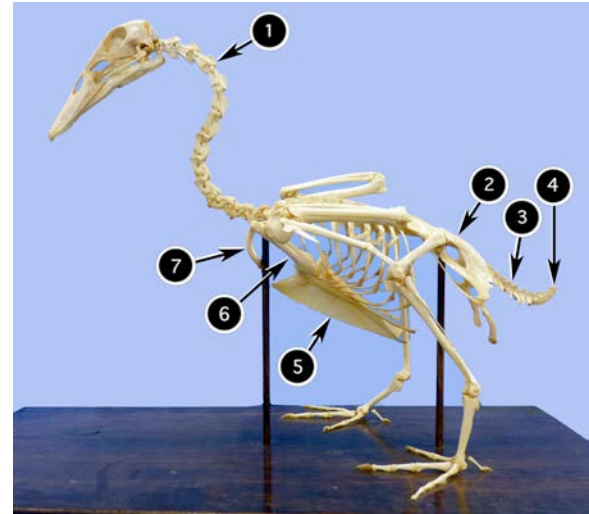


Figure 2-5. Skeleton of duck, left lateral view: (1) cervical vertebrae; (2) os coxae fused with symsacrum (3) free caudal vertebrae; (4) fused caudal vertebrae forming pygostyle; (5) keel of sternum; (6) coracoid bones; (7) furcula.

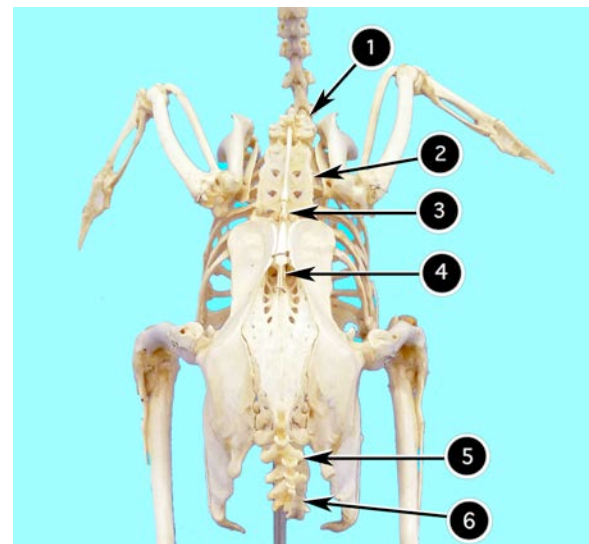


Figure 2-6. Skeleton of chicken, caudodorsal view: (1) free thoracic vertebrae; (2) fused thoracic vertebrae forming notarium; (3) free caudal thoracic vertebrae; (4) symsacrum formed by fused caudal-most thoracic, lumbar, sacral, and cranial-most caudal vertebrae; (5) free caudal vertebrae; (6) fused caudal vertebrae forming pygostyle.

Even in those species with a notarium, there are typically one or more unfused (free) thoracic vertebrae, which provide for an articulation between the notarium and synsacrum. Obviously, this more freely moveable area is a natural “weak point” in the vertebral column, and is subject to additional stress and potential subluxation, commonly known as kyphosis or “kinky back” in broilers.

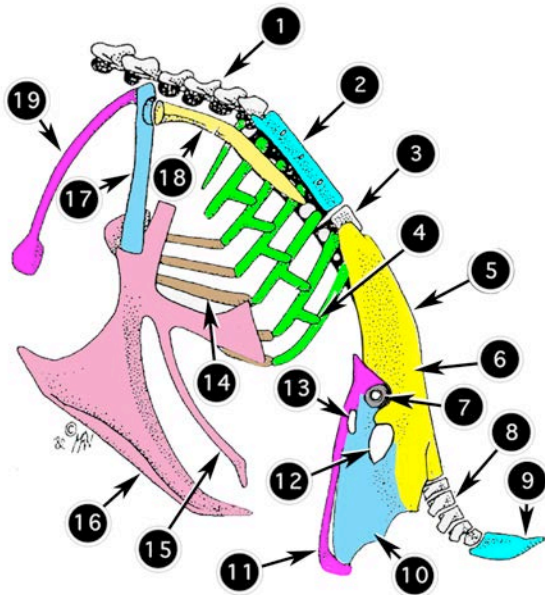


Figure 2-7. Selective components of axial skeleton, and pelvic and pectoral girdles: (1) cervical vertebrae; (2) fused thoracic vertebrae to form notarium; (3) unfused thoracic vertebra; (4) uncinat process of rib; (5) os coxae fused with synsacrum; (6) ilium; (7) acetabulum & acetabular foramen; (8) free caudal vertebrae; (9) fused caudal vertebrae to form pygostyle; (10) ischium; (11) pubis; (12) ilioischadic foramen- transmits sciatic nerve; (13) obturator foramen; (14) sternal rib; (15) caudal process of sternum; (16) carina of sternum; (17) coracoid bone; (18) scapula; (19) furcula (fused clavicles).

The complete **ribs** of birds consist of two components, **vertebral** and **sternal**. The vertebral part bears a caudally directed **uncinate process**, which serves for additional muscular attachment (Fig 2-7). The sternal part of the rib is the homologue of the costal cartilage of mammals, and articulates with the vertebral part of the rib at a cartilaginous joint. Incomplete or

“floating” ribs consist only of a vertebral component, and some of these are associated with cervical vertebrae.

Unlike that of mammals, the **sternum** of the bird is unsegmented and forms an important “cradle” for the thoracic and much of the abdominal viscera (Fig. 2-7). In birds of flight, the sternum has a prominent **carina** or keel that provides the skeletal attachment for the large muscles of flight. In contrast, the sternum of ratites is broad and flat (raft like) and does not have a carina (Fig. 2-8). The sternum has numerous large processes extending dorsally and caudally from the body of the bone.

The sternum of the bird articulates with the large **coracoid bones** of the thoracic girdle (Figs. 2-7 & 2-9). Despite its impressive size, the sternum of most birds is remarkably light, owing to its pneumatization *via* extensions of the clavicular air sac. And in some species (*viz.* swans), the trachea forms one or more loops within the “hollowed-out” sternum. (See Chapter 6).

Owing to the completely different function of the forelimbs, the **thoracic limb** of the bird is adapted for flight rather than for weight support, as in quadrupedal mammals. As already mentioned, the large **coracoid bones** connect the sternum with the shoulder joint (Fig. 2-9). These prominent bones provide important support “struts” against the downward pull of the powerful pectoral muscles.

The **clavicles** do not attach directly to the sternum, but rather in many species of birds unite medially to form a fused unit known as the **furcula** (Fig. 2-9). In other birds (*viz.* some parrots and owls), the two clavicles do not fuse, but are united by fibrous tissue. The furcula is greatly

reduced or even absent in other species of Australian parrots, including the budgerigar.

The **scapula** (Fig. 2-9) is a slender, blade-like bone, which is firmly anchored to the thoracic cage by muscles and ligaments. The **glenoid cavity**, which is formed by the scapula and coracoid bone, receives the head of the humerus to form the shoulder joint.



Figure 2-8. Skeleton of ostrich, left lateral view. Note the lack a carina or keel on its sternum.

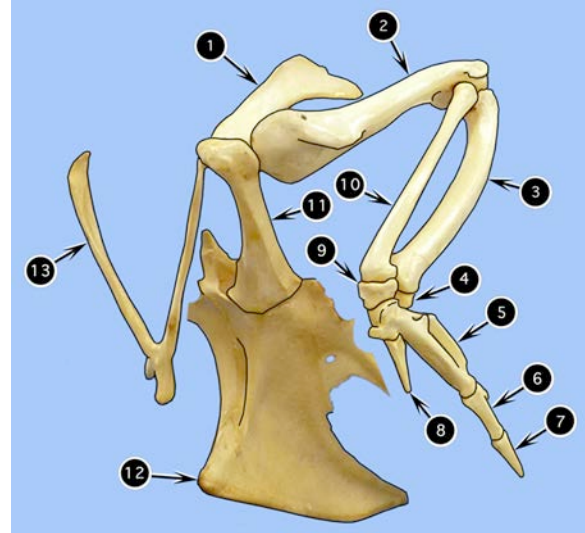


Figure 2-9. Left pectoral girdle & wing of turkey skeleton, craniolateral view: (1) scapula; (2) humerus; (3) ulna; (4) ulnar carpal bone; (5) carpometacarpal bones; (6) proximal phalanx of major digit; (7) distal phalanx of major digit; (8) alula (digit 1); (9) radial carpal bone; (10) radius; (11) coracoid bone; (12) carina of sternum; (13) furcula.

Together with the coracoid bone and scapula, the proximal end of the clavicle forms a short **triosseal canal**, through which the tendon of the **supracoracoideus muscle** passes (Fig. 2-10). During the upstroke of the wing, the supracoracoideus muscle contracts, and its tendon, which terminates on the humerus, is pulled through the triosseal canal in a pulley-like fashion to raise the humerus and wing. This action works with gravity and requires far less effort than the down-stroke, which is produced by the downward pull of the far more powerful **pectoral muscles**.

The **humerus** of most domestic species is rather short, and due to its orientation with the body, its proximal end carries **dorsal** (greater) and **ventral** (lesser) **tubercles**. The humerus of most avian species is pneumatized by an extension of the clavicular air sac, which enters the bone *via* a **pneumatic foramen**, near the ventral (lesser) tubercle. The powerful pectoral muscles attaches to the humerus along the

pectoral crest. When the wing is folded, the humerus is directed caudally alongside the thorax (Fig. 2-9).

Of the two bones that form the skeleton of the antebrachium, the **ulna** is larger and typically longer than the **radius** (Fig. 2-9). The ulna of powerful flight birds is often marked by caudal and ventral papillae (small tubercles) to which the quills of the secondary flight feathers (remiges) are anchored. When the wing is folded, the radius and ulna lie parallel to the humerus with the elbow joint fully flexed (Fig. 2-9).

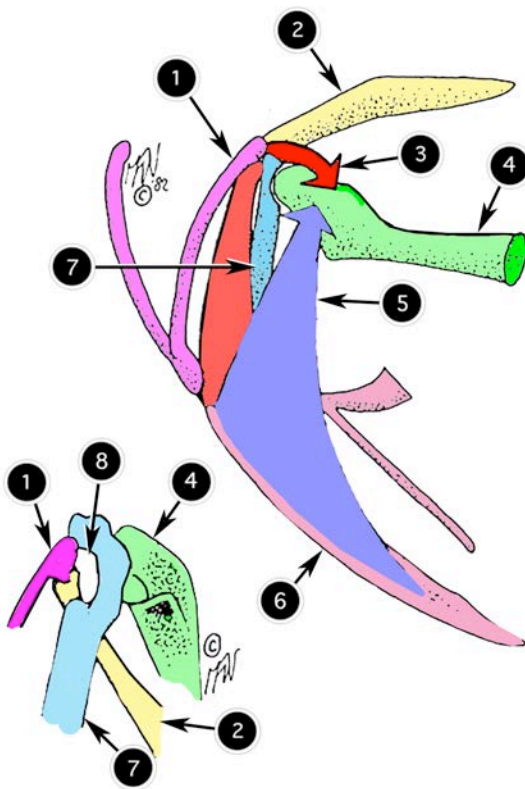


Figure 2-10. Arrangement of bones of thoracic girdle forming triosseal canal: (1) fused clavicles forming furcula; (2) scapula; (3) tendon of supracoracoideus muscle passing through triosseal canal; (4) humerus; (5) pectoral muscle; (6) sternum; (7) coracoid bone; (8) triosseal canal.

The radius and ulna articulate distally with the **radial** and **ulnar carpal bones**

respectively (Fig. 2-9). The distal carpal bones fuse with the metacarpal bones to form the **carpometacarpus**. Although some debate still exists in numbering wing digits, *Nomina Anatomica Avium* considers the bird to possess three thoracic digits: the **alula** (digit 1), a **major digit**, and a **minor digit** (Fig. 2-11). The large primary flight feathers attach to the skeletal components of the carpometacarpus and the major and minor digits. The alula can be abducted away from the other digits in some birds. In a few species of birds (*viz.* ostrich), this vestigial digit even retains a claw-- perhaps as a subtle reminder of the bird's reptilian predecessors.

Pinioning, a surgical procedure to prevent flight and escape of some captive birds, can be accomplished in several ways. One method involves amputation of a wing through the proximal part of the carpometacarpus, which is typically done in waterfowl less than 1 week of age. Another technique involves tenectomy of the extensor carpi radialis at the level of the carpus, which will prevent the bird from bringing its primary flight feathers into action. Any pinioning technique should be done **bilaterally** to prevent clumsy flight attempts that could result in injury to the bird.

With the exception of the ratites, the two **os coxae** of the pelvis do not fuse ventrally along a pelvic symphysis (Fig. 2-7). As previously mentioned, however, the two ilia do fuse with the synsacrum to form a single large pelvic bone. Caudal to the acetabulum, the **ilium** (caudodorsally) and the **ischium** (cranioventrally) surround the **ilioischadic foramen** through which the sciatic nerve passes (Fig. 2-12).

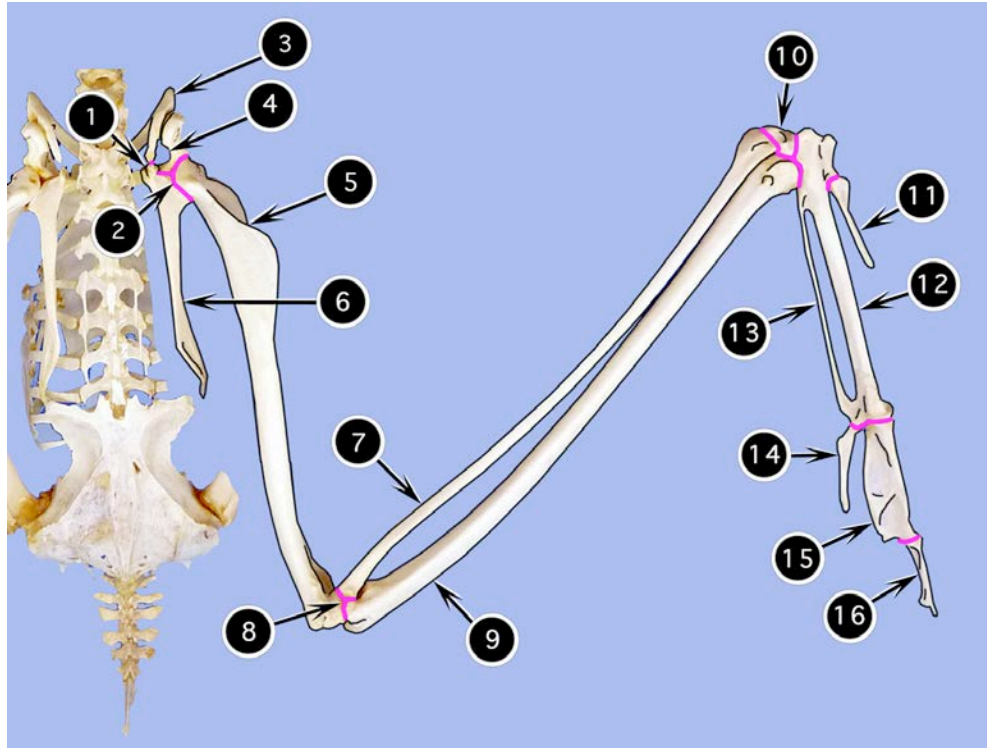


Figure 2-11. Skeleton of right wing of osprey, dorsal view: (1) acromion of scapula articulating with clavicle; (2) glenoid cavity, formed by scapula & coracoid bone; (3) clavicle; (4) triosseal canal for tendon of supracoracoideus muscle; (5) humerus; (6) scapula; (7) radius; (8) elbow (cubital) joint; (9) ulna; (10) radial carpal bone; (11) alula (digit 1); (12) carpometacarpal bone of major digit; (13) carpometacarpal bone of minor digit; (14) proximal phalanx of minor digit; (15) proximal phalanx of major digit; (16) distal phalanx of major digit.

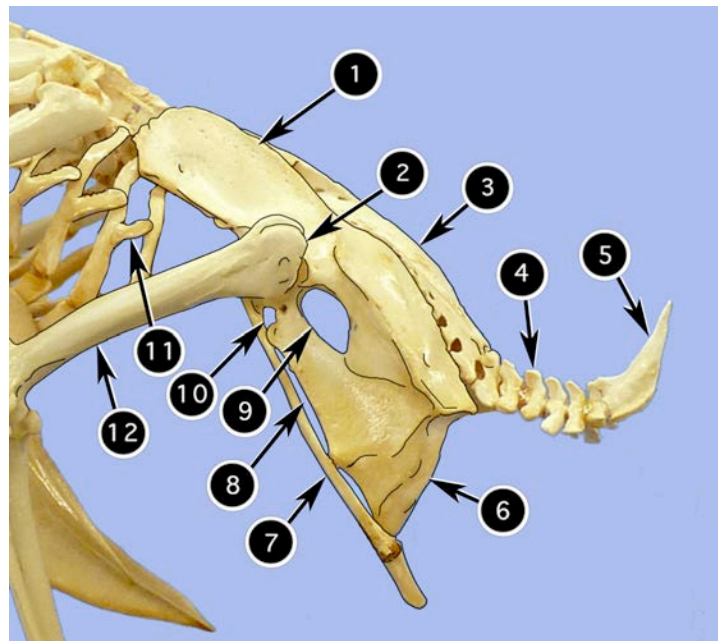


Figure 2-12. Skeleton of pelvic area of turkey, left lateral view: (1) ilium; (2) greater trochanter of femur; (3) synsacrum; (4) caudal vertebrae; (5) pygostyle; (6) ischium; (7) pubis; (8) ischiopubic fenestra; (9) ilioischadic foramen for passage of sciatic nerve; (10) obturator foramen; (11) uncinat process of rib; (12) femur.

The **obturator foramen** is located ventral to the acetabulum, between the ischium and **pubis**, which is typically a long slender bone in the bird (Fig. 2-12). Further ventrally there is another elongated window between the ischium and pubis, which is the **ischiopubic fenestra**. The open space between the pubic bones increases when birds are laying, and by palpation of this distance, one can estimate roughly the egg laying status of a pullet. As bipedal animals, birds must support all of their body weight on their pelvic limbs.

The **acetabulum**, the floor of which is perforated at the **acetabular foramen**, receives the head of the femur, while the greater trochanter also articulates with a pelvic projection located dorsal to the acetabulum. This process is known as the **antitrochanter**, and its secondary articulation with the femur limits the degree of abduction allowed at the **coxal joint** (Fig. 2-13). The internal surface of the pelvis is excavated by an extensive **renal fossa**, which has several recesses that accommodate different divisions of the kidney and other structures.

The **femur** of the bird is similar to that of mammals, and much shorter than the **tibiotarsus**, which is formed by the fusion of the tibia and proximal tarsal bones (Fig. 2-14). The **fibula** is typically reduced to a splinter of a bone along the lateral side of the **tibiotarsus**. One problem that is now clinically recognized in young ostriches is a developmental rotation of the tibiotarsal bone. Both the femur and tibiotarsus can be used to harvest bone marrow in most birds; however, the femur of most raptors is pneumatized. The **patella** articulates with the patellar groove (femoral trochlea); however, it is considered a sesamoid bone of the femorotibialis muscle in birds. Well-

developed, **medial** and **lateral menisci** are present in the genual joint.

The proximal end of the tibiotarsus has **cranial** and **lateral cnemial**¹ crests with a groove between them. The distal end of the **tibiotarsus** forms roller-like **medial** and **lateral condyles**, which articulate at the **intertarsal joint** with respective cotylae² on the proximal end of the **tarsometatarsus**. Associated with the intertarsal joint of some species there are one or two **menisci**.

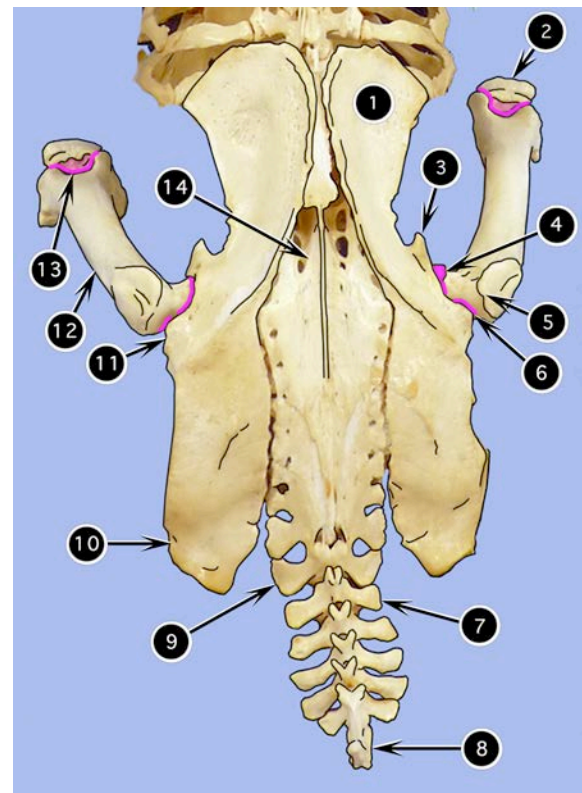


Figure 2-13. Pelvic skeleton of turkey, dorsal view: (1) ilium; (2) patella; (3) preacetabular tubercle; (4) head of femur (coxal joint); (5) greater trochanter of femur; (6) articulation of femur with antitrochanter of pelvis (part of coxal joint); (7) caudal vertebrae; (8) pygostyle; (9) caudal vertebra fused with synsacrum; (10) ischium; (11) antitrochanter of pelvis (12) body of femur; (13) femoropatellar joint.

¹ cnemial- (ne-me-al) of or pertaining to the “shin” or shin bone

² cotyla- distinct cavitation, deeper than a fossa; *i.e.*, the acetabulum is a cotyloid cavity.

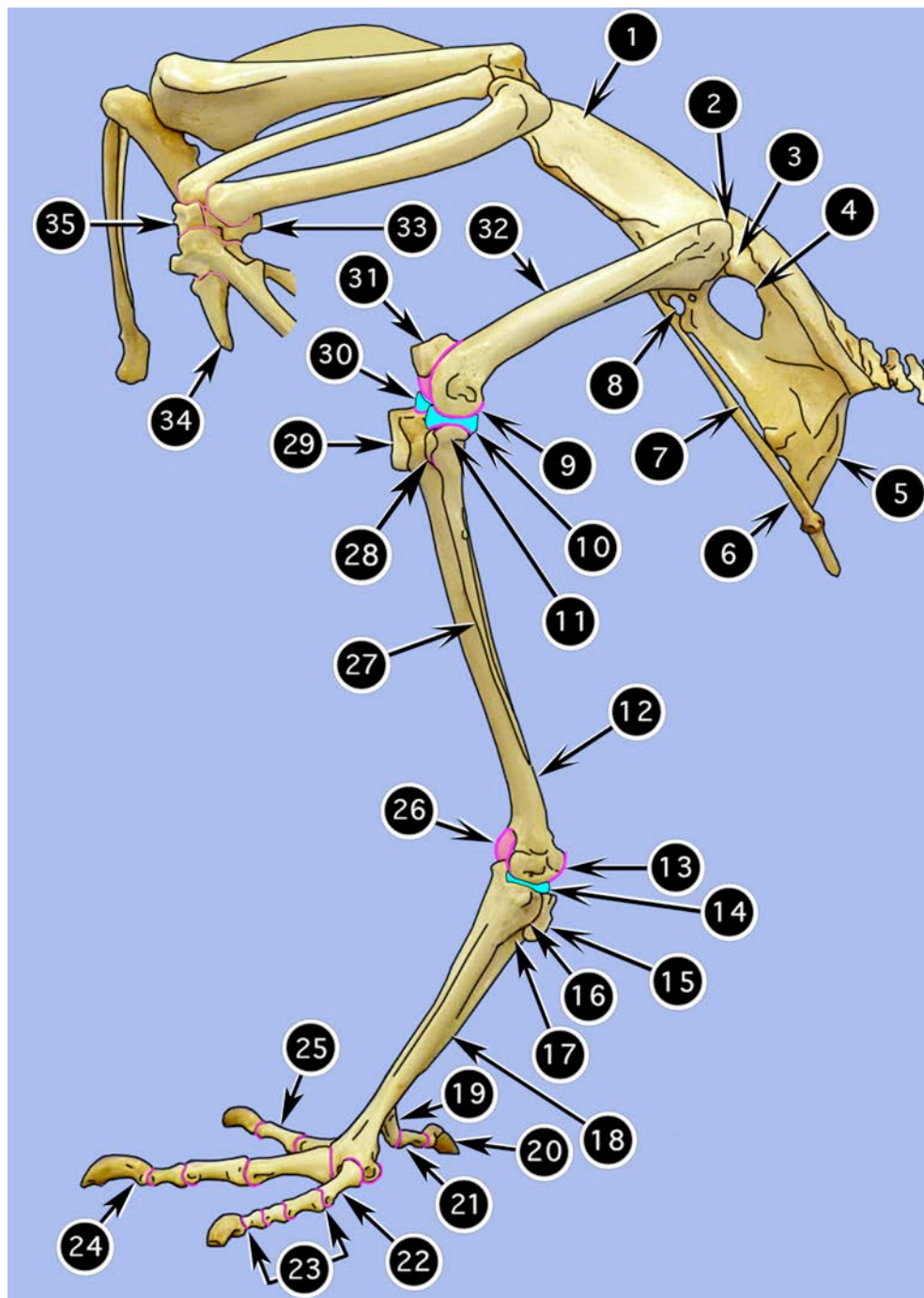


Figure 2-14. Pelvic limb skeleton of turkey, lateral view: (1) ilium; (2) greater trochanter of femur; (3) antitrochanter; (4) ilioischadic foramen; (5) ischium; (6) pubis; (7) ischiopubic fenestra; (8) obturator foramen; (9) lateral condyle of femur; (10) lateral meniscus of genual joint; (11) head of fibula; (12) body of tibiotarsus; (13) lateral condyle of tibiotarsus; (14) lateral meniscus of intertarsal joint; (15) medial hypotarsal crest; (16) lateral hypotarsal crest; (17) hypotarsal groove; (18) body of tarsometatarsus (fusion of metatarsal bones 2-4); (19) metatarsal bone 1; (20) distal phalanx of digit 1; (21) proximal phalanx of digit 1; (22) proximal phalanx of digit 4 (5 phalanges); (23) middle phalanges of digit 4; (24) distal phalanx of digit 3; (25) middle phalanx of digit 2; (26) medial condyle of tibiotarsus; (27) body of fibula; (28) lateral cnemial crest; (29) cranial cnemial crest of tibiotarsus; (30) medial meniscus of genual joint; (31) patella; (32) body of femur; (33) ulnar carpal bone; (34) alula; (35) radial carpal bone.

In the chicken, only a lateral meniscus is present, while in the turkey and psittacines, both medial and lateral menisci are well developed. The intertarsal joint is frequently examined in the processing plant as part of routine meat inspection.

The **tarsometatarsus** is formed by the fusion of the distal tarsal bones and metatarsal bones 2-4 (Fig. 2-14). Metatarsal 1 is a small bone, attached by ligaments to the medial aspect of the tarsometatarsus. The plantaroproximal aspect of the tarsometatarsus in most birds features a prominent groove, the **hypotarsus**, which accommodates the digital flexor tendons. Some galliform birds (chicken, turkey) have a prominent calcaris process projecting from medial border of the tarsometatarsus, which is particularly well developed in the male. The calcaris process forms the osseous core of the “spur” or calcar, which can be used as an effective offensive weapon.³

Birds typically retain **pelvic digits 1-4**, but unlike mammals, the digits contain a variable number of phalanges. Each digit contains one more phalanx than its number; *i.e.*, digit 1 has 2 phalanges, digit 2 has 3, digit 3 has 4, and digit 4 has 5.⁴ It appears that the more time birds spend walking (*vs.* flying or swimming), the fewer digits they retain. Most species retain all four digits; however, big walker-runners like the ostrich have, like the horse, disposed of some unnecessary digits. The **ostrich** has only two toes- one big one, **digit 3** (4 phalanges) and a smaller, lateral one, **digit 4** (5

phalanges); the lateral digit of the ostrich does not even retain the claw (Fig. 2-15).

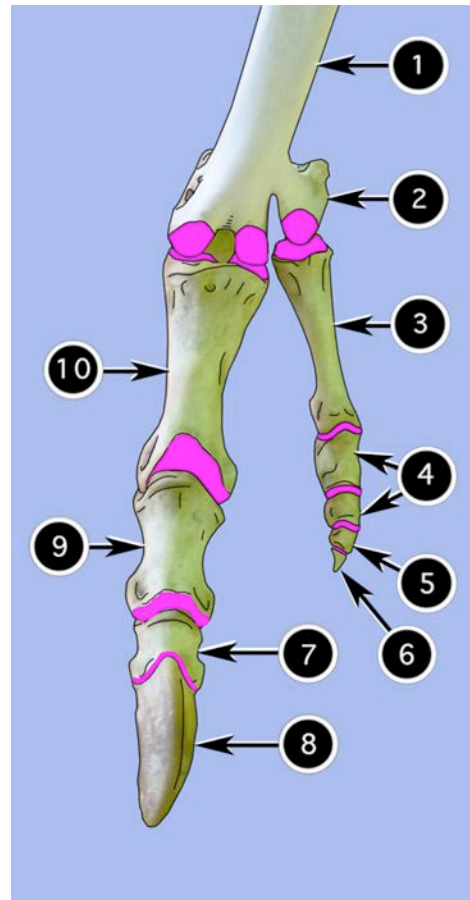


Figure 2-15. Pelvic digits of ostrich, dorsal view: (1) metatarsal bone 3; (2) metatarsal bone 4; (3) proximal phalanx of digit 4; (4) middle phalanges of digit 4; (5) distal middle phalanx of digit 4; (6) distal phalanx of digit 4; (7) distal middle phalanx of digit 3; (8) distal phalanx of digit 3; (9) middle phalanx of digit 3; (10) proximal phalanx of digit 3.

Although most birds retain all four pelvic digits, there is obvious variation in how the digits are directed. In most birds, such as the chicken, digit 1 is directed plantarly, while digits 2-4 radiate in a more dorsal direction. A familiar variation is present in parrots and some other birds in which digit 4 is rotated to join digit 1 in a plantar orientation. The 3-1 orientation appears to work best for walking, while the 2-2 modification gives an advantage for climbing and clinging to vertical surfaces.

³ Having had my forehead bloodied by a rooster as a child while trying to remove a string from a hen's foot, I speak from personal experience.

⁴ This little bird digit formula comes in handy when you are faced with the uncommon dilemma of trying to figure out which digits a particular bird retains; *i.e.*, count the phalanges and subtract 1.

More about the avian skull: Now that we have looked at an overview of the avian skeleton, we will take a closer look at the unique skull of birds. The following figures use the skull of the duck to identify some of the more salient structures and bones of the skull (Figs. 2-16, 2-17, 2-18, & 2-19). Unless a moveable joint remains, the bones of the avian skull fuse very early in development, leaving no clear suture lines in the adult skull.

As mentioned in Chapter 1, ratites represent a more primitive order of birds (Struthioniformes), with only a few remaining members (Figs. 1-1 & 1-2). Ratites belong to the superorder **Paleognathae**, meaning “old jaw.” In these birds, certain bones of the skull do not fuse in the same way those of the more modern superorder **Neognathae**. Figures 2-20, 2-21, 2-22 & 2-23 show the arrangement of the bones in the ostrich skull for comparison with those of the duck or other more modern birds.

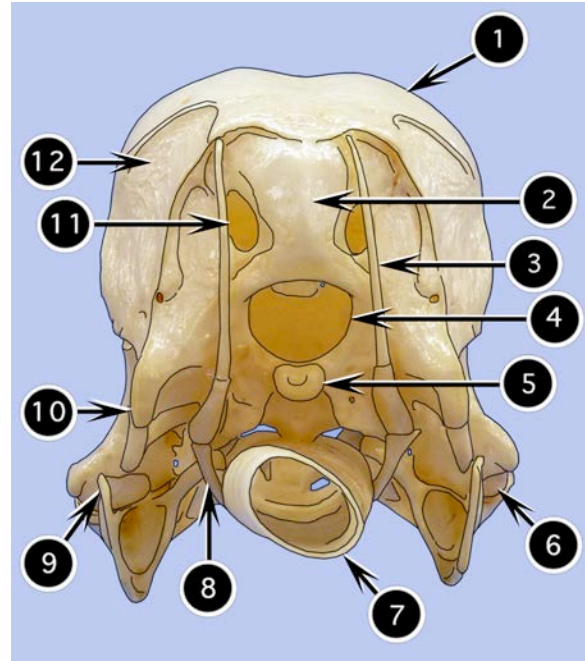


Figure 2-16. Occipital region of duck skull, caudal view: (1) frontal bone; (2) occipital bone; (3) ramus of hyobranchial apparatus; (4) foramen magnum; (5) occipital condyle; (6) articular fossa of mandible; (7) trachea; (8) ramus of hyobranchial apparatus continued; (9) angular process of mandible; (10) tympanic wing of occipital bone; (11) foramen for external occipital vein; (12) parietal bone.

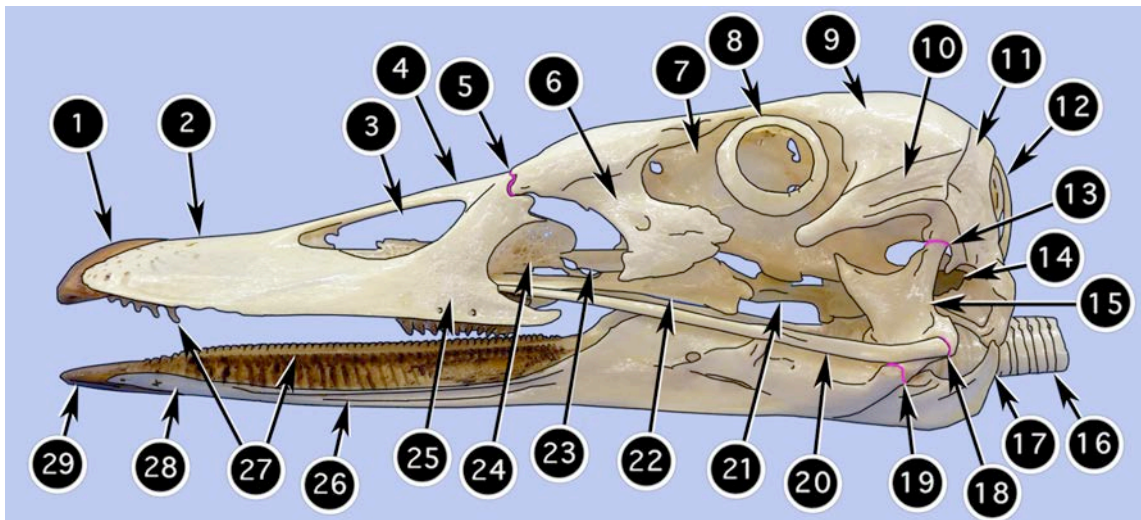


Figure 2-17. Skull of duck, left lateral view: (1) maxillary nail of rhamphotheca; (2) premaxilla; (3) nasal aperture; (4) nasal bone; (5) craniofacial hinge; (6) lacrimal bone; (7) interorbital septum; (8) scleral ossicles; (9) frontal bone; (10) temporal bone; (11) parietal bone; (12) ramus of hyobranchial apparatus; (13) quadratotemporal joint; (14) external acoustic opening; (15) quadrate bone; (16) trachea with overlapping cartilages (complete rings); (17) angular process of mandible; (18) quadratozygomatic joint; (19) quadratomandibular joint; (20) jugal (zygomatic) arch; (21) pterygoid bone; (22) palatine bone; (23) vomer; (24) ethmoid bone; (25) maxilla; (26) mandible; (27) keratinized lamellae along edges of upper & lower bills (partly removed); (28) dental bone; (29) mandibular nail of rhamphotheca.

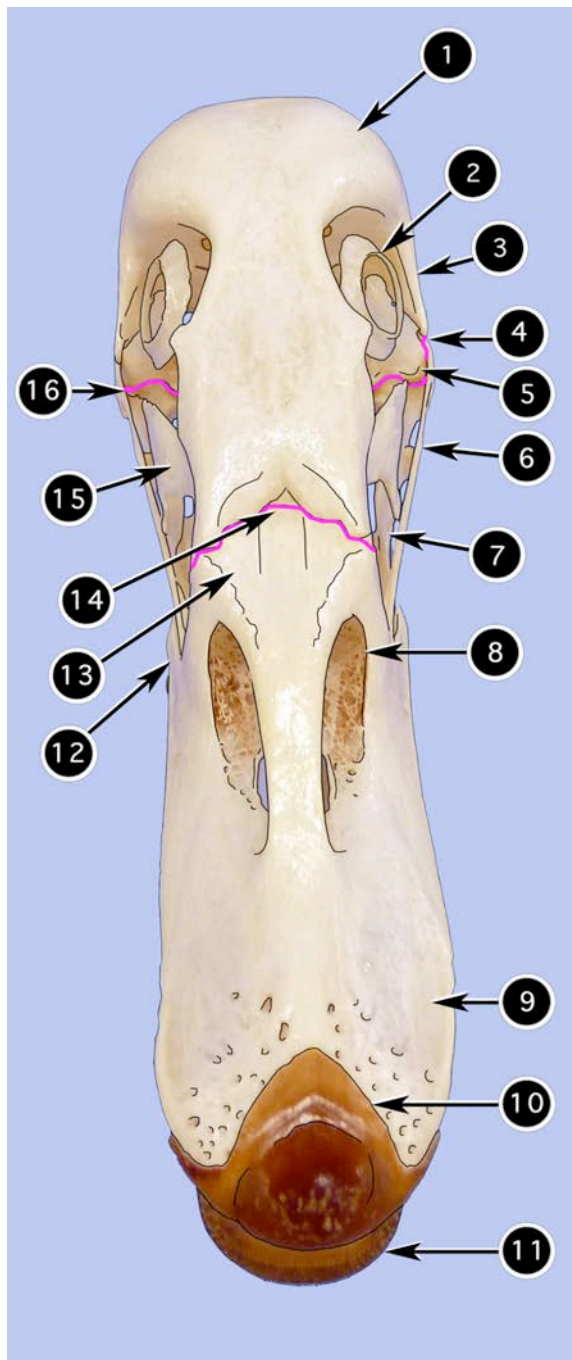


Figure 2-18. Skull of duck, rostradorsal view: (1) frontal bone; (2) scleral ossicles; (3) temporal bone; (4) quadratozygomatic joint; (5) quadrate bone; (6) zygomatic (jugal) arch; (7) mandible; (8) nasal aperture; (9) premaxilla; (10) maxillary nail; (11) mandibular nail; (12) maxilla; (13) nasal bone; (14) craniofacial hinge; (15) lacrimal bone; (16) quadratomandibular joint.

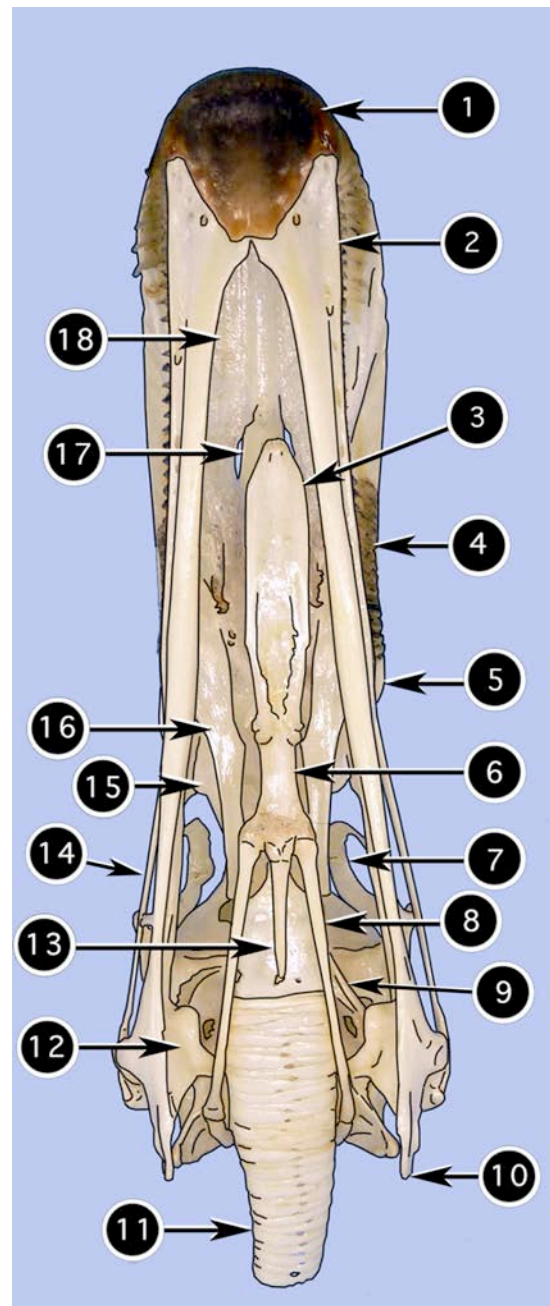


Figure 2-19. Skull of duck, ventral view: (1) mandibular nail; (2) dental bone; (3) os entoglossum; (4) keratinized lamellae along edges of upper bill (partly removed); (5) maxilla; (6) basibranchiale rostrale (basihyoid bone); (7) scleral ossicles; (8) ramus of hyobranchial apparatus; (9) pterygoid bone; (10) angular process of mandible; (11) trachea; (12) quadrate bone; (13) os basibranchiale caudale (urohyoideum); (14) zygomatic (jugal) arch; (15) frontal bone; (16) palatine bone; (17) vomer; (18) premaxilla.

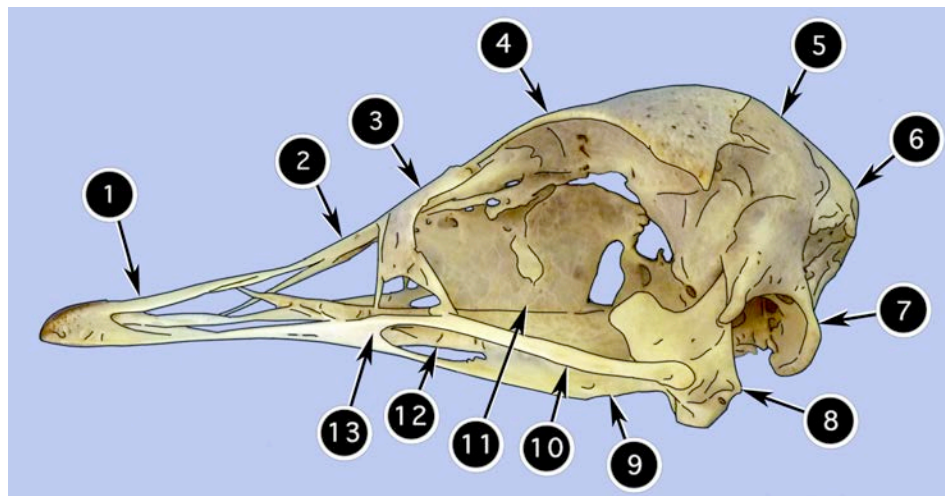


Figure 2-20. Skull of ostrich without mandibles, left lateral view: (1) premaxilla; (2) nasal bone; (3) lacrimal bone; (4) frontal bone; (5) parietal bone; (6) occipital bone; (7) temporal bone; (8) quadrate bone; (9) pterygoid bone; (10) zygomatic (jugal) arch; (11) sphenoid bone; (12) palatine bone; (13) maxilla.

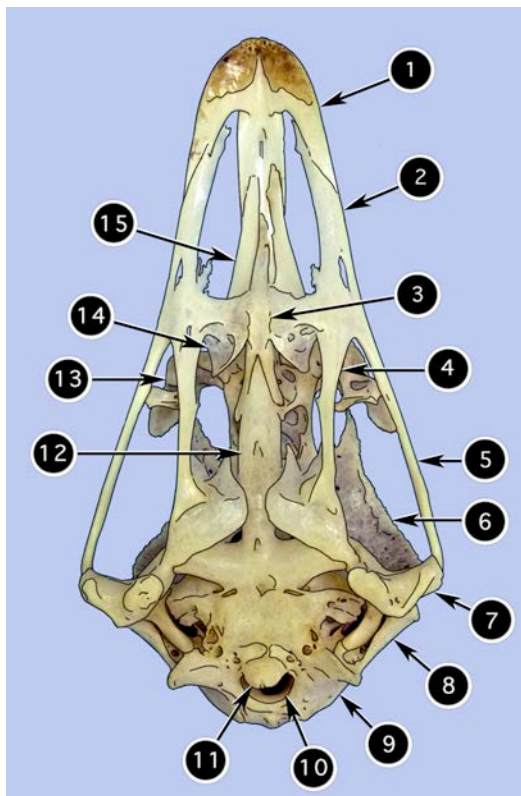


Figure 2-21. Skull of ostrich without mandibles, ventral view: (1) premaxilla; (2) maxilla; (3) vomer; (4) pterygoid bone; (5) zygomatic (jugal) arch; (6) frontal bone; (7) quadrate bone; (8) temporal bone; (9) occipital bone; (10) foramen magnum; (11) occipital condyle; (12) sphenoid bone; (13) lacrimal bone; (14) palatine bone; (15) nasal bone.

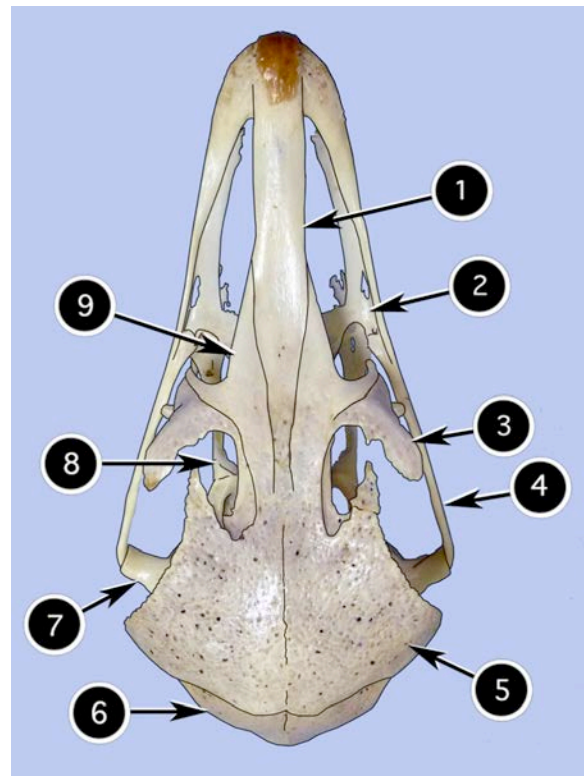


Figure 2-22. Skull of ostrich without mandibles, dorsal view: (1) premaxilla; (2) maxilla; (3) lacrimal bone; (4) zygomatic (jugal) arch; (5) frontal bone; (6) parietal bone; (7) quadrate bone; (8) pterygoid bone; (9) nasal bone.

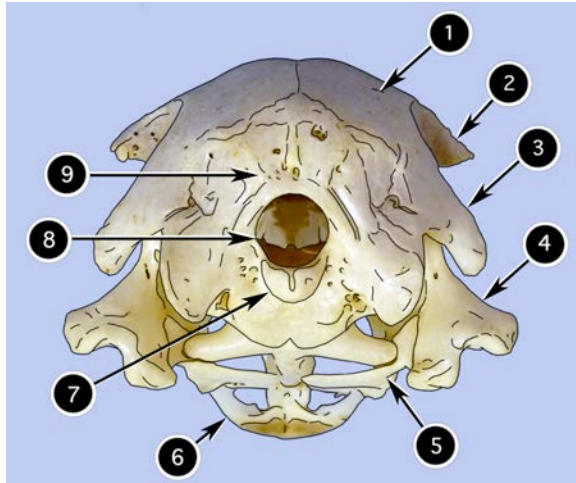


Figure 2-23. Skull of ostrich without mandibles, caudal view: (1) parietal bone; (2) frontal bone; (3) temporal bone; (4) quadrate bone; (5) pterygoid bone; (6) premaxilla; (7) occipital condyle; (8) foramen magnum; (9) occipital bone.

The following figures show the skulls of two species of psittacine birds, the **cockatiel** (Fig. 2-24) and the **white cockatoo** (Fig. 2-25).

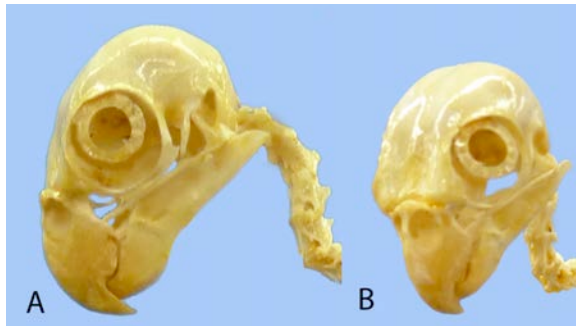


Figure 2-24. Skull of cockatiel (*Nymphicus hollandicus*): (A) left lateral view; (B) left rostralateral view.

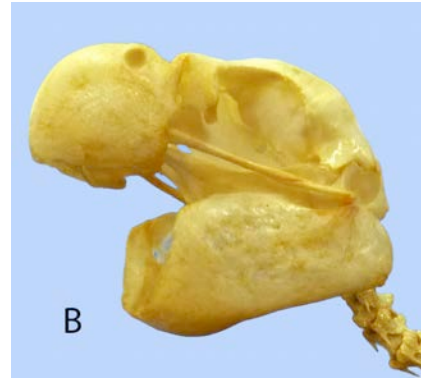
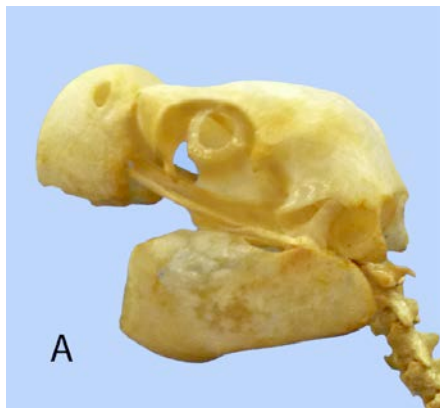


Figure 2-25. Skull of white cockatoo (*Cacatua alba*): (A) left lateral view; (B) left rostralateral view.

Figure 2-26 shows the skull of the **common toucan**. There are some 40 species of toucans belonging to the order **Piciformes**, which also includes woodpeckers. Toucans are neotropical birds belonging to the family **Ramphastidae**.

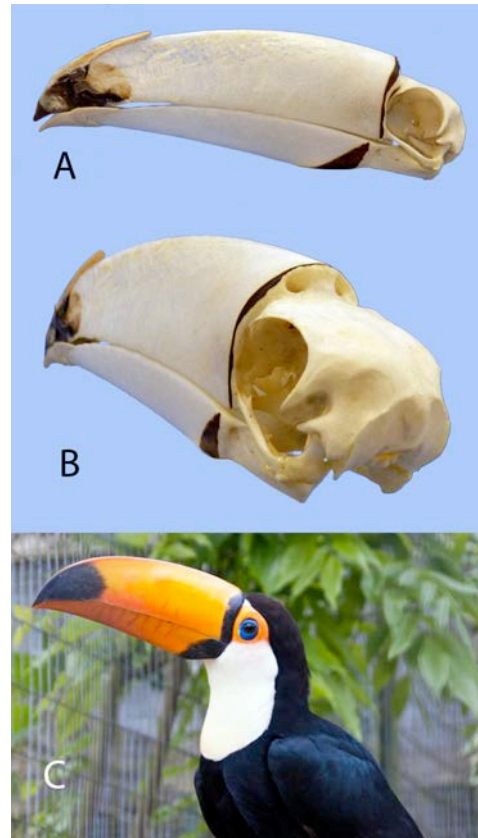


Figure 2-26. Skull of common toucan (*Ramphastos toco*): (A) left lateral view; (B) left caudolateral view; (C) photo of common toucan courtesy of: http://en.wikipedia.org/wiki/File:Ramphastos_toco-Birdworld_Farnham_Surrey_England-8a.jpg.

The following figures show the skulls of the **red-shouldered hawk** (Fig 2-27), the **osprey** (Fig. 2-28), the **turkey vulture** (Fig. 2-29), the **barred owl** (Fig. 2-30), the **great-horned owl** (Fig. 2-31), and the **eastern screech owl** (Fig. 2-32).



Figure 2-27. Skull of red-shouldered hawk (*Buteo lineatus*), left lateral view.

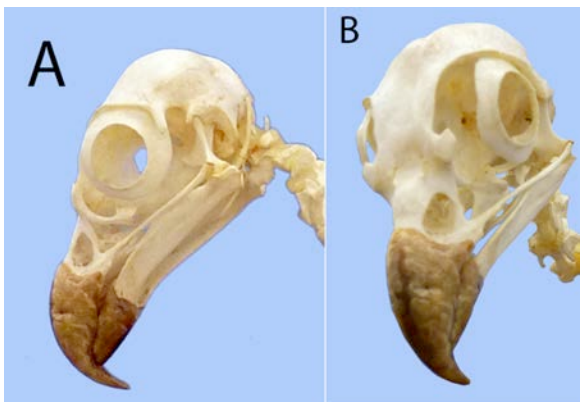


Figure 2-28. Skull of osprey (*Pandion haliaetus*): (A) left lateral view; (B) left rostralateral view.



Figure 2-29. Skull of turkey vulture (*Cathartes aura*): (A) left lateral view; (B) left rostralateral view.

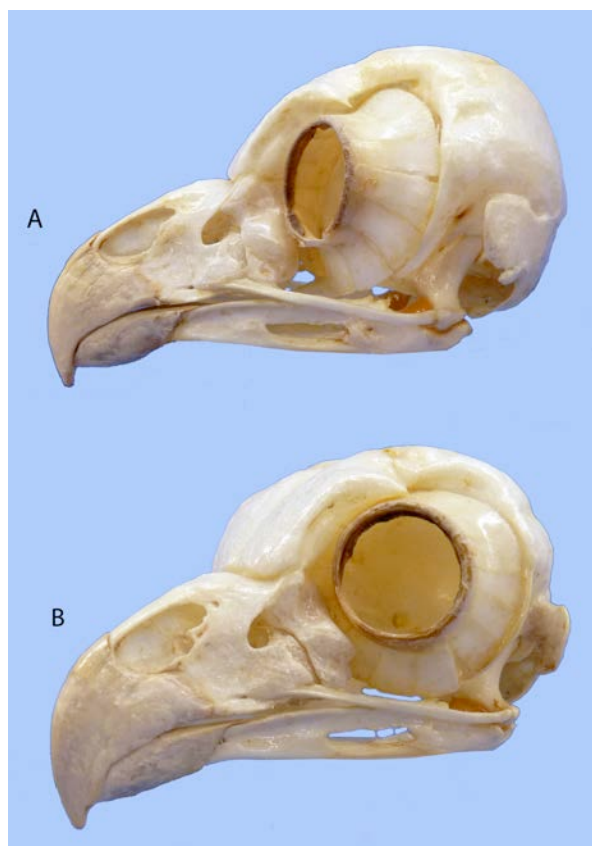


Figure 2-30. Skull of barred owl (*Strix varia*): (A) left lateral view; (B) left rostralateral view.

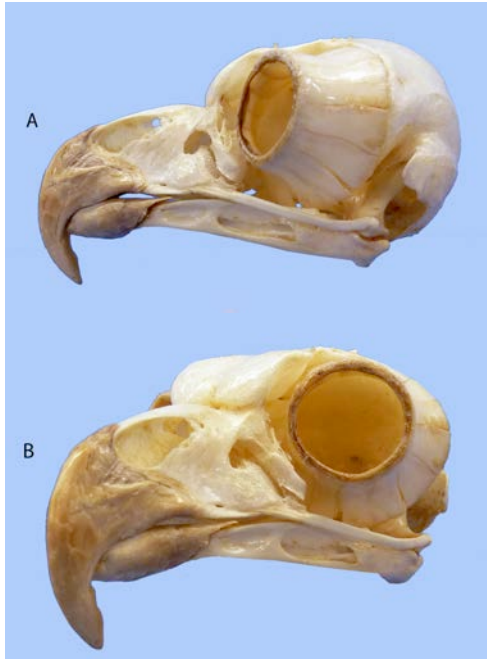


Figure 2-31. Skull of great-horned owl (*Bubo virginianus*): (A) left lateral view; (B) left rostralateral view.



Figure 2-32. Skull of eastern screech owl (*Megascops asio*): (A) left lateral view; (B) left rostralateral view.

The following figures show the skulls of the **domestic chicken** (Fig. 2-33), the **domestic turkey** (Fig. 2-34), and the common pigeon (Fig. 2-35).



Figure 2-33. Skull of domestic chicken (*Gallus gallus domesticus*), left lateral view.

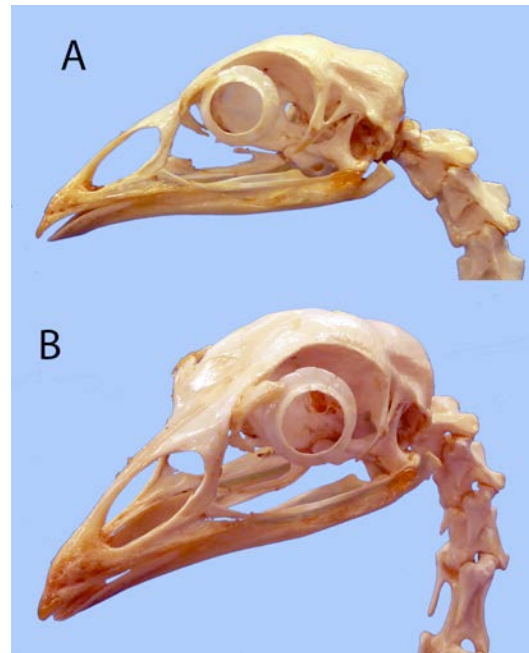


Figure 2-34. Skull of domestic turkey (*Meleagris gallopavo*): (A) left lateral view; (B) left rostralateral view.



Figure 2-35. Skull of common pigeon (*Columba livia*), left lateral view.

The following figures show the skull of the **African pigmy goose** (Fig. 3-36), a **crane** of unknown species (Fig. 3-37), and the **ruby-throated hummingbird** (Fig. 3-38).

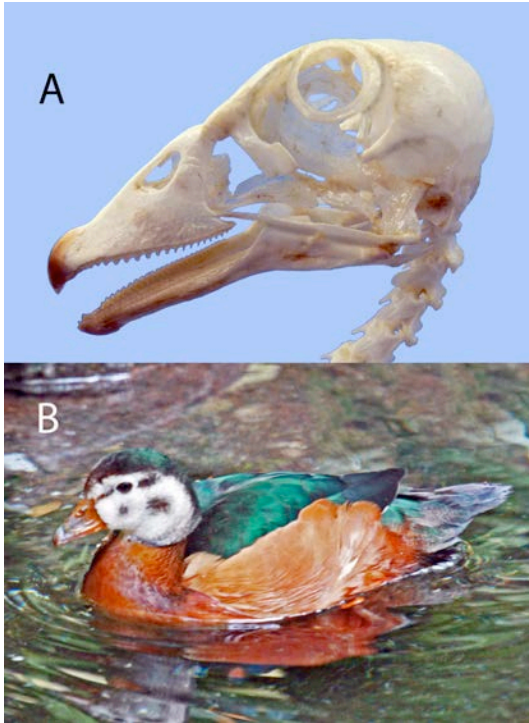


Figure 2-36. Skull of African pigmy goose (*Nettapus aurituslivia*): (A) left lateral view; (B) female African pigmy goose, which is actually a small perching duck. (Photo courtesy: http://en.wikipedia.org/wiki/File:African_Pygmy_Goose_female_RWD.jpg).



Figure 2-37. Skull of crane of unknown species, left lateral view.



Figure 2-38. Skull of ruby-throated hummingbird (*Archilocus colubris*), left lateral view.



Wood sculpture of female belted kingfisher
James E. Smallwood, 2013

Chapter 3 • Evolution of Birds and Integument

EVOLUTION OF BIRDS

Following its original discovery in Germany in 1861, the fossilized remains of *Archaeopteryx* (Fig. 3-1) enjoyed more than 100 years of being generally accepted by paleontologists as the predecessor of modern birds. Yet in recent years, the discoveries of some small, feathered dinosaurs in China have brought in to question whether *Archaeopteryx* is the ancestor of modern birds or is it just an “early bird.” With its long, wing-like forelimbs, there is no argument that *Archaeopteryx* is a bird, but is it the earliest ancestor of modern birds?



Figure 3-1. *Archaeopteryx lithographica*, specimen displayed at the *Museum für Naturkunde* in Berlin. (Photo courtesy: [http://en.wikipedia.org/wiki/File:Archaeopteryx_lithographica_\(Berlin_specimen\)\)](http://en.wikipedia.org/wiki/File:Archaeopteryx_lithographica_(Berlin_specimen))).

What do all birds have in common? **Feathers**, of course. Feathers were originally believed to represent *modified scales*, and the transformation from scale to feather is thought to have evolved initially to

provide insulation against cold and to allow birds to maintain a high body temperature (105-109°F). This theory has more recently been questioned, and it now appears that feathers evolved independently as hollow tubular extensions of skin, not from gradual modification of a scale.¹ Birds are now believed to have evolved from small dinosaurs² (Fig. 3-2) that were able to slowly evolve feathers, which were especially welcomed with the coming of an ice age. Feathers on the forelimbs also came in handy as “bug swatters” in their running pursuit of large flying insects. Well, one thing led to another, and after a million or so years those little dinosaurs were “gliding” along between strides, and well, you know the rest of the story.³



Figure 3-2. Model of *Sinosauropteryx* created for *National Geographic* magazine in 1996, when this dinosaur was announced as the first to have feathers. The artist, Brian Cooley, worked closely with paleontologist Philip Currie to create this reconstruction.

¹ <https://www.youtube.com/watch?v=p8B0Ug2IXEQ>

² The discovery of two turkey-sized, feathered dinosaur fossils (dated at about 130 million years) in China strengthened the theory that birds evolved from dinosaurs (see *National Geographic*, July, 1998).

³ The fact that feathers just happened to enable birds to fly was an unexpected, yet not insignificant, “spin-off” of this evolutionary transformation.

When these “feathered dinosaurs” were originally discovered in China in the 1990s, it naturally raised questions among scientists about just how *Archaeopteryx*, the earliest known bird, fit into the evolutionary story of birds, and even what it meant to be a bird. The “*Archaeopteryx*” group argued that these newly discovered “feathered dinosaurs” weren’t old enough to be the ancestors of birds because they could not be dated back as far as their beloved icon, *Archaeopteryx*, which could be dated to about 150 million years.

This debate went on for more than ten years, but then in about 2008, more feathered dinosaurs, including one called *Anchiornis* (Fig. 4-3), were discovered also in China. And, if that weren’t enough, these fossils were dated to greater than 150 million years, and thus pre-date *Archaeopteryx*.

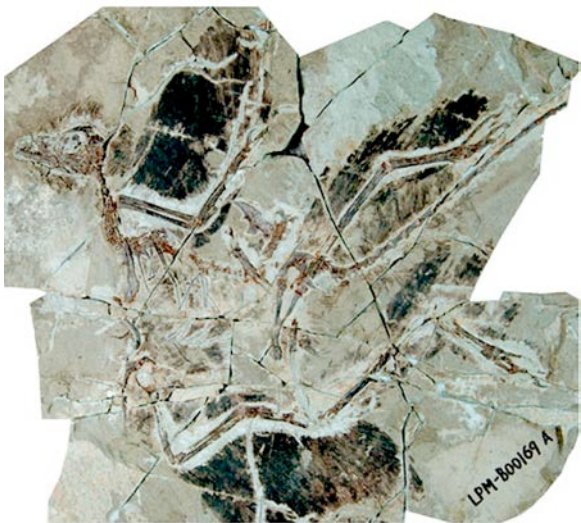


Figure 3-3. *Anchiornis*, a very bird-like feathered dinosaur described in 2008, has been confirmed to be older than *Archaeopteryx*. (Photo courtesy of Xu Xing/IVPP).

Old ideas die hard, especially when that’s the way its been taught for a hundred years, but it looks like the long-dominant theory that modern birds evolved from

Archaeopteryx is just not true.⁴ Figure 3-4, taken from the July, 1998 issue of the *National Geographic Magazine*, gives a beautiful depiction of how modern birds are thought to have evolved from dinosaurs, with *Archaeopteryx* being just one step along the way from dinosaurs to modern birds.

FEATHERS

In addition to serving as insulation and in flight, feathers are used in nest building, and in displays of aggression and courtship behaviors. The **basal part** of the feather is the attached end, whereas the tip of a feather is termed its **apex**.

There are three main types of feathers: (1) *contour feathers*; (2) *plumules* or down feathers; and (3) *filoplumes*. Of these, the **contour feathers** or penna are the most conspicuous in that they cover the adult bird’s body, wings, and tail and basically account for the shape of the bird. The large flight feathers of the wing (remiges) and the tail (rectrices) are the most conspicuous of the contour feathers.

In most water birds, the contour feathers trap air, which not only insulates the bird, but also gives it buoyancy. The exposed part of a typical contour feather is flat and is supported by a central **rachis**, flanked on two sides by a **vane** (Fig. 3-5). The more proximal part of the feather, which is embedded in a follicle, is termed the **calamus** or quill, and the combined calamus and rachis make up the hollow **shaft** or scapus of the feather.

⁴ As you may know Galileo got in big trouble with the Pope for proposing the “preposterous idea” that the earth actually revolved around the sun, which was contrary to the teachings of the Church. Although not executed for his beliefs, Galileo was sentenced to “house arrest” for much of his adult life.

The calamus is hollow and is divided internally into smaller compartments by **epidermal septae** called “pulp caps.” At the junction of the calamus and rachis is an opening into its cavity known as the **distal** (superior) **umbilicus** (Fig. 3-5). The **proximal** (inferior) **umbilicus** is the opening at the tip of the calamus into which

the dermal papilla of the follicle projects. On some feathers, a secondary feather (hypopenna) may branch from the underside of the main feather at the level of the distal umbilicus (Fig. 3-5). These “afterfeathers” are typically much smaller than the main feather; however, in the emu, they are as large as the primary feather.

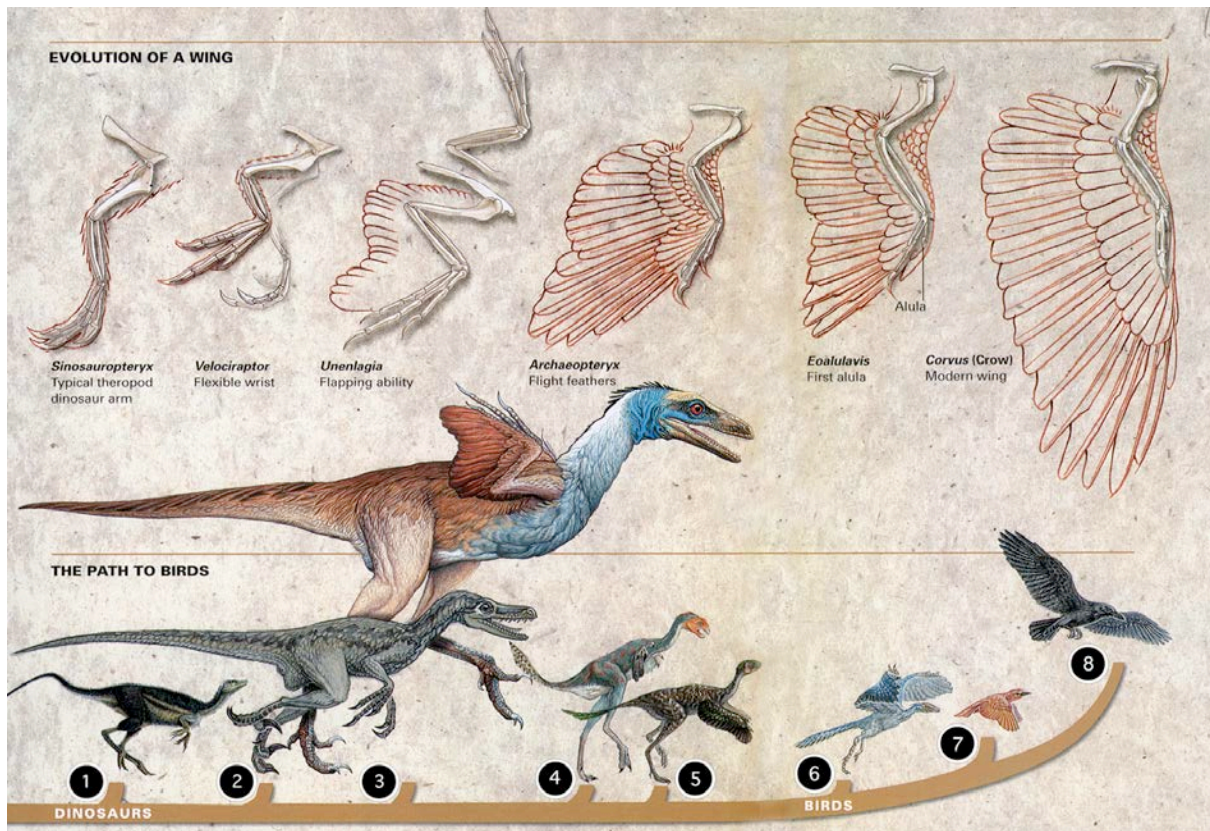


Figure 3-4. “Evolution of a Wing” and “The Path to Flight” from *National Geographic Magazine*, July 1998 issue. *Sinosauropteryx* by Michael Skrepnick; *Unenlagia* by Aldo Chiappe; based on fossil interpretation by Fernando Novas: (1) *Sinosauropteryx* (China) was a runner that was covered with filaments and had short forelimbs with 3 thoracic digits; (2) *Velociraptor* (Mongolia) had a carpus capable of rotation, a motion necessary for flight; (3) *Unenlagia* (Patagonia) was about 8 feet long and could move its forelimbs up and down, which is necessary for flight; (4) *Caudipteryx* (China) was a fast runner, which was covered with primitive feathers; (5) *Protarchaeopteryx* (China) resembles *Archaeopteryx*, but had more primitive feathers, and was probably not capable of achieving powered flight; (6) *Archaeopteryx* (Germany) had a more advanced feather design in that the leading edge was narrower and more streamlined than the trailing edge, and it was very likely capable of some elementary flying; (7) *Eoalulavis* (Spain) is the oldest bird with an *alula*, the movement of which is necessary for more advanced flying; (8) *Corvus* (crow) and other modern birds have developed many more adaptations for controlled flight and maneuverability.

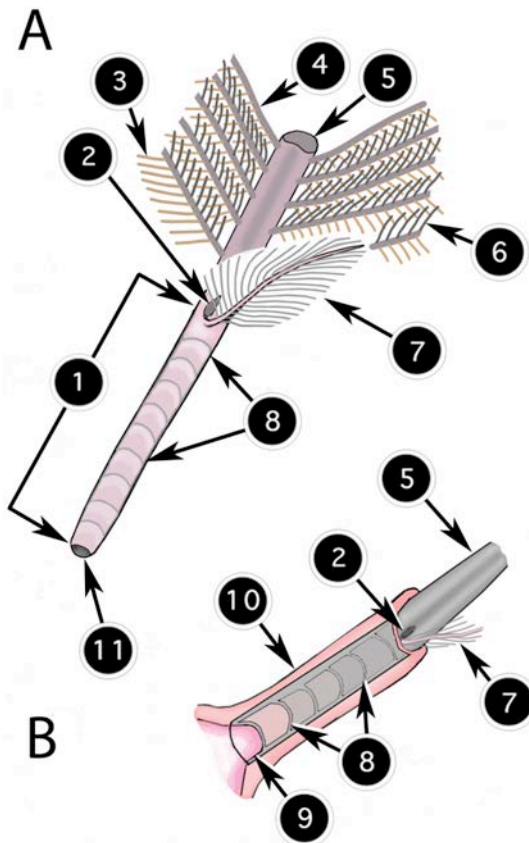


Figure 3-5. Drawings of (A) calamus and proximal vane of contour feather; (B) growing feather in feather sheath: (1) calamus exposed; (2) distal umbilicus; (3) proximal barbules; (4) barb; (5) rachis (cut); (6) distal barbule; (7) hypopenna (after-feather); (8) epidermal septae forming pulp caps; (9) dermal papilla projecting into proximal umbilicus; (10) feather sheath surrounding calamus; (11) proximal umbilicus.

The **vane** or **vexillum** is the part of the feather extending out to either side of the rachis (Fig. 3-6). The main branches from the rachis are the **barbs**, and from the barbs, smaller branches known as **barbules** arise at about 45° angles (Figs. 3-6 & 3-7). Those barbules directed back toward the calamus are termed **proximal barbules**, while those directed toward the tip of the feather are termed **distal barbules**. The distal barbules of contour feathers have numerous **hooklets** that lock over small flanges located on the proximal barbules from the adjacent barb. It

is this complex interlocking of the barbules that maintains the smooth shape of the contour feathers.

The most proximal group of barbs on a contour feather, typically lack interlocking barbules and as a group forms a “downy barb” arrangement (Fig. 3-6).⁵ Healthy birds want to be well groomed and give immediate attention to “frazzled feathers.” They restore the interlocked arrangement of the barbules by passing the feathers through their beak in the grooming ritual known as “preening.”

The filament like barbules of **down feathers** or *plumules* do not interlock with one another, which accounts for the naturally fluffy (plumaceous) appearance of these feathers. The softness of a down feather is enhanced by the absence of a rigid rachis, which is the main supporting shaft of the contour feather. Down feathers cover the body of the hatchling in many species and later in life may be retained as an “undercoat” to the outer contour feathers of the adult bird.

Stealth Technology? As you know, aeronautical engineers have developed a “stealth technology” so that aircraft can slip through radar detection. This technology involves the implementation of “soft edges” on the wings and fuselage so that they do not reflect radar waves. This is pretty high-tech stuff, but the owl was way ahead of those engineers. When most birds fly, the movement of their wings disturbs the air along the crisp leading edge of the wing, thus producing the “swoosh-swoosh” sound (or the “hum” of the humming bird) as the wings disrupt the air.

⁵ Having no need for flight feathers, the contour feathers of the ostrich have poorly developed barbule hooklets; thus, their fluffy plumes have found a use as adornments to ladies’ attire.

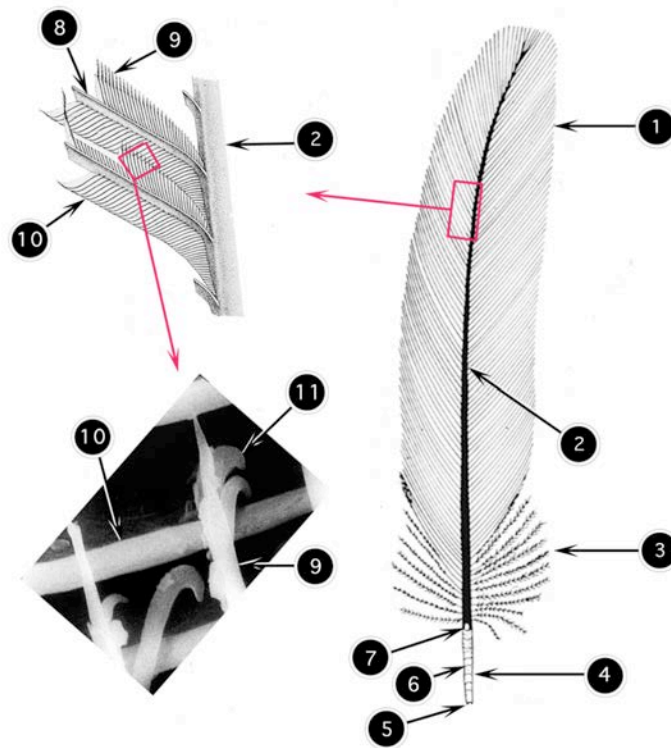


Figure 3-6. Anatomy of a contour feather: (1) vane; (2) rachis; (3); (4) calamus; (5) proximal umbilicus; (6) pulp caps; (7) distal umbilicus; (8) barb (9) distal barbules; (10) proximal barbules; (11) hooklets on distal barbules. (Modified after King & McLelland, 1975 & Nickel, Schummer, Sieferle, 1977.)

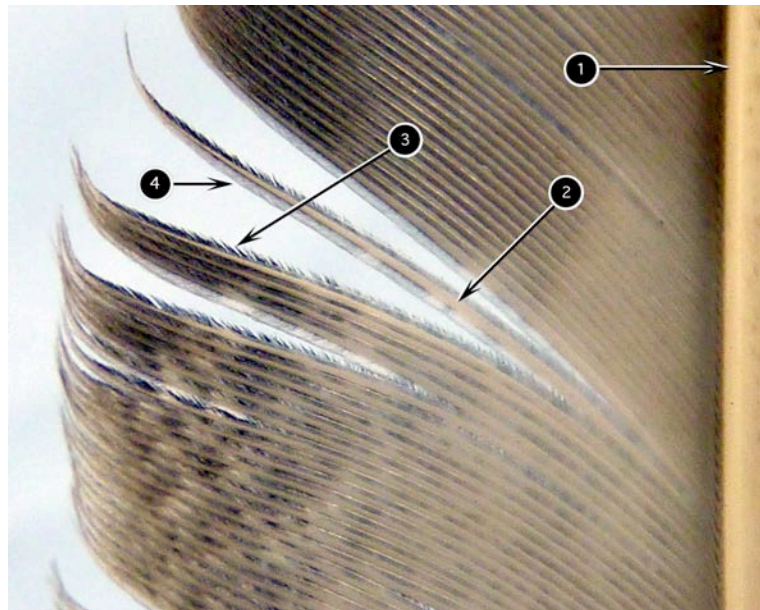


Figure 3-7. Close-up photograph of vane of contour feather: (1) rachis; (2) barb with proximal & distal barbules; (3) distal barbules with hooklets; (4) proximal barbules without hooklets.

Owls are nocturnal predators, and their prey are very “tuned-in” to “sounds in the night.” To avoid detection by the keen hearing of their prey, owls have developed (evolved) a “stealth technology” of their own. To “soften” the leading edge of their

flight feathers, the distal barbules along the leading wing edge do not contain functional hooklets, creating a soft, flexible edge (Fig. 3-8). Owls fly virtually soundlessly, and by the time their prey detects an “incoming” owl, it is too late.

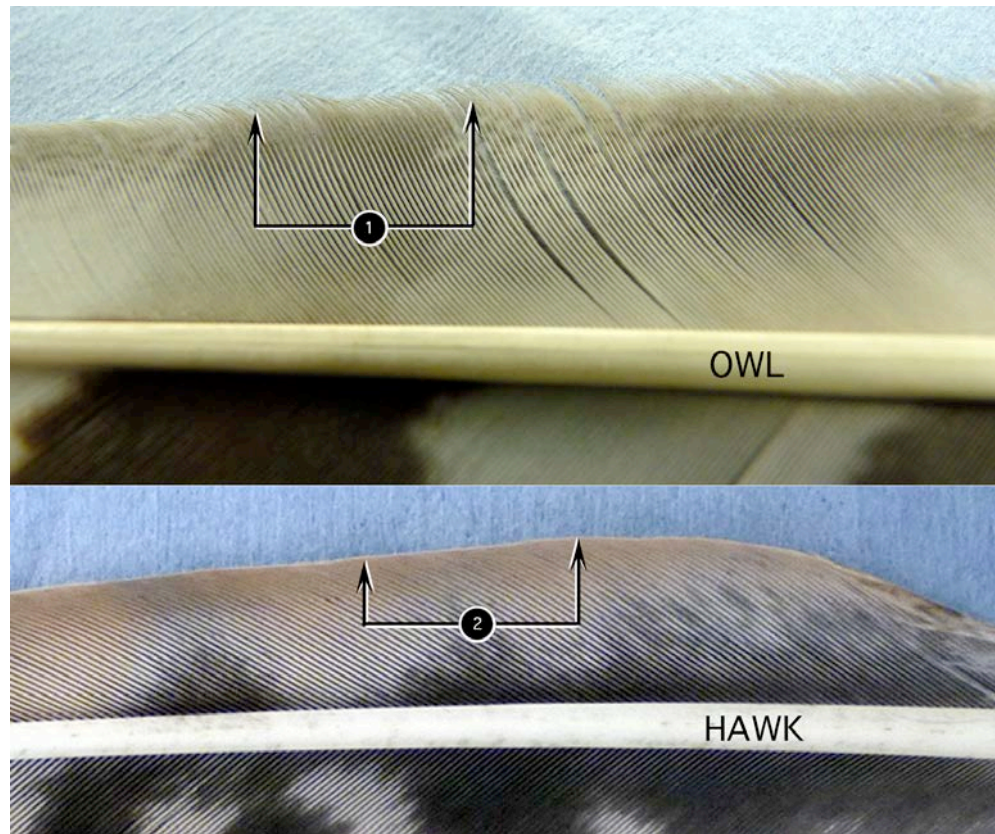


Figure 3-8. Remiges of owl and hawk: (1) soft (unlocked) leading edge of owl feather; (2) sharp (locked) leading edge of hawk feather. The soft, flexible leading edge of owl feather allows for virtually silent flight.

Filoplume feathers are hair-like and typically consist of a flexible shaft that may have a tuft of barbs near its apex. Owing to this design, these feathers are sometimes referred to as “tufted bristles”, which are commonly found on the head and neck.⁶

⁶ Filoplumes are also those pesky little hair-like feathers that remain on the bird carcass after routine plucking. These feathers are removed in the poultry processing plant by singeing the carcass.

Although not obvious to the more casual observer, contour feathers are not uniformly distributed over the body of the adult bird. Rather they are arranged in species-specific tracts known as **pterylae**. The pattern of the pterylae can be appreciated by observing the skin of a plucked chicken or turkey while you’re rubbing it with those secret herbs and spices.

Pterylae are separated by poorly feathered areas referred to as **apteryia**.

Whenever feasible, *surgical incisions should be made in these less densely feathered areas*. In the domestic chicken, there are about 70 named pterylae.⁷

The most impressive and functionally significant contour feathers of flight birds are those of the wings and tail (Fig. 3-9). The feathers of the wing are divided into **remiges**, which are the longer flight feathers, and **coverts** or tectrices, which are the smaller feathers that cover and contour the more cranial part of the wing. Remiges are further divided into **primary flight feathers**, which are the longer more distal group that attach to the carpometacarpus and phalanges (manus), and **secondary flight feathers**, which are the shorter feathers that attach to the ulna (antebrachium). For any species of bird, there is a constant number and arrangement of remiges.

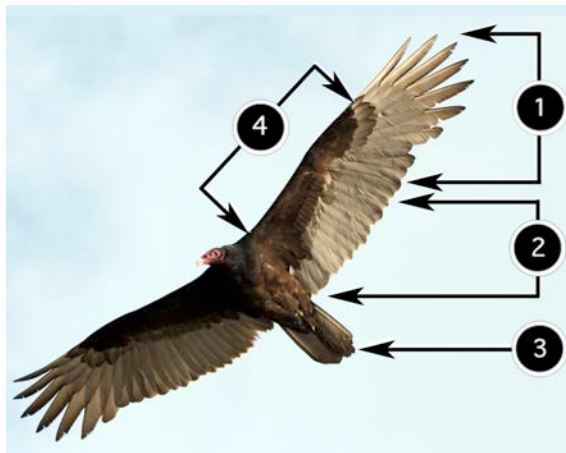


Figure 3-9. Contour feathers of turkey vulture: (1) primary remiges associated with manus; (2) secondary remiges associated with ulna (antebrachium); (3) rectrices (primary tail feathers); (4) covert feathers giving smooth contour to cranial edge of wing as well as body and tail. (Photo courtesy: http://en.wikipedia.org/wiki/File:Cathartes_aura_-Florida_-USA_-flying-8-4c)

To prevent *temporarily* certain captive birds from flying away, most of the remiges of the wings can be trimmed short, a procedure known as “clipping” or “cropping” the wing(s).⁸ The large feathers of the tail, known as **rectrices**, are bilaterally symmetrical, and again, the number, size, and arrangement of these feathers is species specific. Smaller covert feathers cover the more proximal part of the tail.

Birds routinely replace their feathers by a process called **molting**. In wild birds, molting typically takes place once a year, at the end of their natural breeding season. The onset of molting is hormonally induced and the timing is usually determined by changes in the photoperiod and temperature. Molting represents a stressful time in the life of birds, and during the molt, they require added nutrients to support the rapid production of the new feathers. In most species, the primary flight feathers are lost sequentially as new ones come in to replace them. Ducks and geese, however, replace most all their flight feathers at about the same time so that they are unable to fly very well during this period. This molting period of ducks and geese typically coincides with the time with they have young that are also incapable of flight.

New feathers are produced within the **feather follicle**, which is a sheath or inverted tube of skin (Fig. 3-5). At the base of the follicle is a **dermal papilla**, which projects a short distance into the feather through the proximal umbilicus. Feathers are produced by the replication and keratinization of epidermal cells surrounding the dermal papilla. Feathers continue to

⁷ For a detailed description of pterylosis (arrangement of feather follicles) in various species, see Lucas & Stettenheim, *Avian Anatomy: Integument, Parts I & II*, USDA Agriculture Handbook # 362, 1972.

⁸ It should be kept in mind that these “clipped” feathers will be replaced with perfectly good ones at the next molt; thus the word *temporarily* was emphasized in the referenced sentence.

grow out from the follicle only until the definitive length of that feather is achieved, at which time growth ceases. Like hair or horn tubules, the oldest (first-formed) part of a feather is at its apex, and the youngest (most recently formed) part is represented by the basal region. However, unlike hair, feathers do not continue to grow indefinitely.

During early development of a feather, a vascular **dermal core** extends outward into the epidermal cylinder that will become the feather. When a new feather first emerges from the follicle, it is encapsulated by a thin epidermal sheath that ruptures to release the unfolding barbs and barbules of the feather. Prior to rupture of the outer sheath, newly emerged feathers are commonly referred to as **pinfeathers**. Successive generations of feathers are produced over the same dermal papillae throughout life, with a new feather developing to replace its predecessor. This replacement occurs regardless of whether the old feather was lost during the natural molting process or was unceremoniously plucked from its follicle by man, beast or turbulent weather.

As keratinized epidermal structures, feathers are primarily proteinaceous appendages into which various substances can be incorporated. Among these are both dietary and synthesized pigments (carotenoids, lipochromes, etc.), which account, in part, for the variety of coloration among feathers. Selective incorporation of specific pigments into certain feathers is both genetically prescribed and hormonally influenced. The plethora of coloration patterns varies, not only from feather to feather, but also among specific barbs and barbules of a single feather. The diversity in coloration patterns is virtually endless.

In some female birds, an area of feathers on the ventral surface of the body may be shed or plucked during the nesting season. This temporarily featherless region is the so-called “**brooding patch**,” which allows the eggs to come in more direct contact with a highly vascularized area of skin for incubation purposes. Actually, some male birds (*viz.*, *pigeon*) develop brood patches. Because commercial layers get paid to lay not sit on their eggs, broodiness has pretty much been eliminated in these birds through selective breeding.

And speaking of selective breeding, some broiler lines (“slow-feather”) of chickens have been genetically modified so that the birds can be sexed as day-old chicks using feather length on the wing (Fig. 3-10). Not all lines of broilers have been genetically modified to exhibit this trait, and vent-sexing is still used in “fast-feather” lines.

Once you get below the feathers of the bird, you should note that the skin is rather thin and relatively inelastic. In most areas of the body, the skin is rather loosely attached to the deeper tissues. Birds tend to store quite a bit of fat in their skin, which explains its yellowish color and why removing the skin from a piece of fried chicken before one ingests same can greatly reduce the calorie and fat content of the meal.⁹ A complex system of dermal muscles interconnects and acts upon groups of feather follicles. Acting much like the arrector pili muscles of mammals, these dermal muscles can elevate the feathers of a body region in unison to “ruffle” them or to raise the crest in a cockatoo.

⁹ Unfortunately, this procedure also reduces the flavor content of the soon- to-be-consumed morsel.

Feather Sexable Chickens- Use Top of Wing at time of Hatch



Male: Coverts as long as or longer than primary flight feathers



Female: Coverts shorter than primary flight feathers

Photo Courtesy of Dr Kate Barger, NCSU-CVM, Class of 2002

Figure 3-10. Dorsal view of wings of day-old chicks from slow-feather line of broilers, which have been genetically modified so that birds can be sexed using feather length on the wing. Not all lines of broilers have been modified to exhibit this trait.

Non-feathered Integument

Not all parts of the bird are covered with feathers. The **scales** (podotheca) that cover the legs and feet of birds are highly cornified epidermal plates that are reminders of the reptilian ancestry of birds (Fig. 3-11). As previously mentioned, the **calcar** or spur of some birds is a modified epidermal projection, overlying the **calcaris** process of the tarsometatarsus. Some nestling birds (*viz.*, toucans) have highly cornified **heel pads** over the plantar aspect of the hypotarsus, which are shed during the fledgling stage of growth.

The foot of the bird typically has a **metatarsal pad** and **digital pads** (Fig. 3-11). Although greatly reduced in most terrestrial birds, aquatic species have well-developed **interdigital webs** (tela interdigitalis) between digits 2-4, and in pelicans (and related species) also between digits 1 and 2.

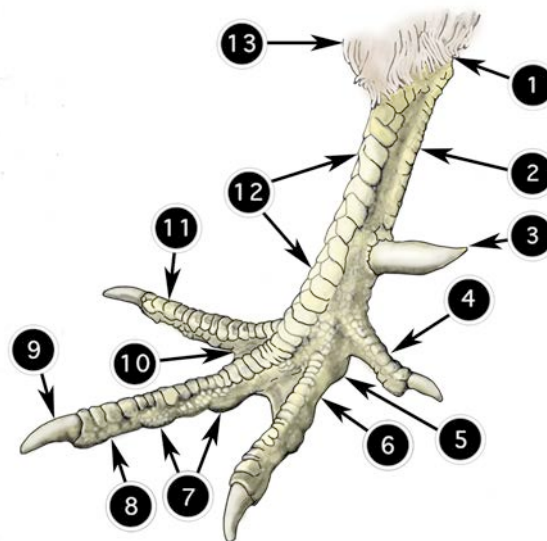


Figure 3-11. Right foot of chicken, medial view: (1) tarsus; (2) tarsometatarsus; (3) calcar (epidermal sheath over calcaris process); (4) digit 1; (5) metatarsal pad; (6) digit 2; (7) digital pads; (8) digit 3; (9) nail or claw; (10) interdigital web; (11) digit 4; (12) scales (podotheca) on tarsometatarsus; (13) feathers on tibiotarsus. (Modified after Nickel, Schummer, Siefertle, 1977.)

The head and neck of birds are often adorned with one or more cutaneous modifications. The chicken typically exhibits the comb, wattles, ricti, and earlobes (Fig. 3-12). The **comb**, which is typically better developed in the male bird, can serve as a general index of health in the chicken, with a bright red comb being indicative of the onset of egg production in the pullet. Among commercial and exotic breeds of chicken, there is also considerable variation in the size and shape of the comb. (See Chapter 1.)

The comb represents a fleshy crest (crista carnosa) and is a highly vascular structure, which will bleed readily when traumatized. Because of this vulnerability, the comb of day-old chicks is routinely “dubbed” or trimmed to prevent injury. **Plumed crests** (crista pennaum) are present in many species of domestic and wild birds (*viz.* cockatoo, crowned pigeon, and some chicken breeds).

The **wattles** (palea) are the two cutaneous appendages associated with the mandibles (Fig. 3-12). Intradermal injections can be made into the edges of the wattles. The **ricti** are fleshy areas at the angles of mouth, which in some birds are brightly colored. They are associated with the maxillae and mandibles and are more or less homologous to the lips of mammals. Because the **earlobes** (lobus auricularis) exhibit considerable variation in color among different breeds of chickens, its color is sometimes used to distinguish a particular breed. Chicken breeds with white earlobes typically lay white eggs, while those with colored earlobes lay colored eggs.

Decorative adornments associated with the head and neck of the turkey typically consist of the snood, dewlap, and cutaneous caruncles (Fig. 3-13). Like the comb of the chicken, the extensible **snood** (frontal process) is better developed in the male; however, unlike the comb, the snood does not contain erectile

tissue. To prevent injury, the snood of baby poults is routinely removed (“desnooding”).

The **dewlap** (palear) is a simple skin fold in the throat region, while the entire head and neck of the turkey is characterized by cutaneous **caruncles** and a sparse covering of bristle feathers. In addition to the above ornaments, a filamentous **beard** (*barba cervicalis*) develops from a papilla near the base of the neck on the ventral midline of the tom (sometimes present in hen) (Fig. 3-14).

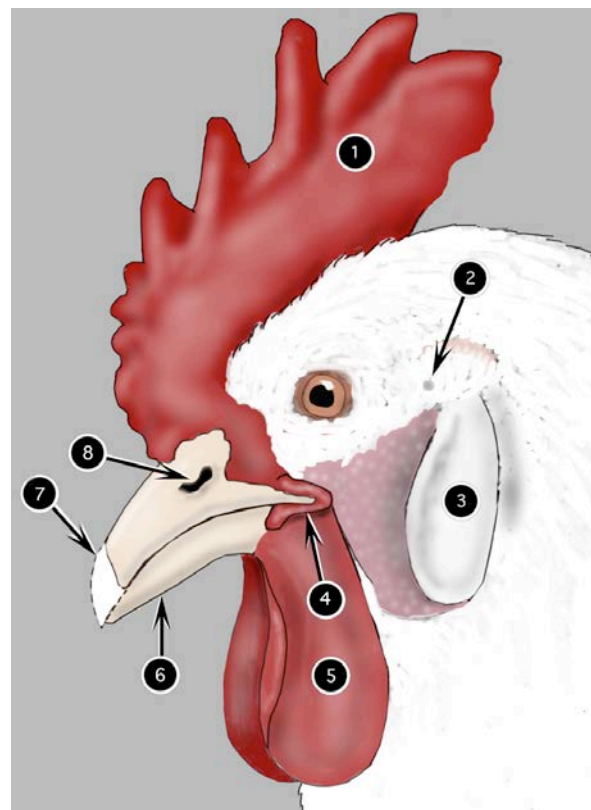


Figure 3-12. Head of chicken: (1) comb; (2) external acoustic meatus (covered by feathers); (3) earlobe; (4) rictus; (5) wattles (palea); (6) lower beak; (7) upper beak, properly “debeaked”; (8) operculum, overhanging naris.

The **beak** or **bill** (rostrum) consists of a heavily keratinized sheath, the rhamphotheca, which covers the upper and lower jaws. In most birds the rhamphotheca grows continuously throughout life, and in some captive species (*viz.*, parrots) may require

periodic trimming to prevent overgrowth. In commercial poultry operations, the upper beak is routinely trimmed (debeaking) to prevent cannibalism during confined housing situations. **Debeaking** is typically performed in day-old birds (*viz.*, turkeys and chickens), and when done, should include no more than 1/3 of the upper beak as measured from the tip of the beak to the external nares (Fig. 3-12).

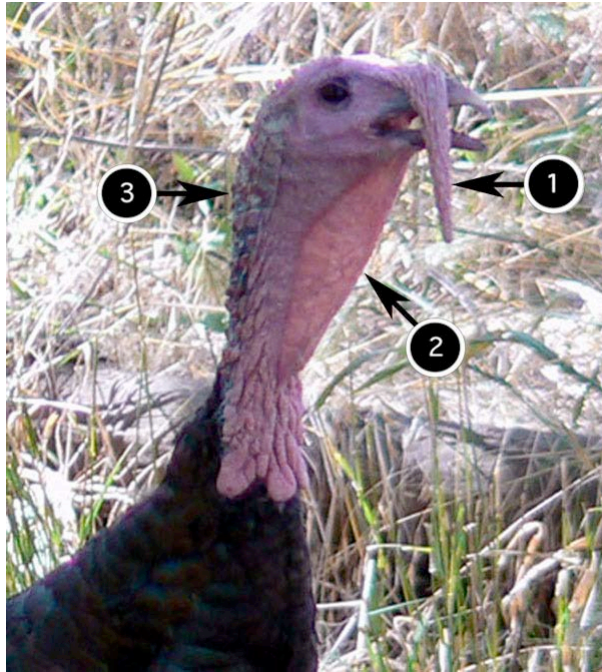


Figure 3-13. Head and neck of wild turkey tom (gobbler): (1) snood; (2) dewlap; (3) caruncles. (Photo courtesy: http://en.wikipedia.org/wiki/File:Meleagris_gallopavo_Wild_Turkey).

The cutting edge of the rhamphotheca is termed the **tomia**, which is functionally the avian homologue of teeth in mammals. In ducks and other anseriforms, there are **lamellae** or serrations along the edge of the rhamphotheca, which serve in the filtration of food. (See Fig. 2-17.) There is also a "nail" (*unguis maxillaris*, *unguis mandibularis*) on the tip of each bill in many anseriform birds. (See Figs. 2-18 & 2-19.)

In pigeons, psittacines, and some other birds (*viz.*, eagles, falcons, hawks) there is a soft saddle of thickened skin over the caudal

part of the upper beak termed the **cere** (Fig. 3-15). The cere, which may be feathered or bare, typically surrounds the external nares, and is often colored. In the budgerigar, its color may be used to determine the sex of the bird. In the male bird the cere is blue, while in the female it is typically pink or light brown.



Figure 3-14. Wild turkey gobbler. The beard (arrow) of the gobbler is the trophy of the turkey hunter. (Photo courtesy: <http://en.wikipedia.org/wiki/File:Gall-dindi>).



Figure 3-15. Cere of pigeon and male budgerigar.

Newly hatched birds have an “**egg tooth**” (which is actually not a tooth at all) that functions in cracking open (“pipping”) the egg shell (Fig. 13-16). The egg tooth typically drops off within a day or two after hatching.

As previously mentioned, birds take good care of their feathers through the process known as preening. On the dorsal aspect of the tail is the **uropygial papilla**, upon which open the paired ducts of the bilobed **uropygial gland** (Figs. 3-17 & 18). In the absence of sweat glands and generally distributed sebaceous glands, this is the major cutaneous gland in birds. The uropygial gland serves as the source of a holocrine sebaceous secretion or *sebum*.

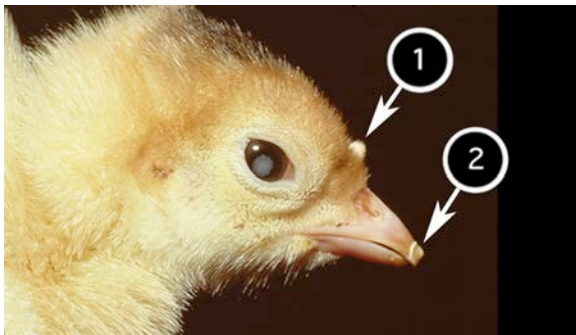


Figure 3-16. Head of newly hatched turkey poult: (1) snood; (2) “egg tooth” used in pipping the egg shell.

During preening, the bird uses its beak to obtain the fatty secretion from this large gland, and by pulling its feathers through its beak, coats them with this material. The gland is particularly important in aquatic birds in that the oily coating serves to waterproof the feathers as well as to reduce the incidence of skin infections. Although present in the budgerigar, the uropygial gland is absent in some other parrots (*viz.*, Amazon parrot) and in some pigeons.

Once you get below the feathers of the bird, you should note that the skin is rather thin and relatively inelastic. In most areas of the body, the skin is rather loosely attached to the deeper tissues. Birds tend to store quite a bit of fat in their skin, which explains its yellowish color and why removing the skin from a piece of fried chicken before one ingests same can greatly reduce the calorie

and fat content of the meal.¹⁰ A complex system of dermal muscles interconnects and acts upon groups of feather follicles. Acting much like the arrector pili muscles of mammals, these dermal muscles can elevate the feathers of a body region in unison to “ruffle” them or to raise the crest in a cockatoo.

More about bird feet: In the anatomy laboratory at NC State College of Veterinary Medicine, we have a collection of dried bird feet, and I wanted to include some photographs to demonstrate the diversity of foot types among birds. Figure 3-19 shows the left foot of a duck, demonstrating the classic 3-1 digital design, which is the best arrangement for walking and swimming. Aquatic birds typically show greatly enhanced interdigital webbing for swimming (Fig. 3-19). In many aquatic species, the webbing is developed only between digits 2 and 3 and between digits 3 and 4; however, the pelican and its relatives (*viz.*, frigatebirds, gannets, cormorants, anhingas) have webbing between all four digits.

¹⁰ Unfortunately, this procedure also reduces the flavor content of the soon- to-be-consumed morsel.

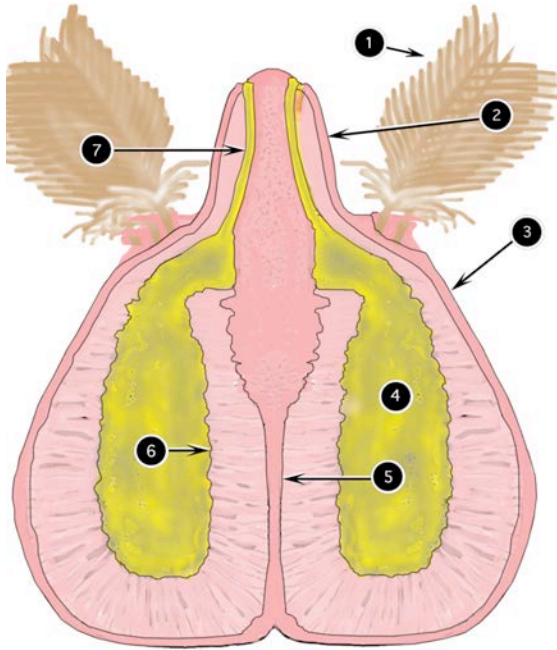


Figure 3-17. Semischematic of uropygial gland: (1) circle of down feathers present in some species; (2) uropygial papilla; (3) fibrous capsule; (4) lumen of gland filled with sebum; (5) septum between two lobes of gland; (6) holocrine tubular glands; (7) paired ducts opening on apex of uropygial papilla.

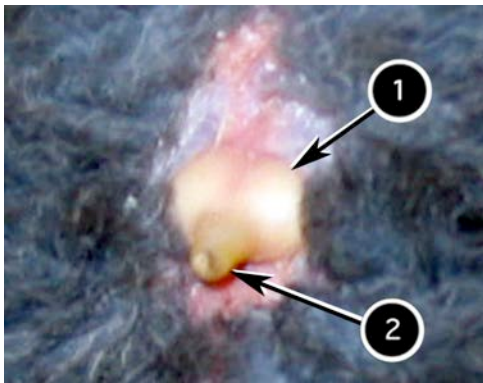


Figure 3-18. Uropygial or "preen" gland of barred owl (*Strix varia*): (1) bilobed gland; (2) uropygial papilla.

Figure 3-20 shows the right foot of a short-eared owl, demonstrating the modified 2-2 digital alignment. Digit 4 has rotated plantarly to work with digit 1 in opposition to digits 2 and 3. This arrangement allows for much stronger grasping. Actually, most owls can rotate digit 4 to form either the 2-2 or the 3-1 arrangement. As you may note, feathers

in this owl extend all the way to the toes. Most owls and a few other nocturnal raptors have feathers extending all the way to their toes. Owls typically kill their prey using their powerful feet, not their beak.

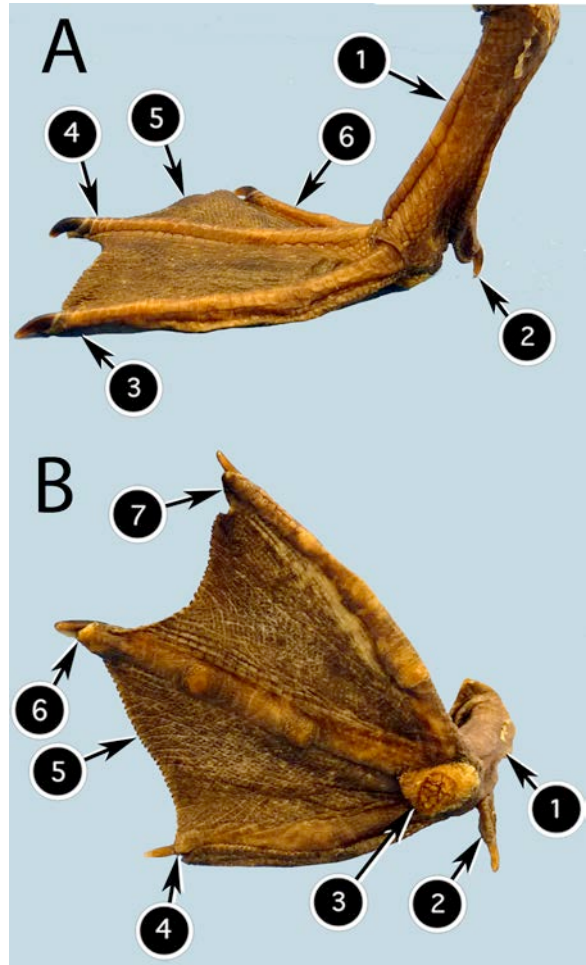


Figure 3-19. Left foot of a duck. (A) **Lateral view:** (1) tarsometatarsus; (2) digit 1; (3) digit 2; (4) digit 3; (5) interdigital web; (6) digit 4. (B) **Plantar view:** (1) tarsometatarsus; (2) digit 1; (3) metatarsal pad; (4) digit 2; (5) interdigital web; (6) digit 3; (7) digit 4.

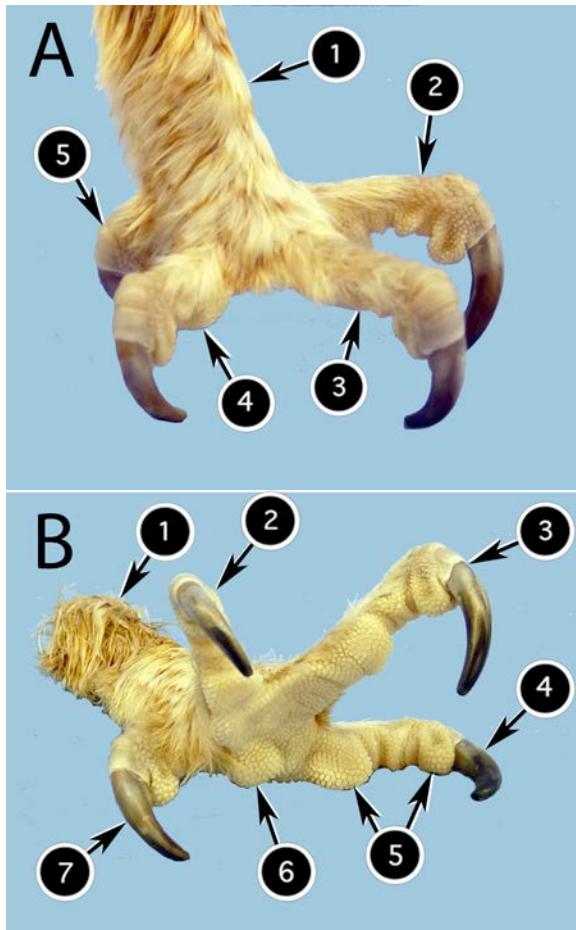


Figure 3-20. Right foot of a short-eared owl. **(A) Lateral view:** (1) tarsometatarsus; (2) digit 2; (3) digit 3; (4) digit 4 (rotated plantarly); (5) digit 1. **(B) Plantar view:** (1) tarsometatarsus; (2) digit 4 (rotated plantarly); (3) digit 3; (4) digit 2; (5) digital pads; (6) metatarsal pad; (7) digit 1.

Figure 3-21 shows the right foot of a red-shouldered hawk, demonstrating the 3-1 digital alignment. This bird has very sharp talons, and its feathers extend only to the proximal part of the tarsometatarsus, which is typical for most hawks.

In figure 3-22, we show the left foot of an American Black Vulture (*Coragyps atratus*). The claws or “talons” of these birds are relatively blunt, and are poorly adapted for grasping. These birds also have small webs between digits 2 and 3, and between 3 and 4.

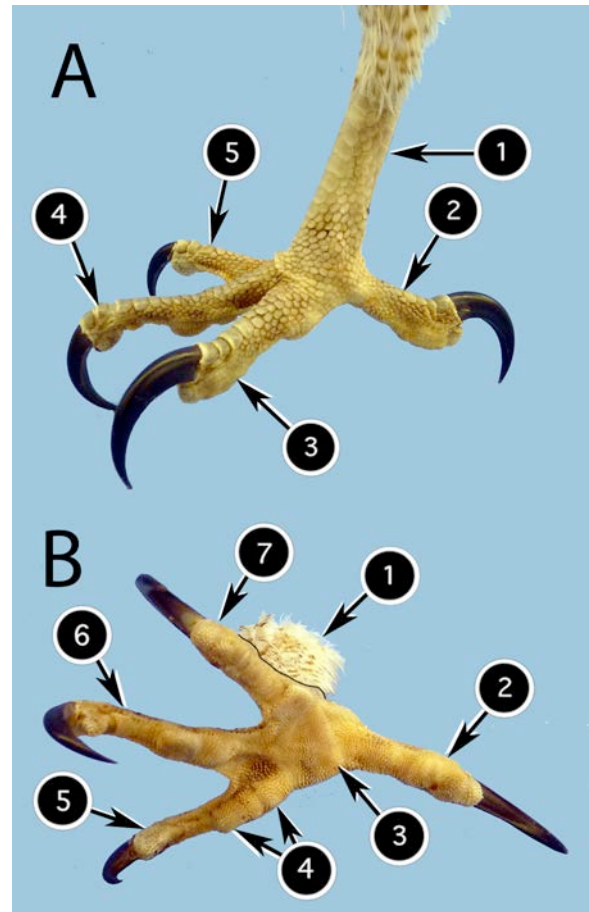


Figure 3-21. Right foot of red-shouldered hawk. **(A) Medial view:** (1) tarsometatarsus; (2) digit 1; (3) digit 2; (4) digit 3; (5) digit 4. **(B) Plantar view:** (1) tarsometatarsus; (2) digit 1; (3) metatarsal pad; (4) digital pads; (5) digit 4; (6) digit 3; (7) digit 2.

Figure 3-23 shows the 2-2 digital arrangement, which is characteristic of psittacine birds. Figure 3-24 shows the foot of a great horned owl.

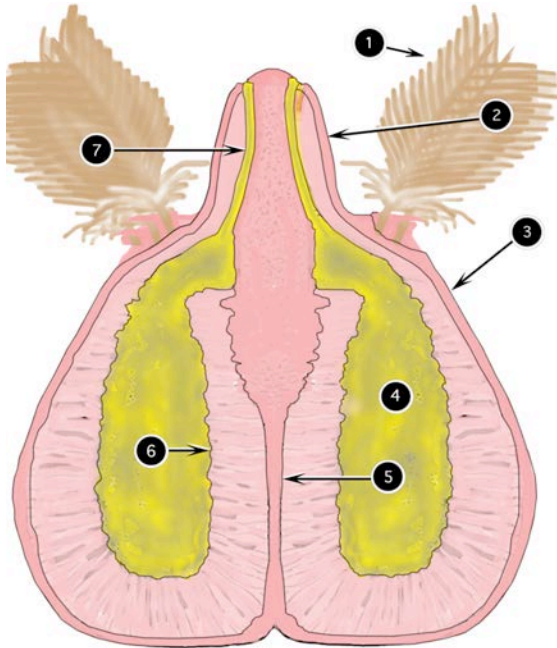


Figure 3-17. Semischematic of uropygial gland: (1) circle of down feathers present in some species; (2) uropygial papilla; (3) fibrous capsule; (4) lumen of gland filled with sebum; (5) septum between two lobes of gland; (6) holocrine tubular glands; (7) paired ducts opening on apex of uropygial papilla.

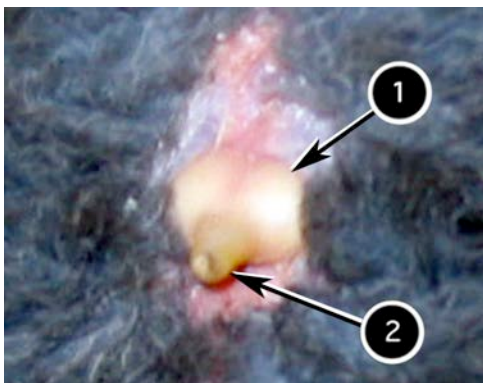


Figure 3-18. Uropygial or "preen" gland of barred owl (*Strix varia*): (1) bilobed gland; (2) uropygial papilla.

Figure 3-20 shows the right foot of a short-eared owl, demonstrating the modified 2-2 digital alignment. Digit 4 has rotated plantarly to work with digit 1 in opposition to digits 2 and 3. This arrangement allows for much stronger grasping. Actually, most owls can rotate digit 4 to form either the 2-2 or the 3-1 arrangement. As you may note, feathers

in this owl extend all the way to the toes. Most owls and a few other nocturnal raptors have feathers extending all the way to their toes. Owls typically kill their prey using their powerful feet, not their beak.

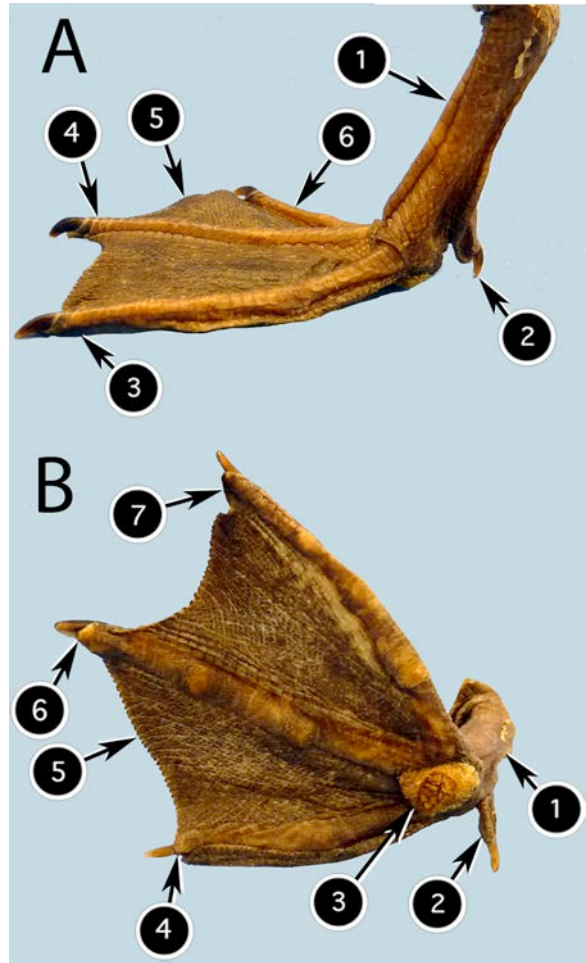


Figure 3-19. Left foot of a duck. (A) **Lateral view:** (1) tarsometatarsus; (2) digit 1; (3) digit 2; (4) digit 3; (5) interdigital web; (6) digit 4. (B) **Plantar view:** (1) tarsometatarsus; (2) digit 1; (3) metatarsal pad; (4) digit 2; (5) interdigital web; (6) digit 3; (7) digit 4.

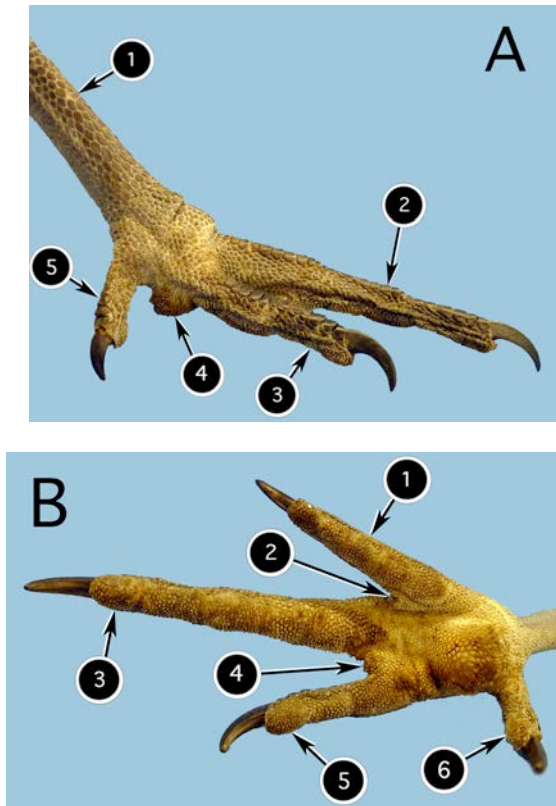


Figure 3-22. Left foot of American Black Vulture (*Coragyps atratus*). (A) **Medial view**: (1) tarsometatarsus; (2) digit 3; (3) digit 2; (4) metatarsal pad; (5) digit 1. (B) **Plantar view**: (1) digit 4; (2) small web between digits 3 & 4; (3) digit 3; (4) small web between digits 2 & 3; (5) digit 2; (6) digit 1.

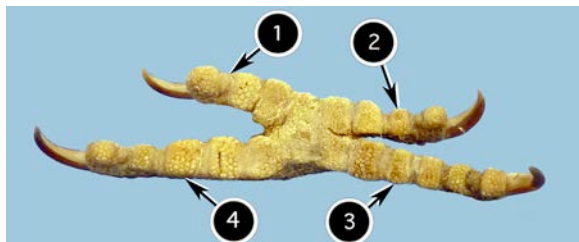


Figure 3-23. Left foot of African grey parrot (*Psittacus erithacus*), plantar view: (1) digit 1; (2) digit 2; (3) digit 3; (4) digit 4 rotated to join digit 1 in 2-2 alignment.

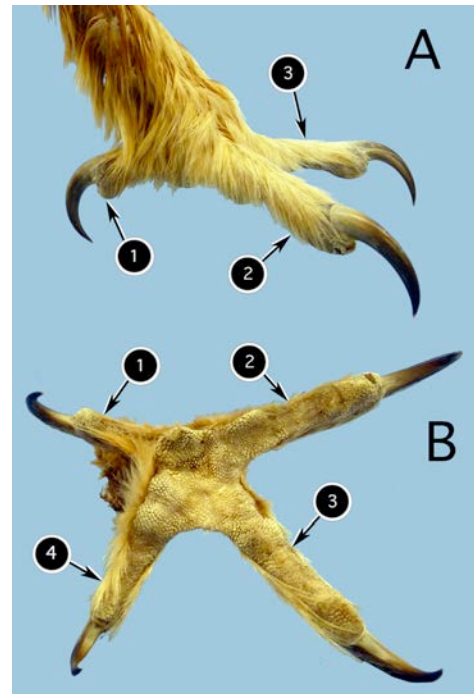


Figure 3-24. Left foot of great horned owl. (A) **Medial view**: (1) digit 1; (2) digit 2; (3) digit 3. (B) **Plantar view**: (1) digit 1; (2) digit 2; (3) digit 3; (4) digit 4.

Pigmentation of Feathers

Pigmentation of feathers varies not only from feather to feather, but also among specific barbs and barbules of a single feather (Fig. 3-8). The almost limitless combination of color patterns is dictated by genetics and is influenced by diet. Most birds incorporate carotenoid pigments into their feathers, which accounts for their coloration. Most natural carotenoids are yellow, and to be converted to other colors, such as red, must be changed by enzymes produced by the bird.

Production of enzymes is genetically controlled, and if all goes well, there are sufficient enzymes available for this conversion in coloration. But as you should already know, mutations occur in all living organisms daily, if not hourly.

I like to think of **mutations** falling into one of three categories: (1) **positive**; (2) **negative**; and (3) **neutral**. I believe that most mutations actually fall into category 3. That is to say that

most mutations are of little to no consequence because they **do not disrupt any important biologic process**; i.e., they go completely unnoticed.

Many mutations have a **positive effect**, which is exactly how organisms get **better adapted to their environment**. In birds, that mutation may result in something like a slightly thicker beak, a slightly longer beak, a slightly more curved beak, etc. Whatever the effect, it gives the “mutant” a **biologic advantage**, allowing it to perhaps **survive in tough times**, while others die off.

However, on other occasion, the mutation changes things in a **negative** way. For example, a key enzyme may be rendered non-functional, and whatever process it controls just doesn’t happen.

Ever heard of a yellow cardinal? Well its OK if you haven’t because these birds are extremely rare. In fact, you have a better chance of winning the lottery¹¹, than for this mutation to occur (probability < 1 in 3 million). In February 2020, a lady named Chelsea Curry photographed a yellow cardinal in her backyard in Illinois (Fig. 3-25).

According to Professor Geoffrey Hill of Auburn University, this rare coloration occurs when there is a **genetic mutation** that controls the bird’s **enzyme responsible for converting the yellow dietary carotenoid pigments to red**. When that happens, those feathers that should be red come out yellow.



Figure 3-25. Rare Yellow Cardinal (Photograph by Chelsea Curry, February 2020). See <https://www.usatoday.com/story/news/2021/03/11/yellow-cardinal-couples-backyard-illinois/4644752001/>

By the way, this is not the first report of a yellow cardinal. Similar birds have been seen in Alabama (2018), and in Florida (2019, 2020).

¹¹ I always say the lottery is just another tax on the mathematically challenged.

Chapter 4 • Myology

Because most of us typically think of the muscles of birds in terms of “white meat” (breast) or “dark meat” (thigh & drumstick), our coverage of myology will be rather superficial. To do a comprehensive study of the muscular system would take many pages and a great deal of time, so I will limit any detailed coverage of the muscles to those of particular interest, either from a physiologic or clinical standpoint. Figure 4-1 shows selected muscles of the head, trunk, and pelvic limb of the chicken.

As you can see, many of the muscles have names similar to their mammalian counterparts. In addition, birds have quite a few highly modified muscles that make possible some of their unique movements of the wings, pelvic limb, and tail.

One of the most remarkable things about birds is their great stamina in being able to fly for hours at a time, presumably in an aerobic state of muscle metabolism. This ability is undoubtedly related to their efficient respiratory system, which allows them to exert strenuous muscular activity for prolonged periods without creating an oxygen deficiency in their skeletal muscles.

The **pectoral** and **supracoracoideus** muscles were schematically shown with the skeletal system. (See Fig. 2-10.) As previously mentioned, many of the muscles in birds are similar to those of mammals; however, there are some muscles developed in birds that are not recognized in our domestic mammals. The supracoracoideus muscle is a lot like the deep pectoral muscle of mammals, while the much stronger pectoral muscle is

homologous to the superficial pectoral muscle of mammals.

Figure 4-2 shows selected muscles of the wing. Again there are many similarities to domestic mammals, but other muscles are unique to the bird. The **patagium** is a double fold of skin, which forms the so-called “wing web.” Numerous muscles of the patagium are used to tense or otherwise manipulate this skin fold, to which feathers are embedded. The patagium contains considerable elastic tissue, which allows it to accommodate extension and folding of the wing. As mentioned previously, one method of **pinioning** birds is by doing a tenectomy of the **extensor carpi radialis** muscle. This procedure prevents the bird from extending its carpal joints and bringing its primary flight feathers into position for flight.

Figure 4-3 shows selected muscles of the abdominal wall, medial thigh, and cranial leg. One difference in birds is that the **gastrocnemius** muscle is more extensive than in mammals, with part of the muscle wrapping around the cranial aspect of the proximal tibiotarsus to originate from the cranial and lateral **cnemial crests** of that bone. (See Fig. 2-14.) Thus the term “gastrocnemius” makes more sense in that it arises from the “cnemial” region of the “shin” bone. Also, the **fibularis** (peroneus) **longus** is a large muscle that covers the proximal parts of the **cranial tibial** and **long digital extensor muscles**. Unlike the situation in mammals, the long digital extensor muscle does not arise from the extensor fossa of the femur, but originates from the proximal aspect of the tibiotarsus.

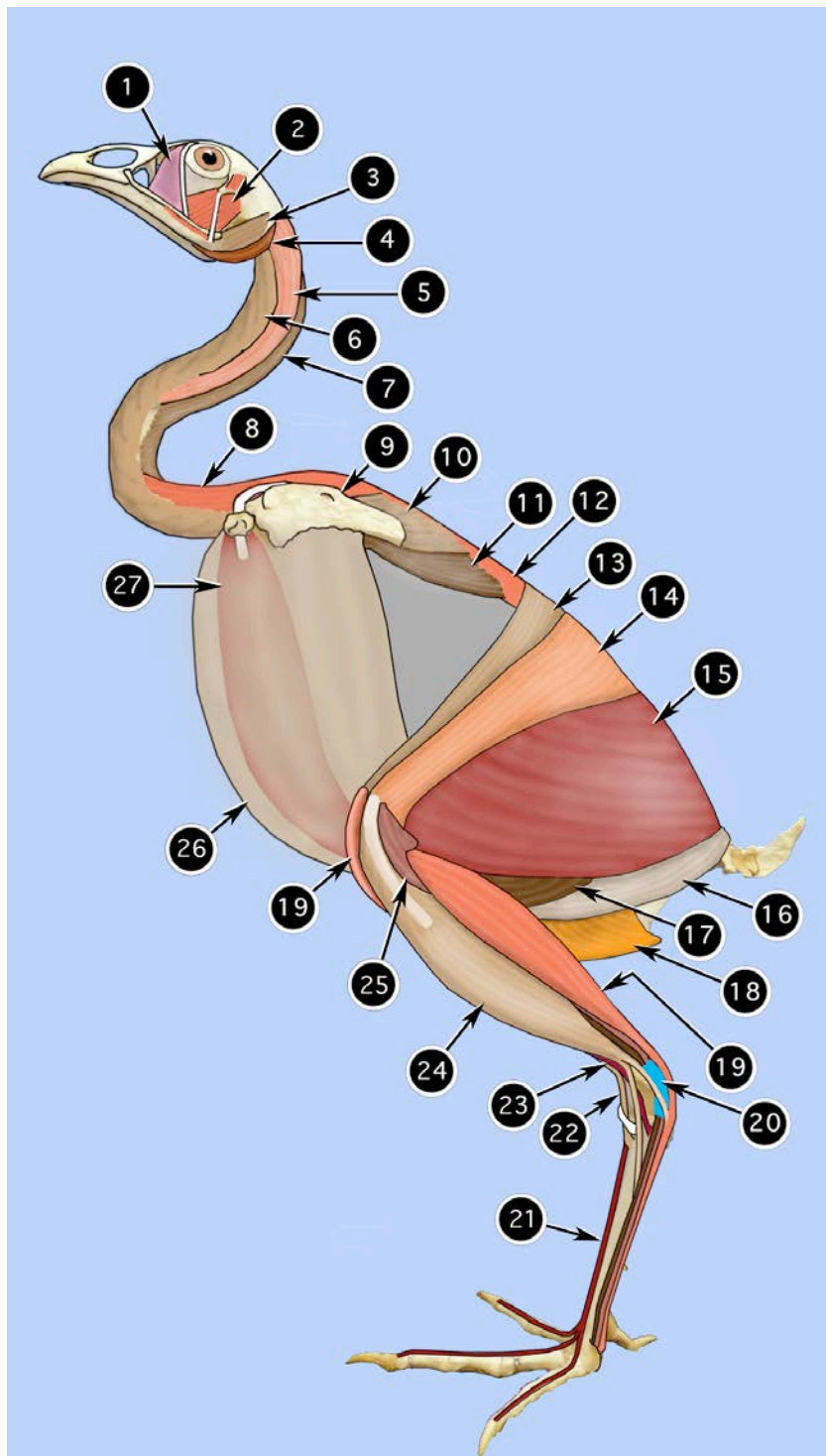


Figure 4-1. Selected muscles of trunk, & pelvic limb of the chicken, left lateral view: (1) infraorbital sinus; (2) external mandibular adductor (masseter); (3) depressor mandibulae (occipitomandibularis); (4) stylohyoideus; (5) complexus; (6) longus colli; (7) biventer cervicis; (8) longissimus cervicis; (9) humerus; (10) trapezius; (11) latissimus dorsi; (12) longissimus thoracis *et* lumborum; (13) sartorius; (14) tensor fasciae latae; (15) biceps femoris; (16) semimembranosus; (17) semitendinosus; (18) external abdominal oblique; (19) gastrocnemius; (20) deep digital flexor tendons passing through tibial cartilage; (21) long digital extensor tendon; (22) cranial

tibial tendon; (23) fibularis brevis tendon; (24) fibularis longus; (25) deep digital flexor; (26) pectoral; (27) supracoracoideus with tendon passing through triosseal canal.

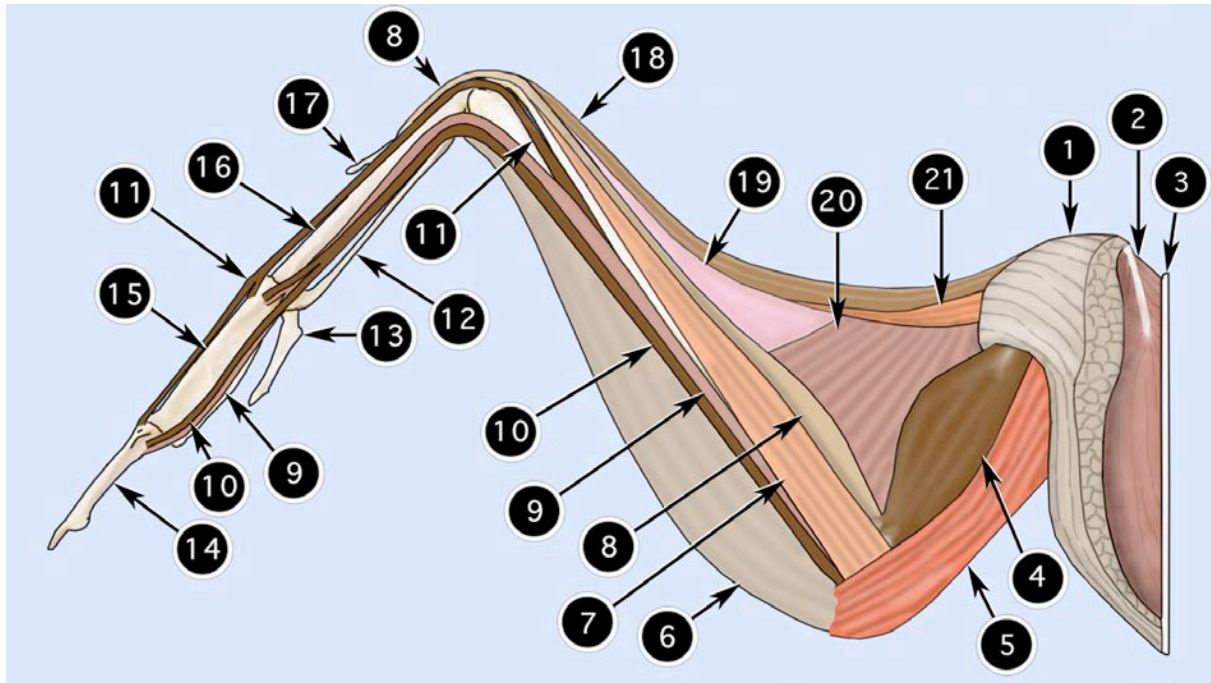


Figure 4-2. Selected muscles of wing, ventral view: (1) pectoral muscle; (2) supracoracoideus muscle; (3) carina (keel) of sternum; (4) biceps brachii muscle; (5) triceps brachii muscle; (6) flexor carpi ulnaris muscle; (7) pronator longus *et* brevis muscle; (8) extensor carpi radialis muscle; (9) deep digital flexor muscle; (10) superficial digital flexor muscle; (11) extensor indicis longus muscle; (12) carpometacarpal bone of minor digit; (13) proximal phalanx of minor digit; (14) distal phalanx of major digit; (15) proximal phalanx of major digit; (16) carpometacarpal bone of major digit; (17) alula (digit 1); (18) tensor patagii longus muscle; (19) patagium (skin fold forming wing web); (20) tensor patagii brevis muscle; (21) accessory patagii muscle.

Figure 4-4 shows selected muscles of the pelvic limb. The tendon of the large **gastrocnemius** passes over the tibial cartilage and continues into the tarsometatarsus. The tendons of the **superficial digital flexor** also pass over the cartilage, while the tendons of the **deep digital flexor muscle** pass through the tibial cartilage. Also shown in this illustration are the tendons of the **fibularis longus**, **fibularis brevis**, **cranial tibial**, and **long digital extensor muscles**. The **tibial cartilage** is a fibrocartilaginous pad that lies over the plantar aspect of the tibiotarsal trochlea. As previously noted, the tendons

of the gastrocnemius and superficial digital flexor pass over this cartilage, while those of the deep digital flexor pass through it.

Figure 4-5 shows selected muscles of the pelvic limb from a cranial perspective with the tibiotarsus removed. Again, the tendons of the gastrocnemius and superficial digital flexors pass over the tibial cartilage, while the tendons of the deep digital flexor pass through the cartilage. This drawing also illustrates the **lateral meniscus** of the intertarsal joint in the chicken.

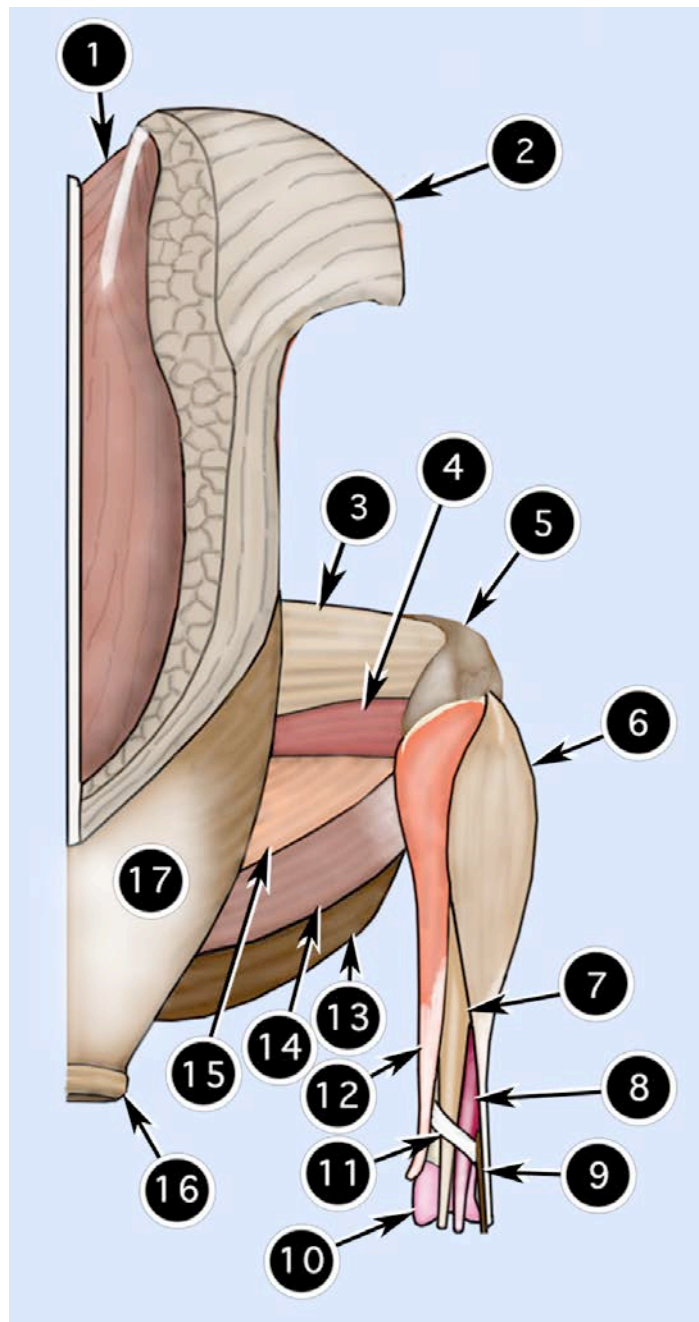


Figure 4-3. Selected muscles of pelvic limb, ventral view: (1) pectoral muscle; (2) supracoracoideus muscle; (3) sartorius muscle; (4) vastus medialis of quadriceps femoris muscle; (5) rectus femoris of quadriceps femoris muscle; (6) fibularis longus muscle; (7) long digital extensor muscle; (8) cranial tibial muscle; (9) fibularis brevis muscle; (10) trochlea of tibiotarsus; (11) proximal extensor retinaculum of tarsus; (12) gastrocnemius muscle; (13) semimembranosus muscle; (14) gracilis muscle; (15) adductor muscle; (16) sphincter cloacae muscle; (17) external abdominal oblique muscle.

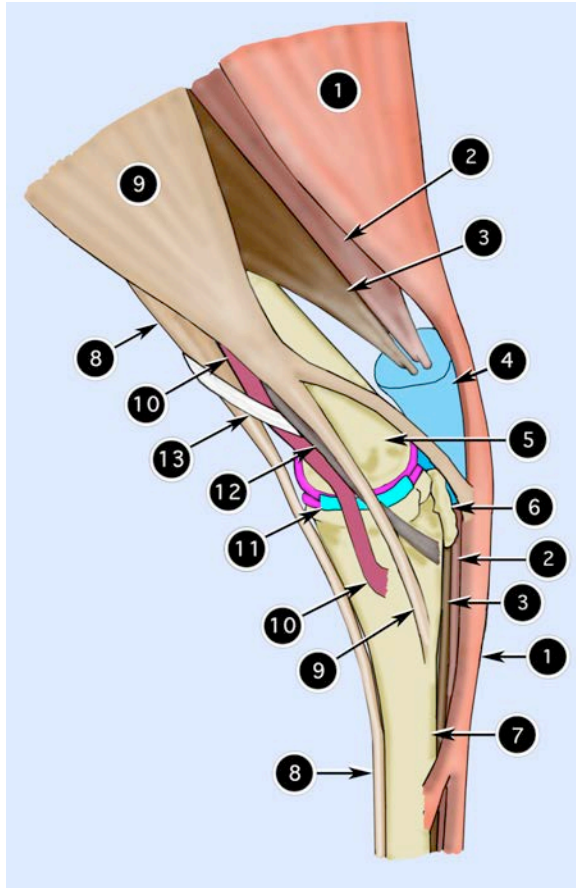


Figure 4-4. Selected muscles of pelvic limb, lateral view: (1) gastrocnemius muscle; (2) superficial digital flexor muscle; (3) deep digital flexor muscle; (4) tibial cartilage; (5) lateral epicondyle of tibiotarsus; (6) lateral crest of hypotarsus; (7) tarsometatarsus; (8) long digital extensor muscle; (9) fibularis longus muscle; (10) cranial tibial muscle; (11) lateral meniscus of intertarsal joint; (12) fibularis brevis muscle; (13) proximal extensor retinaculum of tarsus.

Figure 4-6 is a semischematic representation of the components of the “**perching mechanism**” of the bird. This unique mechanism, which is effected through the digital flexor tendons, allows the bird to grasp a perch with little or no muscular effort.¹ By merely “squatting down” and flexing the tarsus, the resulting tension on the digital flexor tendons acts as a “reciprocal apparatus” to flex the digital

¹ This comes in real handy when they are sleeping on the “roost.”

joints passively.² This, of course, causes the opposed digits (3-1 or 2-2) to grasp or clamp around the perch. It also explains why you should fully extend the tarsus when trimming a bird's nails.

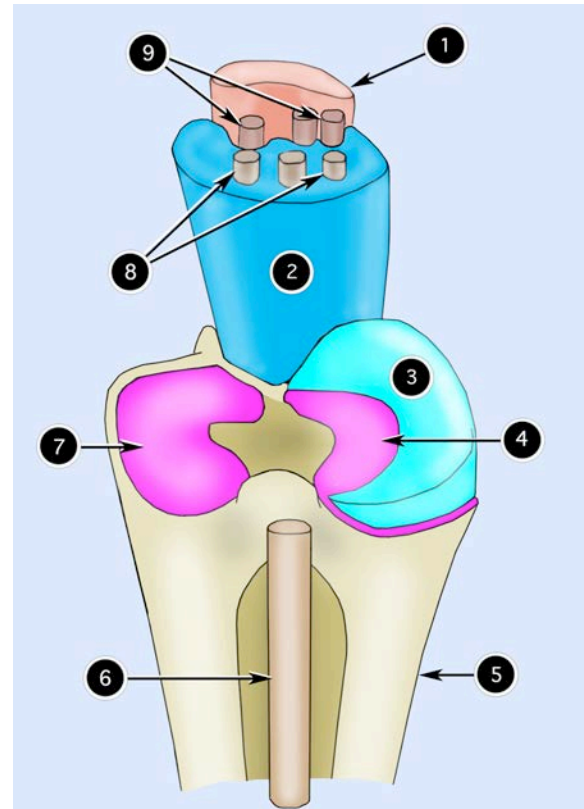


Figure 4-5. Selected muscles of pelvic limb, cranial view: (1) gastrocnemius tendon; (2) tibial cartilage; (3) lateral meniscus of intertarsal joint; (4) lateral cotyloid cavity (condyle) of tarsometatarsus; (5) tarsometatarsus; (6) long digital extensor tendon; (7) medial cotyloid cavity (condyle) of tarsometatarsus; (8) deep digital flexor tendons; (9) superficial digital flexor tendons.

Another feature of many avian species (*viz.*, turkey, owl) is the **ossification of tendons**, particularly in the tibiotarsal and tarsometatarsal regions. These ossified tendons should not be mistaken for

² This knowledge can come in mighty handy if you ever have the unfortunate experience of having a bird grab one of your body parts with its claws. Before attempting to pry the embedded talons out of your bleeding flesh, first extend the bird's limb as fully as possible.

pathologic ossification in radiographs of birds.

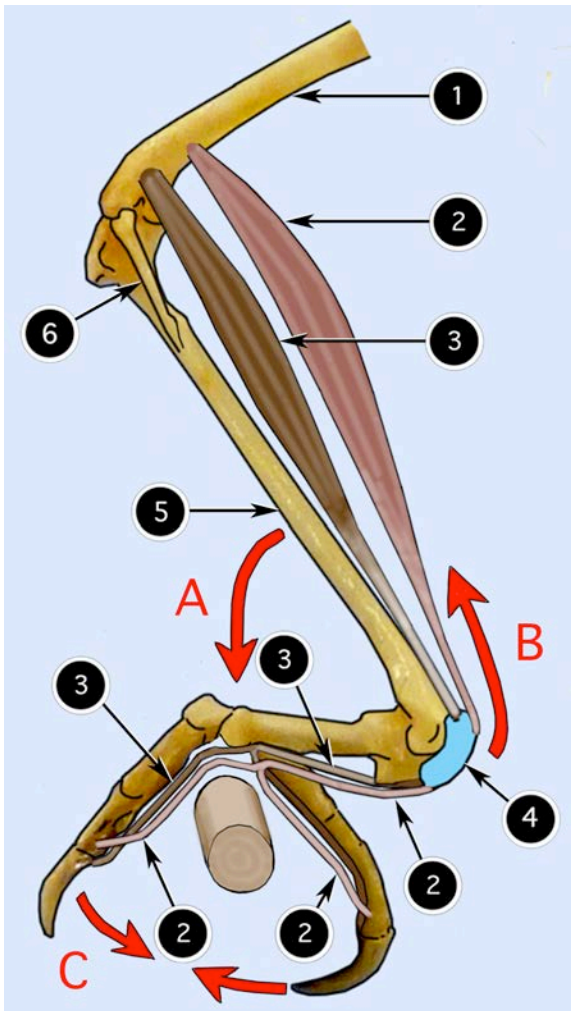
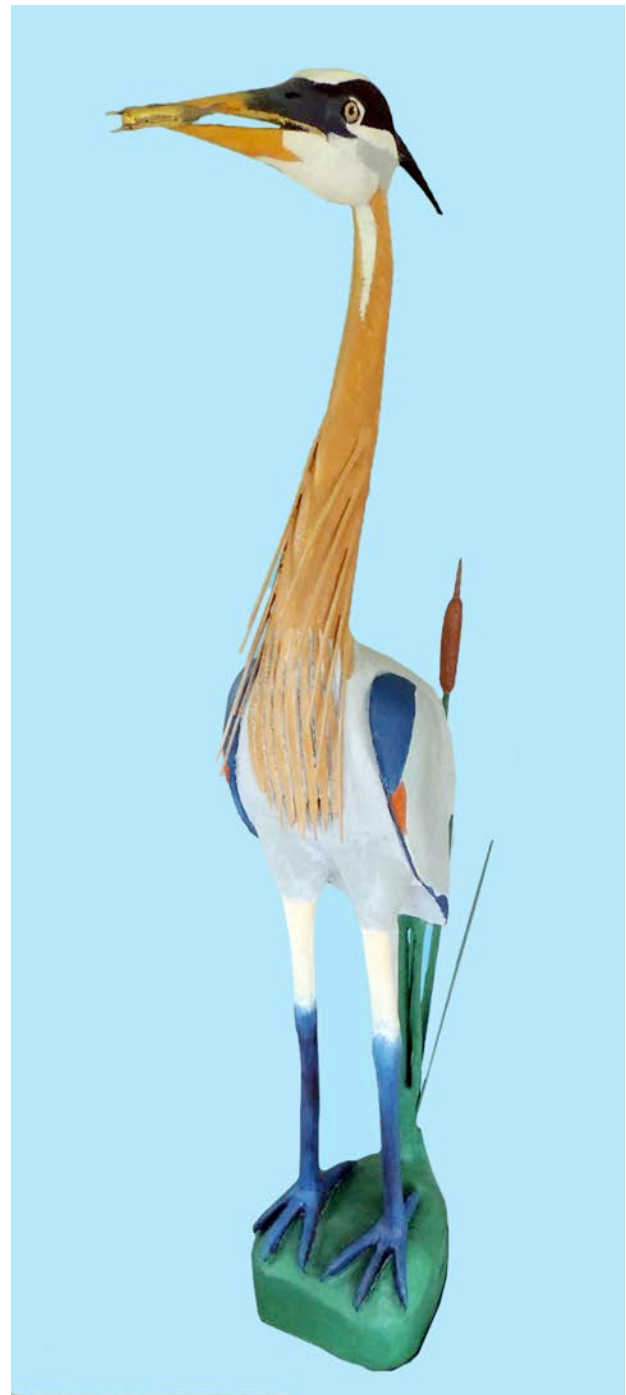


Figure 4-6. Semischematic representation of “perching mechanism” of bird: (1) femur; (2) superficial digital flexor; (3) deep digital flexor; (4) tibial cartilage; (5) tibiotarsus; (6) fibula. The red arrows indicate that when the bird “squats” and flexes its tarsus (A), the digital flexor tendons are pulled proximally around the tibial cartilage (B), and the resulting tension on the flexor tendons causes the opposing digits to clamp on to the perch (C).



Wood sculpture of great blue heron
James E. Smallwood, 2013

Chapter 5 • Digestive System

The digestive system of birds varies widely due to the great diversity of foods consumed by different avian species. Some of these differences will hopefully be pointed out along our tour of the digestive apparatus. We have already looked at the beak and its keratinized sheath, the **rhamphotheca**. Teeth are replaced by the cutting edge of the rhamphotheca, referred to as the **tomia**. In the duck, note the serrated lamellae along the tomia. (See Figs. 2-17 & 2-19.) Note also that the lateral edge of the duck's tongue has a double row of overlapping bristles, which interdigitate with the beak lamellae, and in so doing, assist in the straining of food material from water. The angle of the mouth, when formed by soft keratin or fleshy tissue, is termed the **rictus**, which in some species has a prominent fold that may aid in the prehension of food. (See Fig. 3-12.)

Oropharynx: Lacking a soft palate or other anatomic distinction, the term oropharynx is used in birds to describe the entire area, which in mammals would correspond to the combined oral cavity, oropharynx and laryngopharynx (Fig. 5-1).

Note the hyobranchial apparatus, the numerous, caudally directed mechanical papillae, and some openings of salivary glands. The **choana** and **infundibular openings** are located in the roof of the oropharynx (Fig. 5-1). The **palate** is characterized by numerous transverse ridges, which are used in some species to remove the outer shell of seeds.

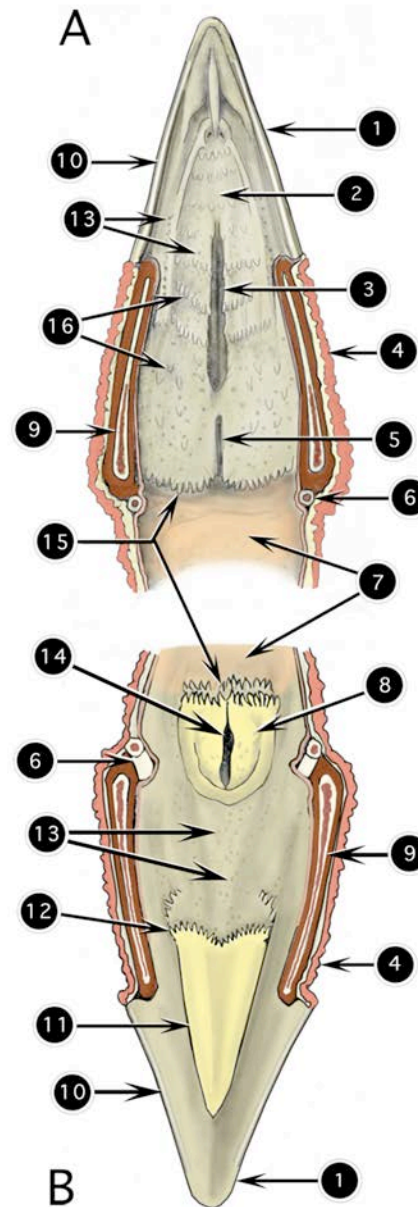


Figure 5-1. Opened oropharynx of chicken, roof A, floor B: (1) rhamphotheca (beak); (2) palate; (3) choana (palatine cleft); (4) rictus; (5) infundibular cleft (common opening of auditory tubes); (6) hyobranchial apparatus; (7) esophagus; (8) laryngeal mound; (9) mandible; (10) tomia, cutting edge of 1; (11) tongue; (12) lingual papillae; (13) openings of salivary glands; (14) glottic cleft; (15) pharyngeal papillae; (16) palatine papillae. (Modified after *Anatomy of the Domestic Birds*, R. Nickel, A. Schummer, E. Seiferle, Springer-Verlag, New York, 1977, page 43.)

The avian **tongue**, which is supported by the hyobranchial apparatus, is as variable as the many types of food eaten by birds. (See Figs. 2-16 & 2-19) Those variations can be considered as adaptations for the collection, manipulation, and swallowing of food. For example, the tongue of woodpeckers can be protruded to collect insect larvae and tree sap, while the tongue of hummingbirds and other nectar feeders can be extended into flowers. (See Fig. 1-59.)

The tongue of some birds is adapted for manipulating food and may be fleshy as it is in many parrots (Fig. 5-2). Other modifications are seen in fish-eating species that use their spiny tongues to help grasp slippery prey (Fig. 5-3), or in filter-feeding and grass-eating geese and ducks. For example, in the dabbling ducks, there are numerous stiff bristles along the lateral margins of the tongue, which interdigitate with the lamellae of the bill (Fig. 5-4). Water containing the small organisms upon which they feed is drawn into the oropharynx, the tongue is pressed against the palate, and the food material is filtered from the water as it is forced out laterally between the lamellae of the bill. This is similar to the way baleen works in some species of whales. Likewise, in grass-eating ducks and geese, similar stiff bristles assist in cutting the blades of grass with the bill.

Numerous **salivary glands**, which show considerable species variation, typically produce a thick saliva, which is needed to lubricate the foodstuff so that it can be propelled by rostrocaudal movements of the tongue, and directed by the mechanical papillae (Fig. 5-1), into the esophagus. During swallowing, the choana and infundibular cleft are closed-off to prevent food from entering these openings.



Figure 5-2. Photograph of macaw showing fleshy tongue used to manipulate food. (Photo courtesy: shutterstock_29064781-1).

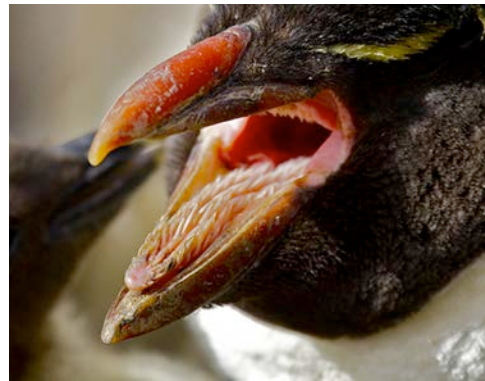


Figure 5-3. Photograph of penguin tongue showing stiff dorsal papillae. (Photo courtesy: 5399202917_ebebb9fcab).

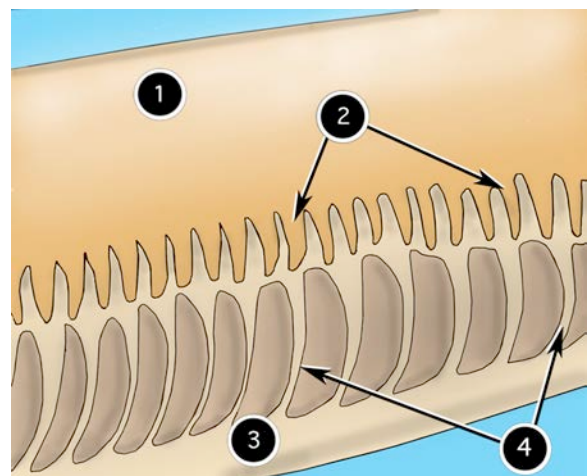


Figure 5-4. Drawing of tongue of dabbling duck, lateral view: (1) fleshy tongue; (2) bristles on lateral margin of tongue; (3) lower bill; (4) lamellae of bill.

There is considerable variation in how birds drink- chickens, and many other birds, raise their head and use "gravity flow," while other species (*viz.*, pigeons) keep their head down while drinking. In the chicken, there are numerous taste buds located at the base of the tongue.

The **laryngeal mound** (larynx) is situated on the floor of the oropharynx, caudal to the root of the tongue (Fig. 5-1). There is no epiglottis, and numerous, caudally-directed pharyngeal papillae are associated with the laryngeal mound. These mechanical papillae are thought to assist in moving food material into the esophagus during swallowing.

Esophagus: In contrast to the typical left-sided path in mammals, the esophagus of the bird courses in a subcutaneous position along the *right side* of the trachea in the cervical region (Fig. 5-5). In many species (*viz.*, chicken, turkey, pigeon, canary, parrots), the esophagus forms a dilatation near the thoracic inlet technically known as the **ingluvies**, but more commonly called the crop. Compared with that of mammals the esophagus of birds has a thinner wall, and is capable of greater distension. Think of a great blue heron swallowing whole a large fish or even a duckling.

Note the subcutaneous position of the crop at the thoracic inlet (Fig. 5-5), where it is palpable and surgically accessible for the removal of foreign bodies or relief of impaction. The crop, which like the esophagus proper has prominent mucous glands associated with it, represents a temporary storage compartment for food waiting to move into the stomach. Like the ruminoreticulum of the ruminant, the crop allows for an eat-now, digest-later advantage so that birds can feed quickly and gain possession of potentially scarce food

material before some competitor gets to it. Many species of birds, including many fish-eating groups (*viz.*, penguins and gulls) do not have a crop. When present, the shape and size of the crop show considerable variation.

The crop of pigeons and doves is especially well developed, consisting of two large lateral sacs. Pigeons produce what is commonly called "**crop milk**," which consists of fat-laden, desquamated (stratified squamous) epithelial cells, mixed with food. This nutritious material is regurgitated by the adults (both sexes) and fed to the young (squabs) for some days after hatching.

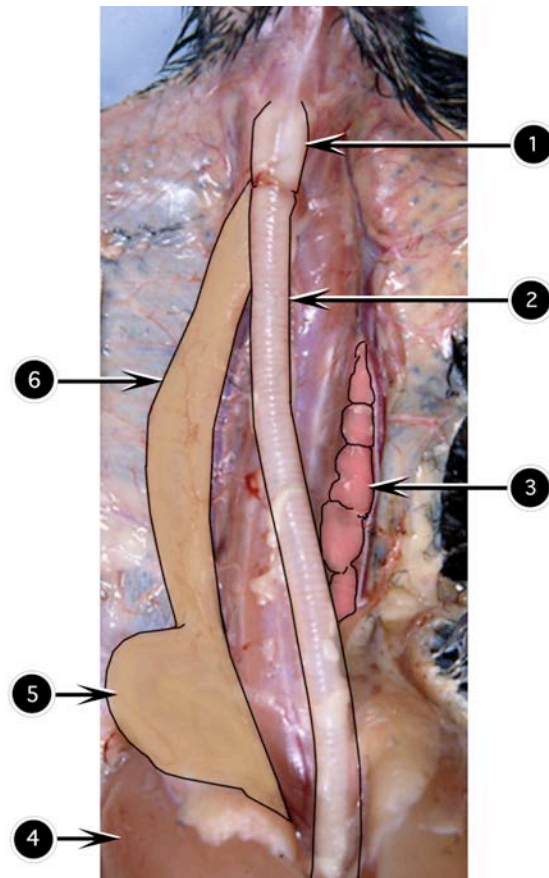


Figure 5-5. Dissection of neck of chicken, ventral view: (1) larynx; (2) trachea; (3) thymus; (4) pectoral muscle; (5) crop (ingluvies); (6) esophagus.

Other birds such as the male Emperor penguin and the greater flamingo also produce a nutritive fluid in their esophagus, which is regurgitated to feed their chicks.

The bird with the greatest development of the crop is most likely the **hoatzin** (Fig. 5-6). This native of the Amazon region eats leaves, fruits, and flowers. Its crop is divided into a large cervical and two thoracic compartments. Much like a ruminant, the hoatzin uses its complex crop for **fermentative digestion**. As a result of this foregut fermentation, the hoatzin releases a rather unpleasant aroma, which contributes to one of its common names—"stink bird." The great development of the crop of the hoatzin even displaces the keel of its sternum, thus reducing the surface area for flight muscles.



Figure 5-6. South American hoatzin (*Opisthocomus hoazin*). (Photo courtesy: http://en.wikipedia.org/wiki/File:Opisthocomus_hoazin.jpg)

Caudal to the thoracic inlet, the esophagus continues ventral to the lungs, which are confined to the dorsal part of the **thoracoabdominal cavity**, crosses the tracheal bifurcation and base of the heart, and enters the glandular proventriculus of the stomach. In the duck, the terminal part of the esophagus contains a prominent aggregation of lymphoid tissue, popularly termed the "esophageal tonsil."

Some species such as the sage grouse, Australian bustard, American bittern, and the prairie chicken have an additional inflatable **esophageal sac** in the more proximal part of their cervical esophagus. Male birds inflate the sac during the mating ritual to attract females; it also functions as a resonating chamber for the mating calls.

Due to the overlying heart and liver, the continuation of the esophagus and the stomach are obscured when the thoracoabdominal organs are viewed ventrally (Figs 5-7 & 5-8).

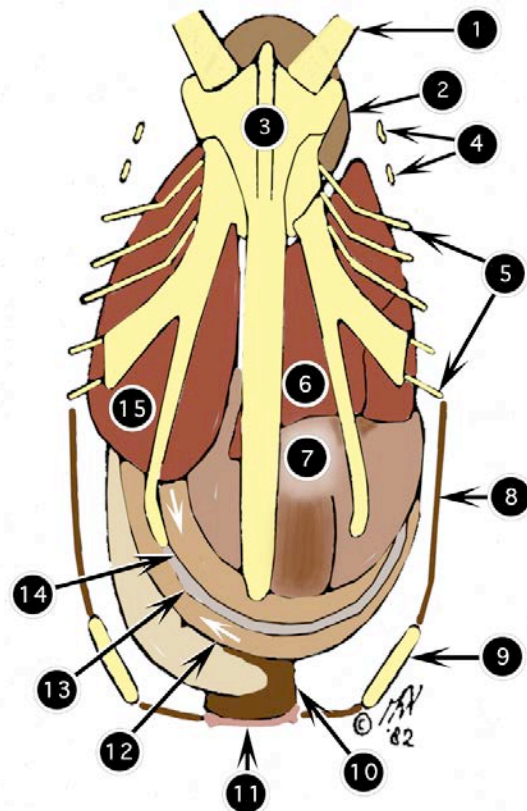


Figure 5-7. Skeletal relationships to thoracoabdominal viscera of chicken, ventral view: (1) coracoid bone; (2) heart; (3) sternum; (4) cervical ribs; (5) thoracic ribs; (6) left lobe of liver; (7) ventriculus (gizzard); (8) body wall; (9) pubic bone; (10) rectum; (11) opening of cloaca (vent); (12) ascending limb of duodenum; (13) pancreas; (14) descending limb of duodenum; (15) right lobe of liver.

Stomach: The stomachs of birds vary considerably with their diet, and are divided into two basic types: type 1 (carnivorous) & type 2 (non-carnivorous). A **type 1 stomach** is relatively large and is designed more for storage and chemical breakdown (proteolysis) than for physical digestion. Thus, this type is typically thin-walled and more sac-like (Fig. 5-9). Also, the distinction between the proventriculus and ventriculus is less obvious on external examination. There is no distinct isthmus between proventriculus and ventriculus, but there is an **intermediate zone** between the glandular and non-glandular parts of the stomach.

The gastric glands of the proventriculus of the carnivorous type may be uniformly distributed or they may be concentrated in tracts (owls), in patches (ostrich) or limited to a proventricular diverticulum (anhinga). The epithelium contains many mucus-secreting columnar cells, but the major glands extend into the lamina propria of the stomach wall. These large glands contain a single cell type (oxynticopeptic cell) that produces both pepsin and hydrochloric acid.

The **type 2 stomach** of most domestic birds consists of two distinct compartments, the **proventriculus** or glandular part, and the **ventriculus** or muscular part, which are connected by a constriction or **gastric isthmus** (Fig. 5-10). In the chicken, the proventriculus is more or less football-shaped.

The wall of the non-carnivorous proventriculus is thickened due to the presence of large multilobular glands. The epithelium contains many mucus-secreting columnar cells, but the major glands extend into the lamina propria of the stomach wall. These large glands contain a single cell type

(oxynticopeptic cell) that produces both pepsin and hydrochloric acid. These secretions enter the proventricular lumen *via* large ducts that open on prominent papillae on the mucosal surface (Fig. 5-10).

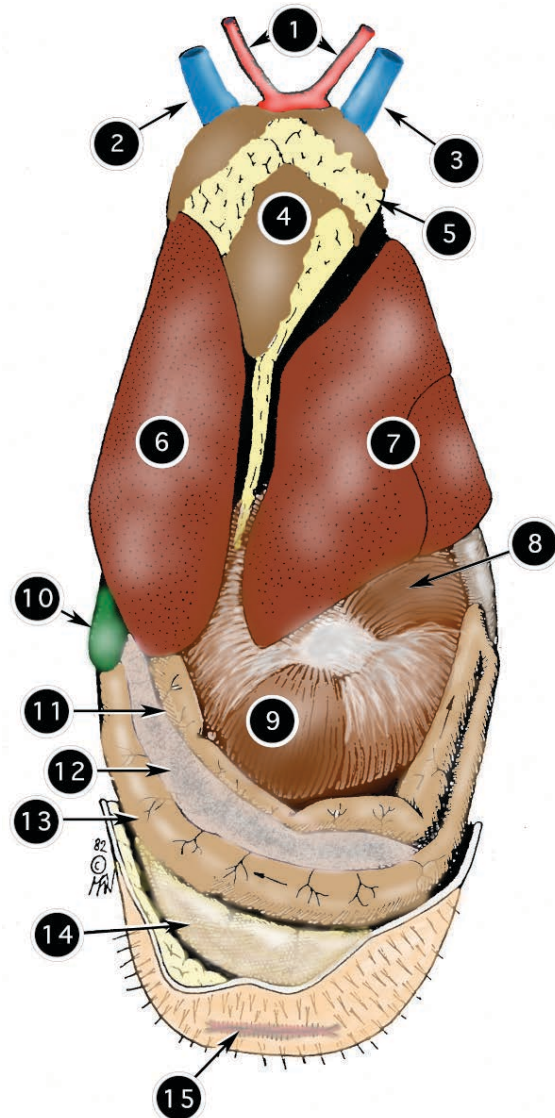


Figure 5-8. Viscera of chicken *in situ*, ventral view: (1) right & left brachiocephalic trunks; (2) right cranial vena cava; (3) left cranial vena cava; (4) heart; (5) fat in coronary groove; (6) right lobe of liver; (7) left lobe of liver; (8) cranial sac of ventriculus; (9) caudal sac of ventriculus; (10) gallbladder; (11) descending limb of duodenum; (12) pancreas; (13) ascending limb of duodenum; (14) one of paired ceca; (15) opening of cloaca (vent).

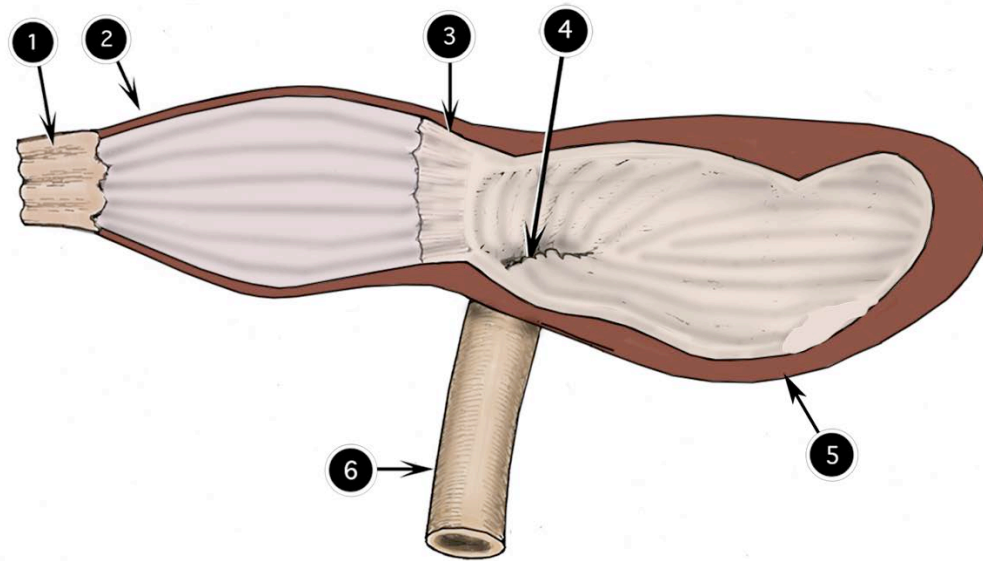


Figure 5-9. Type 1 stomach of carnivorous birds: (1) esophagus; (2) proventriculus; (3) intermediate zone; (4) pyloric part of ventriculus leading to duodenum; (5) thin-walled ventriculus; (6) duodenum.

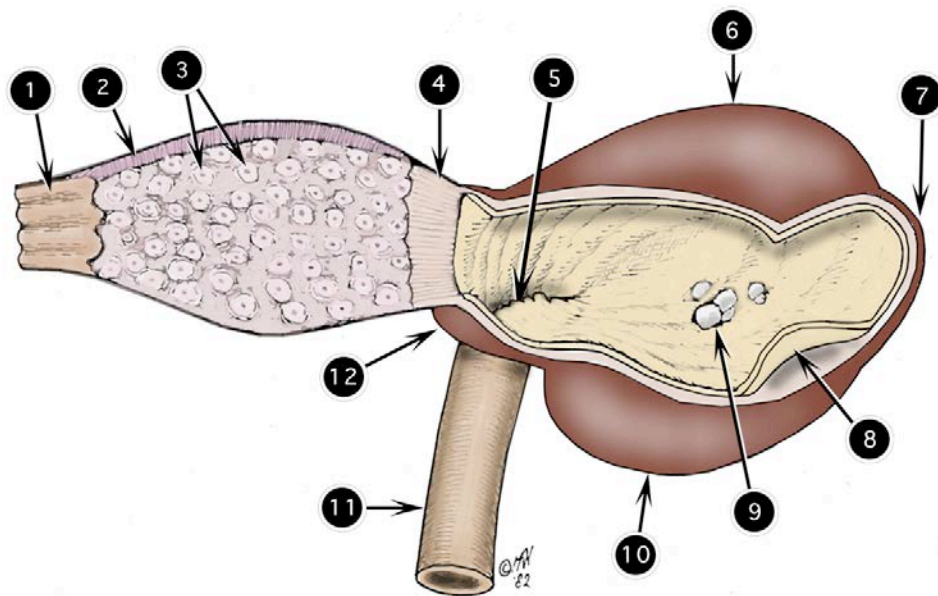


Figure 5-10. Stomach of chicken (opened), left lateral view: (1) esophagus; (2) compound gastric glands forming thick layer in wall of proventriculus; (3) gastric gland opening on papillae; (4) gastric isthmus; (5) pyloric part of ventriculus leading to duodenum; (6) caudodorsal thick muscle of ventriculus; (7) caudal sac of ventriculus; (8) gastric cuticle (koilin layer), partly reflected; (9) grit used to help grind seeds; (10) cranioventral thick muscle of ventriculus; (11) duodenum; (12) cranial sac of ventriculus.

The **ventriculus** or “gizzard” is more or less a flattened oval of muscle; however, the thickness of the muscle is not uniform around the circumference of the organ. Although the ventricular musculature is

composed of smooth muscle, owing to an abundance of myoglobin, it is dark in color and looks grossly more like skeletal muscle, (Fig. 5-10).

Darker colored, thin-muscled areas are present over the cranial and caudal sacs of the ventriculus (Fig. 5-8). The mucosa of the ventriculus is thin, but is protected by a **cuticle** or **koilin layer**, which is produced by glands within the stomach wall. Koilin is a carbohydrate-protein complex that solidifies on the mucosal surface, forming a protective liner for the ventriculus (Fig. 5-10). It is removed in processing the gizzard for food.

In seed-eating birds (*viz.*, chicken, turkey, budgerigar), the ventriculus typically contains small stones or **grit**, which owing to the lack of teeth, functions in the "gastric mastication" of the food material (Fig. 5-10). The presence of this radiopaque grit in the ventriculus of parakeets and other seedeaters can be used to identify the ventriculus in radiographs. Although the pyloric part of the stomach, which arises from the right side of the ventriculus, forms a distinct compartment in some birds, in domestic species it is small and connects the body of the gizzard with the duodenum.

As mentioned above, various species of birds regurgitate material from their crop or stomach to feed their young. Another function of gastric regurgitation in raptors is to purge the stomach of indigestible remnants of their prey. Not only is it normal for hawks and owls to regurgitate this digestive residue, it is essential for the health of the bird. The term **pellet** is used to describe these regurgitated clumps of fur, feathers, bones, teeth, etc. (Fig. 5-11). In falconry the pellets are called **castings**. Regurgitating the pellet, which typically occurs some 6-10 hours after the meal, helps to scour or clean the esophagus.

Falconers, routinely give their birds roughage so that it will be regurgitated to cleanse the crop of bacteria, a process

known as "casting." **Captive birds of prey need to be given roughage in addition to meat.** Although typically associated with hawks and owls, pellets are also regurgitated by herons, kingfishers, cormorants, gulls, terns, grebes, crows, and many shorebirds.



Figure 5-11. Regurgitated bird pellet. Black bars are 1 cm long. (Photo courtesy: http://en.wikipedia.org/wiki/File:Bird_pellet.jpg)

Although the avian stomach is divided into the two main categories of type 1 and type 2, this is an over simplification of the great diversity of stomach design among avian species. Like the esophagus, the stomach of many carnivorous birds (owls, herons) must be large and distensible to accommodate the large prey that is swallowed whole. For example, herons will swallow an adult rat or even a large duckling. In addition, birds can be very indiscriminant in what they ingest, often including foreign bodies, which can lead to serious illness and even death (Fig. 5-12).



Figure 5-12. Foreign bodies removed from stomach of crane at necropsy.

Intestines: The intestines of the bird, which consist of the duodenum, jejunum, ileum, paired ceca, and a rectum, occupy much of the body cavity. The **duodenum** typically forms a distinct loop with descending and ascending limbs; however, there are a few

species with variations of this pattern. The duodenum lies close to the ventral body wall and encloses the pancreas within its loop (Figs. 5-8 & 5-13).

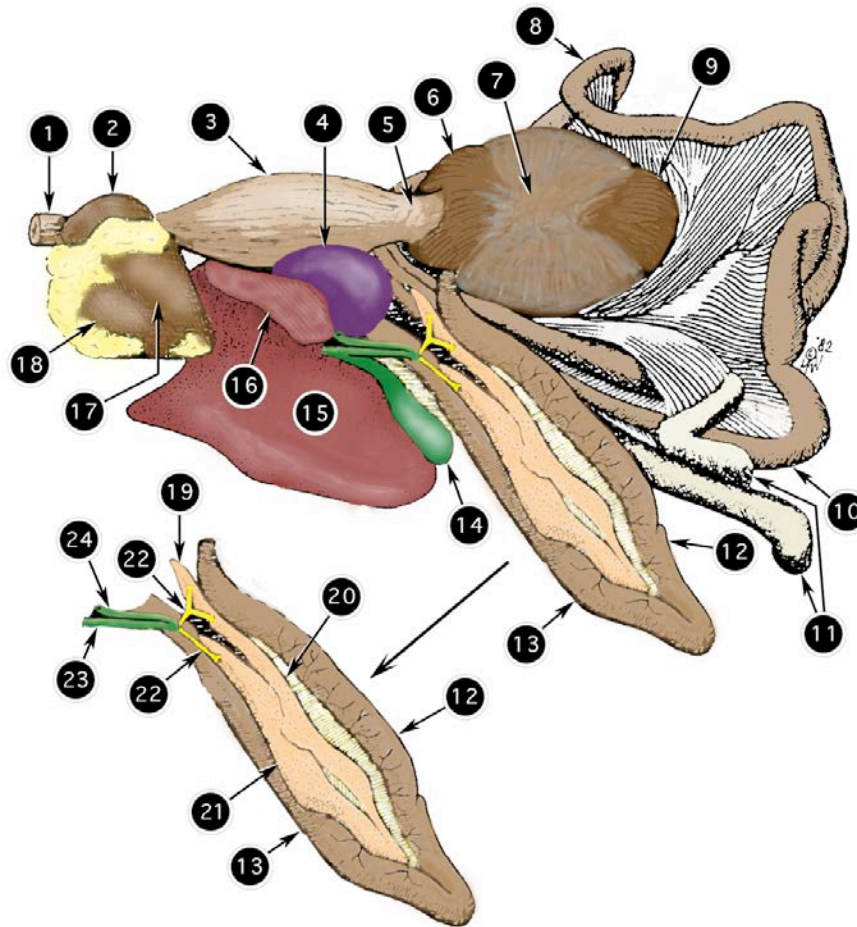


Figure 5-13. Viscera of chicken in situ, left lateral view: (1) esophagus; (2) left atrium of heart; (3) proventriculus; (4) spleen; (5) gastric isthmus; (6) thin muscle covering cranial sac of ventriculus; (7) central tendinous part of ventriculus; (8) jejunum; (9) thin muscle covering caudal sac of ventriculus; (10) ileum; (11) apices of paired ceca; (12) descending limb of duodenum; (13) ascending limb of duodenum; (14) gallbladder; (15) right lobe of liver; (16) cut surface of liver where left lobe of liver was removed; (17) left ventricle of heart; (18) right ventricle of heart; (19) splenic lobe of pancreas; (20) dorsal lobe of pancreas; (21) ventral lobe of pancreas; (22) pancreatic ducts; (23) cystoenteric duct from gallbladder and right lobe of liver; (24) hepatoenteric duct from left lobe of liver.

In the chicken and turkey, the thin-walled **jejunum** forms numerous loosely arranged loops in the free edge of the mesentery (Fig. 5-13). Its junction with the **ileum** is defined in the bird by the presence of the **vitelline** (Meckel's) **diverticulum**, a

small remnant of where the yolk sac was attached to the gut (Fig. 5-14).

In the duck, goose, budgerigar, and canary, the small intestine is arranged in a number of U-shaped loops, the first of which is the duodenal loop. To go a step further,

the small intestine of the pigeon forms a cone-shaped mass, similar to the colon of the pig (*i.e.*, complete with centripetal and centrifugal coils). Near the terminal part of the ileum, there are numerous aggregated

lymphoid nodules, which are especially prominent in the duck. In some species (*viz.*, pelicans, penguins, falcons), the ileum forms a small loop just proximal to the ceca.

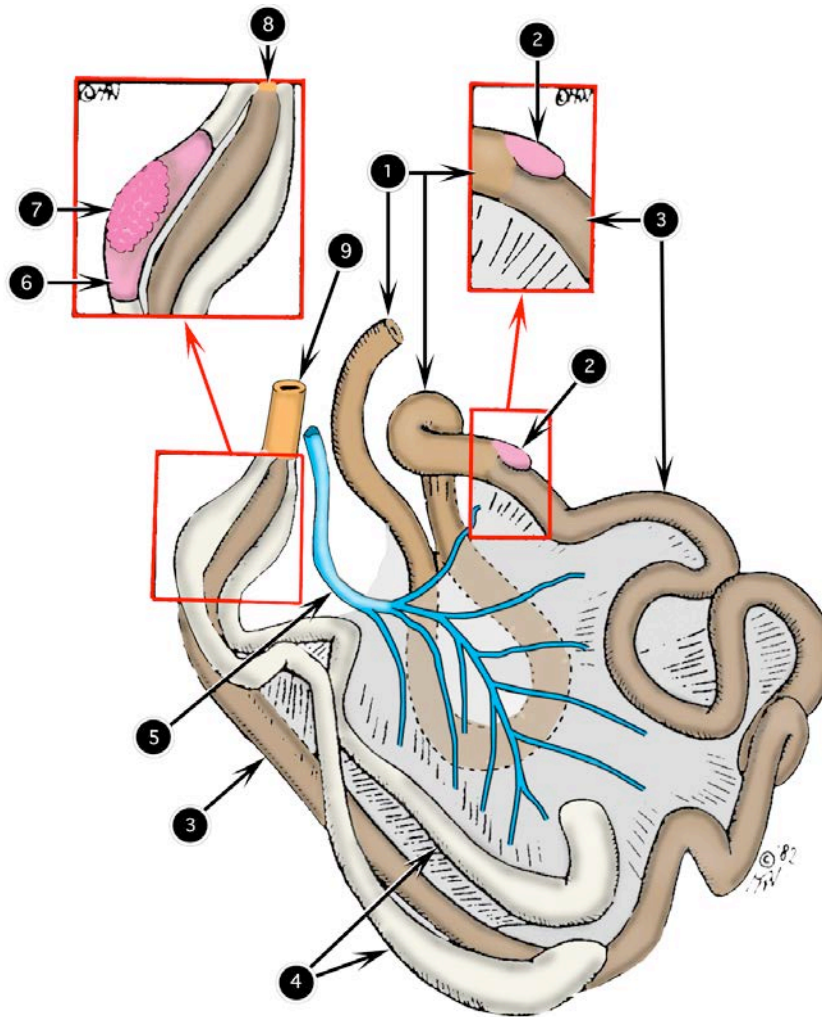


Figure 5-14. Intestines of domestic chicken: (1) jejunum; (2) vitelline (Meckel's) diverticulum; (3) ileum; (4) paired ceca; (5) cranial mesenteric vein; (6) opened cecum to expose mucosal surface; (7) aggregated lymphoid nodule ("cecal tonsil"); (8) ileocecorectal junction; (9) rectum.

The **large intestine** consists of paired **ceca** and a short **rectum**. In the chicken, turkey, duck, goose and owl, two long ceca are held alongside the ileum by the ileocecal folds. In the base of the ceca, their walls contain **aggregated lymphoid nodules**, which are often referred to as the "cecal tonsils." Also the muscular wall is thickest in the base of the ceca, forming the cecal

sphincters. The ceca provide an area of fermentative digestion, similar to what occurs in the horse, pig, and ruminant. They also serve an important role in water resorption.

Ceca are short and poorly developed in the pigeon, and are not present at all in psittacine birds. In the owl, the apical parts

of the ceca are expanded, forming bulb-like endings, while in the helmeted guinea fowl and ostrich, the ceca have haustra or sacculations, similar to those of the horse and pig.

The term **rectum** is used to describe the short, terminal part of the large intestine, which enters the cloaca in the ampulla-like area termed the **coprodeum**. Some texts refer to the rectum as the colon; however, NAA identifies this part of the bowel as the rectum. In the rhea, the rectum forms a loop.

Liver: The liver, which is typically dark reddish-brown in the adult bird, occupies much of the cranial part of the thoracoabdominal cavity. In young hatchlings, the liver has a more yellow color, which is due to the presence of pigments absorbed from the yolk sac. The liver consists of **right** and **left lobes**, which are connected dorsal to the heart (Figs. 5-8 & 5-13). In the chicken, the two lobes are of similar size, and in both chicken and turkey, the left lobe is divided into medial and lateral parts. In most passerine birds, it is the right lobe that is divided. The **gallbladder**, when present, is associated with the visceral surface of the right lobe of the liver.

In the duck, goose, and pigeon, the right lobe is much larger than the left lobe, which is not subdivided as in the chicken and turkey. There is no gallbladder in the ostrich, pigeon or budgerigar; however, some other species of parrots do have a gallbladder.

Typically two **bile ducts** enter the distal part of the ascending limb of the duodenal loop (Fig. 5-13). In the chicken, the common **hepatoenteric duct** drains both right and left lobes. The gallbladder drains

directly into the duodenum *via* the other bile duct, the **cystoenteric duct**. In those species that lack a gallbladder, both bile ducts are termed hepatoenteric ducts.

Pancreas: As previously noted, the pancreas is located within the duodenal loop. It typically consists of three lobes--large **dorsal and ventral lobes**, and a small **splenic lobe** located near the spleen (Fig. 5-13). Typically there are two (sometimes 3) pancreatic ducts that enter the duodenum in close association with the bile ducts. The exocrine secretion of the pancreas is similar to that of mammals, containing amylase, lipase and proteinases.

Spleen: Although not part of the digestive system, the spleen, as in mammals, is located near the stomach, and thus falls victim to description at this point (Fig. 5-13). The spleen of the bird is typically red or dark red in color and varies in shape from spherical (chicken) to triangular (duck) to elongated (pigeon & canary).

Cloaca: The cloaca is common to both the digestive and urogenital systems, and consists of three areas, the **coprodeum**, **urodeum**, and **proctodeum**, which are partly partitioned by two annular folds (Fig. 5-15). The external opening of the cloaca is properly termed the **vent**.

The **coprodeum** receives the fecal matter from the rectum and is separated from the urodeum by the **coprourodeal fold**. In most species, the junction of rectum and coprodeum is indistinct except for an increase in diameter; however, in the ostrich, the junction is marked by a fold, and in ducks, by a change in mucosal pattern. In the latter, this mucosal change corresponds with an abrupt transition to stratified squamous epithelium lining the coprodeum.

As the name implies, the **urodeum** receives the ureters and either the ducti deferentes of the male or the left oviduct in the female. If the coprodeum is full of feces, the coprourodeal fold everts (prolapses) out through the vent during defecation so that the openings of the urogenital system are not contaminated with feces (more on this later). During egg laying, the coprourodeal fold can form a sphincter to prevent (greatly reduce) fecal contamination of the egg.

The **proctodeum** is the terminal part of the cloaca, between the uroproctodeal fold and the vent. In young birds, there is a duct in the dorsal wall of the proctodeum leading to the large **cloacal bursa** (Fig. 5-15). This “bursa,” popularly known as the “bursa of Fabricius,” is in reality a lymphoid diverticulum that is immunologically important. The lymphatic tissue surrounding the lumen of the diverticulum is the site of differentiation of the bursal (B)-

lymphocytes, which are thought to be originally derived from yolk sac stem cells.

The cloacal bursa varies from pear-shaped in most birds, to an elongated spindle shape in ducks (anseriformes). Due to its immunological function, the bursa reaches its maximum development (size) in the first 3 months of life, after which, it involutes (atrophies) prior to sexual maturity. In the ostrich (ratites), the opening of the bursa is so large, that it appears to be a compartment of the proctodeum.

Immediately caudal to the opening of the cloacal bursa, some species of galliformes have a **dorsal proctodeal gland**, consisting of mucous glands and lymphatic tissue (Fig. 5-15). This gland becomes quite large in the sexually mature male quail, and because it produces a frothy fluid, has been called the “foam gland.”

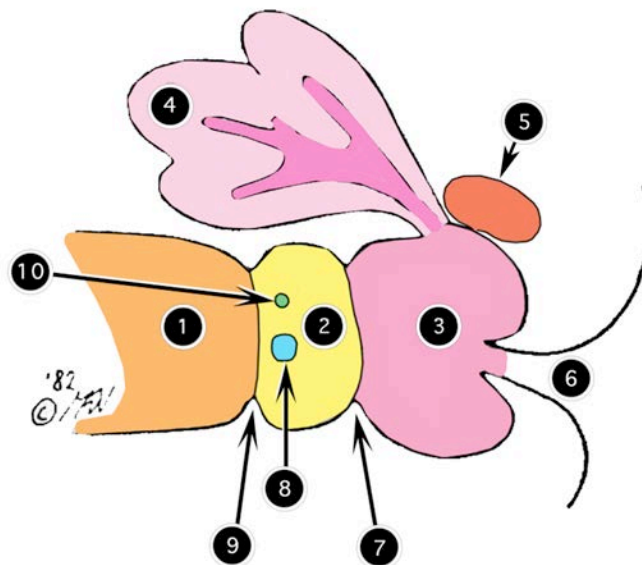


Figure 5-15. Schematic representation of cloaca of young chicken, median section, left lateral view: (1) coprodeum; (2) urodeum; (3) proctodeum; (4) cloacal bursa; (5) dorsal proctodeal gland; (6) vent; (7) uroproctodeal fold; (8) location of papilla of ductus deferens in male or left oviduct in female; (9) coprourodeal fold; (10) opening of ureter.

Chapter 6 • Respiratory System

One of the most remarkable differences in avian species vs. mammals is their highly efficient respiratory system. The **naris** (nostril) is partly protected in the chicken and other species by an over-hanging shelf of horny tissue, the **operculum** (Fig. 3-12). In some species the nares are surrounded by the cere (Fig. 3-15). Albatrosses and petrels (procellariiformes) have tubular nostrils (Fig. 6-1).

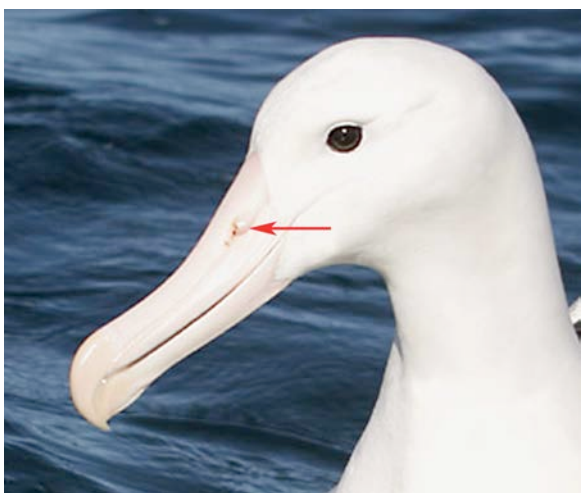


Figure 6-2. Head of southern royal albatross showing tubular naris. (Photo courtesy: http://en.wikipedia.org/wiki/File:070226_southern_royal_albatross_off_Kaikoura_2.jpg)

As in mammals, there is only one **nasal cavity** per bird, which is divided by a nasal septum into right and left sides. The nasal cavity communicates with the oropharynx via the **choana**. Each side of the nasal cavity of the chicken has three **conchae**, however, they are designated as rostral, middle, and caudal (Fig. 6-2). The latter concha is air-filled, and its cavity communicates with the clinically important infraorbital sinus.

The **infraorbital sinus** (Fig. 6-3), which lies ventral to the eye, is subject to infections of various types in the chicken.

In psittacine birds, right and left infraorbital sinuses communicate, not only with one another, but also with extensive pneumatized areas of the skull and neck. Thus, infections of the infraorbital sinuses of parrots and budgerigars are difficult to treat effectively.

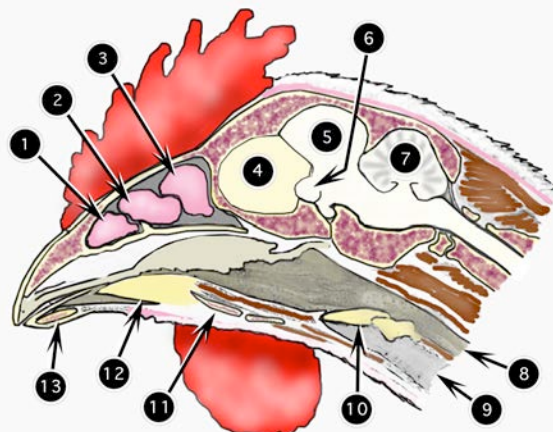


Figure 6-2. Head of chicken, sagittal section: (1) rostral nasal concha; (2) middle nasal concha; (3) caudal nasal concha; (4) interorbital septum; (5) cerebrum; (6) optic chisma; (7) cerebellum; (8) esophagus; (9) trachea; (10) arytenoid cartilage of larynx; (11) hyobranchial apparatus; (12) tongue; (13) mandible. (Modified after *Anatomy of the Domestic Birds*, R. Nickel, A. Schummer, E. Seiferle, Springer-Verlag, New York, 1977, page 45.)

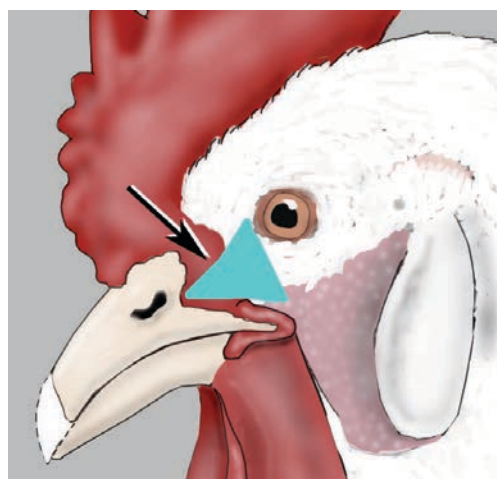


Figure 6-3. Location of left infraorbital sinus of chicken. These paired sinuses are subject to serious infections, which can be difficult to treat, especially in psittacine birds.

The large **nasolacrimal duct** (Fig. 6-4), which is formed by the confluence of the superior and inferior **lacrimal canaliculi** (Fig. 6-5), opens on the ventromedial aspect of the middle nasal concha. Right and left ducts pass through the dorsomedial walls of the infraorbital sinuses and open just dorsal to the choanal cleft. Thus, the tears enter the oropharynx *via* the choanal cleft (Fig. 6-6). (For more information on the lacrimal apparatus, see Chapter 9.)

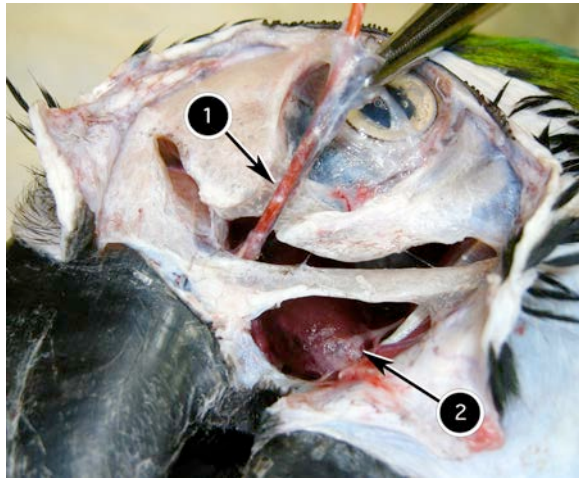


Figure 6-4. Dissection of nasolacrimal duct in blue & gold (yellow) macaw: (1) cannula inserted through inferior lacrimal canaliculus into nasolacrimal duct; (2) infraorbital sinus. (Photo courtesy Lauren Powers, DVM, DABVP.)

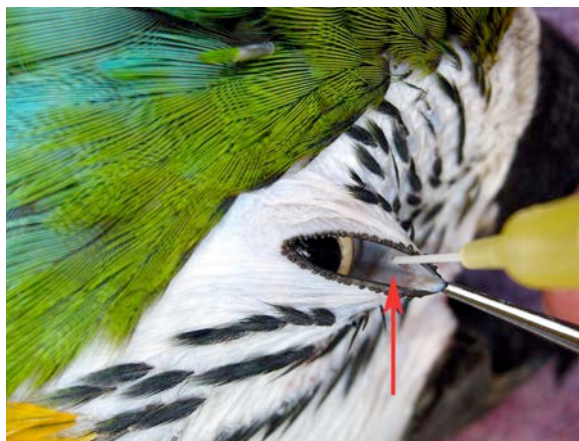


Figure 6-5. Cannulation of inferior lacrimal canaliculus in blue and gold (yellow) macaw. (Photo courtesy Lauren Powers, DVM, DABVP.)

Another duct(s) that opens into the nasal cavity of birds is that of the **nasal gland** (Fig. 6-7), which is not located within the nasal cavity, but rather lies dorsal to the orbit. This is the so-called "salt gland," so named because in some marine birds, the gland has an osmoregulatory function that allows them to drink seawater ($\approx 3\%$ salt) and excrete the salt *via* this gland. The salt is excreted as a hypertonic ($\approx 5\%$) saline solution from the naris.

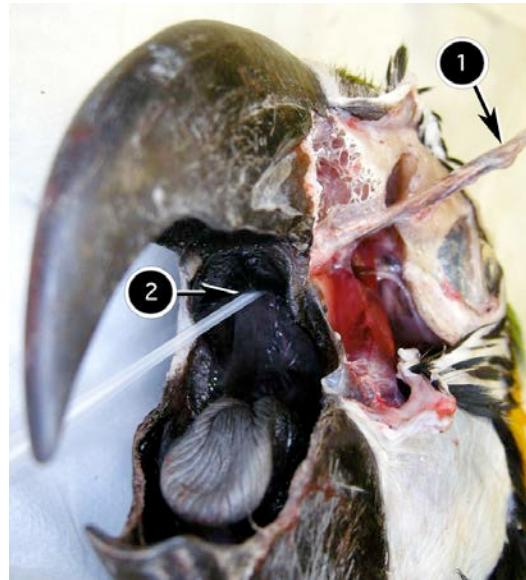


Figure 6-6. Dissection of nasolacrimal duct in blue & gold (yellow) macaw: (1) cannula inserted through inferior lacrimal canaliculus and nasolacrimal duct; (2) cannula emerging through choanal cleft. (Photo courtesy Lauren Powers, DVM, DABVP.)

In some species, the nasal gland consists of medial and lateral lobes, each with its own duct that enters the nasal cavity near the naris. In other species (*viz.*, chicken), only the medial lobe is present. In the albatross (Fig. 6-7), the hypertonic saline solution from the nasal gland emerges from the tubular nostril into a groove in the upper beak, where it is conducted to the rostral aspect of the beak.

Although the gland has a similar osmoregulatory function in some raptors and desert birds that feed on salty prey, it is

present in many other species (*viz.*, chicken), where it has no known salt-excreting function.

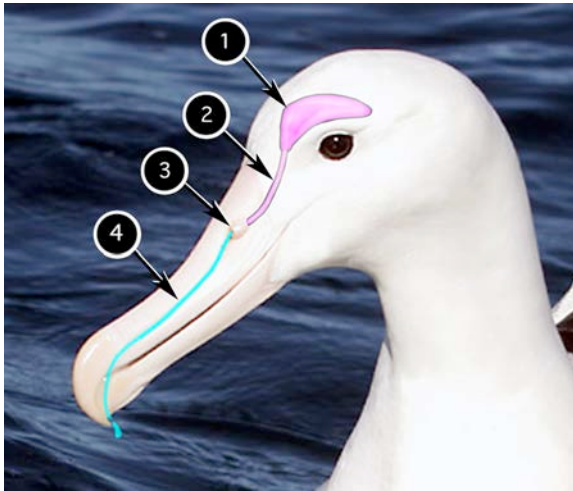


Figure 6-7. Nasal gland of southern royal albatross: (1) nasal gland in supraorbital location; (2) duct of gland leading to nasal cavity near naris; (3) tubular naris; (4) hypertonic saline solution being conducted rostrally *via* groove in upper beak.

The **laryngeal mound (larynx)**, which projects into the floor of the oropharynx, is supported primarily by the cricoid and paired arytenoid cartilages (Fig. 5-1). There is also a small, dorsally located procricoid cartilage that is interposed within the articulations between the two arytenoid cartilages rostrally and the cricoid cartilage caudally. The epiglottic and thyroid cartilages of the mammalian larynx are absent in the bird. Although the larynx is not the site of sound origination, the larynx can serve to modulate the sounds produced in the syrinx.

The **glottis** is not exactly homologous to the mammalian glottis in that there are no vocal folds in birds; however, the paired arytenoid cartilages surround and protect the slit-like opening of the glottis (Fig. 5-1). Closure of the glottis during swallowing protects the lower respiratory tract against aspiration of food material. The opening is also protected in some birds (*viz.*, chicken)

by prominent, caudally-directed papillae. Although most pet birds can be intubated for delivery of anesthetic gases, this can also be accomplished by placing a cannula in the abdominal or caudal thoracic air sac. This can also be used as an alternative route of anesthetic administration in cases of tracheal obstruction or for surgery of the oropharynx.

Unlike the C-shaped **tracheal cartilages** of mammals, those of birds consist of tightly overlapping and complete rings (Fig. 6-8). In some species (*viz.*, passerines) the cartilages are ossified. The trachea accompanies the esophagus through the cervical region and can typically be palpated (Fig. 5-2). Some portions of the trachea of the ostrich are not supported by cartilage. Other species (*viz.*, penguins) have a so-called “double trachea” in which a median septum divides the trachea for a variable length into right and left halves.

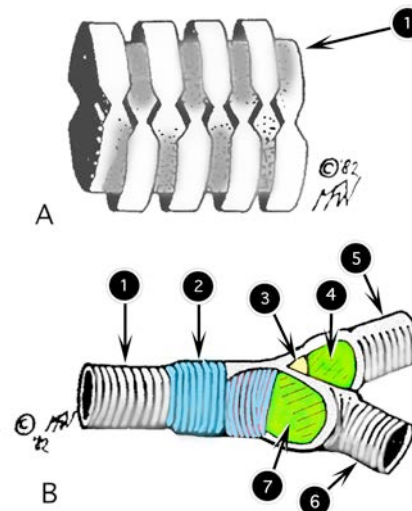


Figure 6-8. Schematic representation of trachea (A) and syrinx (B) of chicken, left lateral view: (1) interlocking tracheal cartilages; (2) tympanum; (3) pessus; (4) medial tympaniform membrane; (5) right principal bronchus; (6) left principal bronchus; (7) lateral tympaniform membrane.

The avian trachea shows a great deal of species-specific variation. For example, the

trachea of the emu and ruddy duck has an inflatable diverticulum, the **tracheal sac**. During gas anesthesia of the emu, the lower neck should be wrapped to prevent inflation of this sac. Some species (*viz.*, swans, cranes, etc.) have rather complicated tracheal loops or coils, which may be partially housed within an excavation of the sternum (Figs. 6-9 & 6-10). Having such a long trachea would appear to increase air-flow resistance; however, the avian trachea has a diameter almost 1.5 times that of a comparably sized mammal. The increased tracheal “dead space” is compensated for by a slower respiratory rate and greatly increased ($\approx 4X$) tidal volume.

It is thought that these species-specific arrangements of loops and coils serve as sound resonating chambers, allowing the unique call of a particular species to be produced with rather low pressure. When one considers the wide variation in tracheal looping among different species, it is certainly suggestive of the variations found in musical instruments such as the trumpet, coronet, trombone, and French horn. In a few species of anseriformes, there is a **tracheal bulla** just proximal to the tracheal bifurcation in the male.

The **syrinx**, which is the source of vocalization in birds, is typically located in the vicinity of the tracheal bifurcation (Fig. 6-8). There is, however, considerable species variation, and even differences between the male and female. In some species the syrinx is entirely tracheal (*viz.*, Furnarioidea), while in others it is entirely bronchial (*viz.*, owls).

In its basic design, the syrinx consists of partially ossified cartilages for support, paired tympaniform membranes that vibrate to produce sound, and various muscles that can alter the tension on the syrinx and its

tympaniform membranes. In the chicken the parts of syrinx include the **tympanum**, which is formed by several fused cartilaginous rings; the **pessulus**, which is a median cartilage located at the bifurcation of the principal bronchi; and right and left pairs of **tympaniform membranes** (Fig. 6-8). The medial tympaniform membranes are considered to be the primary vibrating structures of the syrinx. All “vocalization” in birds is thought to be produced on expiration, when a rise in pressure in the clavicular air sac forces the tympaniform membranes into the lumen of the syrinx. Sound is produced either by vibration of the tympaniform membranes, and/or other mechanisms that produce columns of turbulent airflow through the syrinx.

Muscles that affect the syrinx, either directly or indirectly, are highly variable among avian species. The principal muscles that affect the tympaniform membranes in the chicken are the paired **sternotrachealis muscles**. These muscles extend from the cranio-lateral process of the sternum to the trachea. Apparently these muscles are necessary for a rooster to “crow.” Songbirds have a more complex set of up to five pairs of syringeal muscles.

The syrinx of the male duck should receive special attention because of its peculiar feature, the **syringeal bulla**. This egg-shell-like, osseous bulla is asymmetric, being primarily associated with the left bronchial part of the syrinx (Fig. 6-11). Such a bulla is present in most species of duck; however, according to NAA, it is absent in true geese and swans. Apparently, this bulla serves as an additional resonance chamber to modulate the sound of the male “quack.” It may even serve to soften the sound of the drake as compared with the more boisterous sound of the hen.

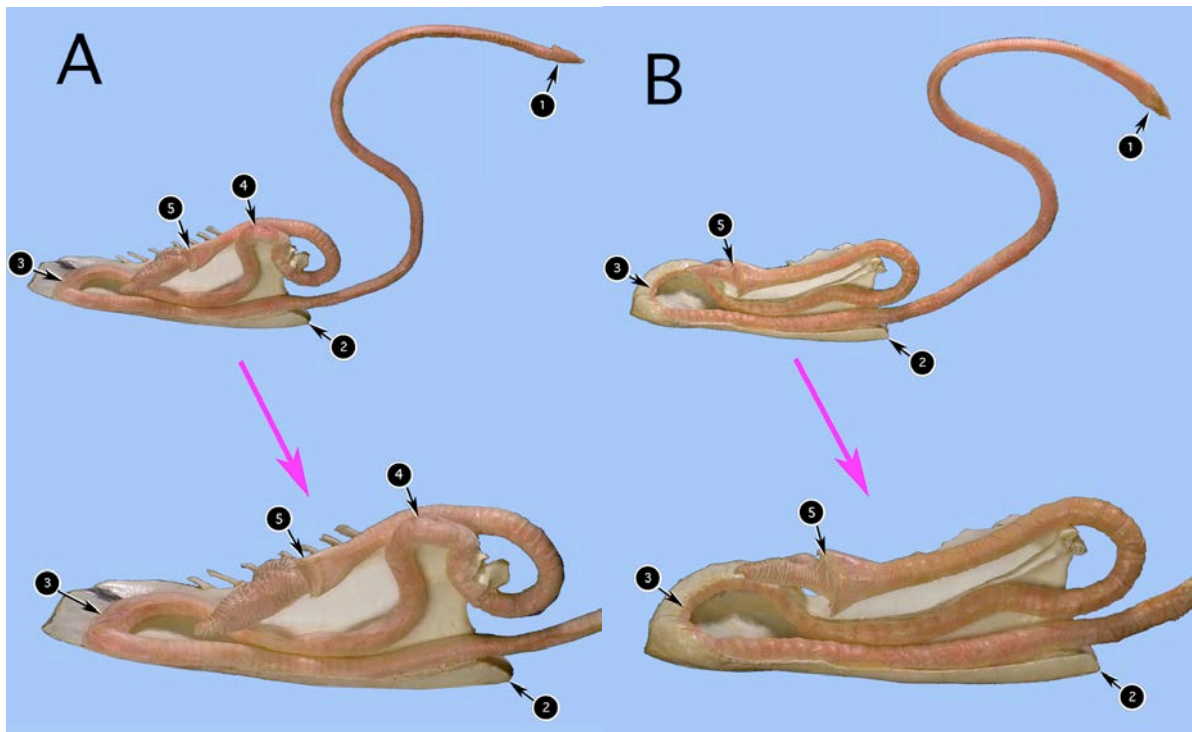


Figure 6-9. Photographs comparing trachea and sternum of trumpeter swan, *Olor buccinator* (A) with that of tundra (whistling) swan, *Cygnus columbianus* (B): (1) larynx; (2) keel of sternum; (3) caudal transverse loop of trachea; (4) dorsal loop of trachea in osseous bulla (A only); (5) syrinx. (Specimens kindly provided by Dr. Laurel Degernes, NC State University College of Veterinary Medicine.)

Lungs: Avian lungs are relatively small for body size, are confined to the craniodorsal part of the thoracoabdominal cavity, and are more or less embedded against the ribs and thoracic vertebral column. They do not extend down around the heart, but are held in their dorsal compartment by a **horizontal septum**. The lungs are loosely attached to their surroundings, there are no pleural cavities as such, and most remarkable, there is very little change in lung volume between inspiration and expiration.

The lungs of birds are bright red in color, are not divided into lobes, and have a quadrilateral to triangular shape (Fig. 6-12). The dorsomedial surface, which is related to the vertebrae, is termed the **vertebral surface**, while the dorsolateral aspect of the lungs applied to the ribs is termed the **costal**

surface. The ventral surface of the lung, which is supported by the horizontal septum is termed the **septal surface**.

When peeled away from the thoracic wall, the lungs retain the impressions made by the vertebral ribs, against which they were embedded. Similar to mammals, the principal bronchus and pulmonary vessels enter the lung at its **hilus**.

Before we go any further, we have to tell you something pretty basic about bird lungs. Sort of like the brain of more intelligent mammals, the lung of the bird has been "added onto" over time. There is the basic "old lung" (paleopulmo), which is present in all birds, and the so-called "new lung" (neopulmo), which is the more recent (phylogenetically speaking) addition.

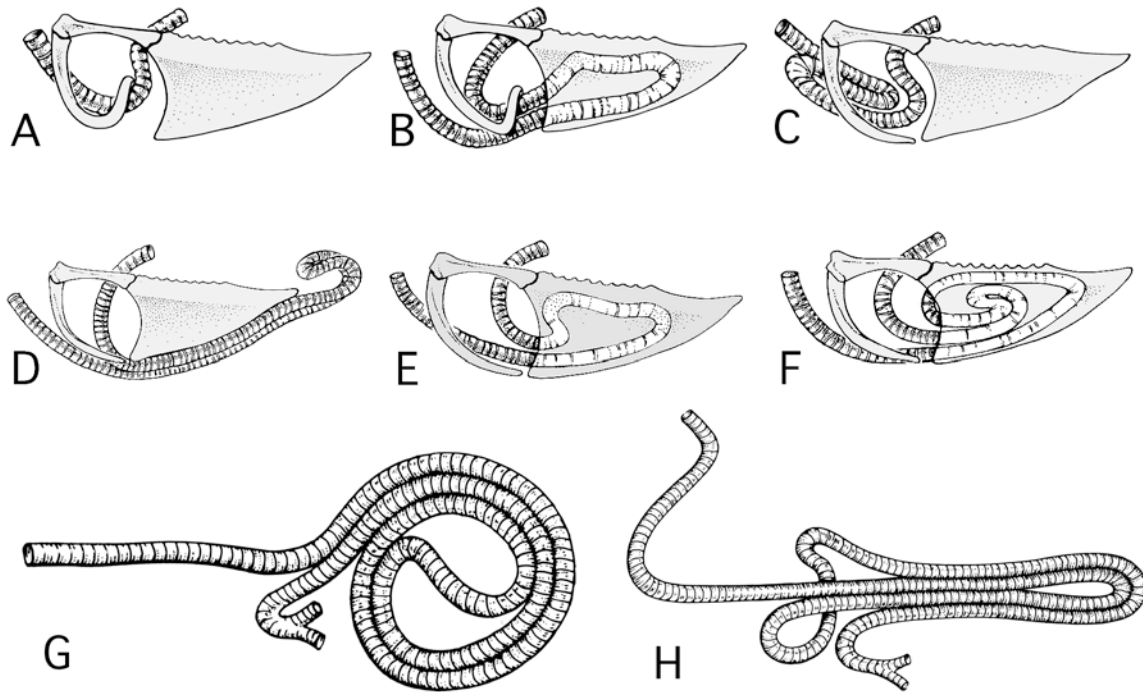


Figure 6-10. Drawings to illustrate wide variation in tracheal looping among various species of birds: (A) black swan, *Cygnus atratus*; (B) whooper swan, *Cygnus cygnus*; (C) white spoonbill *Platalea leucorodia*; (D) helmeted curassow, *Crax pauxi*; (E) crane, *Grus grus*; (F) whooping crane, *Grus americana*; (G) trumpet bird, *Phonygamus keraudrenii*; (H) magpie goose, *Anseranas semipalmata*. (Modified after McClelland, In *Form and Function of Birds*, vol 4., Academic Press, 1989: pp. 84-85).

The **paleopulmo** basically consists of the medioventral and mediodorsal (secondary) bronchi and their parabronchi; the large lateroventral bronchus, which passes through to the caudal thoracic air sac; and two or three other lateroventral bronchi and their parabronchi. The parabronchi of the paleopulmo are generally arranged in a pattern of arch-like connecting loops between two secondary bronchi (Fig. 6-12), and airflow is unidirectional through these parabronchi. In some species of birds (*i.e.*, penguins), the entire lung is formed by the paleopulmo.

In most avian species, the **neopulmo** makes up about 10% of the lung. The neopulmo is made up of a network of anastomosing bronchi consisting of small laterodorsal bronchi and their parabronchi; laterally directed parabronchi of the

lateroventral bronchi; and the connections of this network with the caudal air sacs. In addition to their anastomotic design, the parabronchi of the neopulmo allow gas exchange in either direction— a major advantage.

The term **parabronchi**, which was originally introduced to bird nomenclature along about 1882, has hung-on supposedly because of its "simplicity." What this term actually describes are the **tertiary bronchi**, which includes all bronchi of 3rd order or smaller. Although more logical, attempts (dating back to 1875) to use the term tertiary bronchi for these structures have been largely unsuccessful. Parabronchi are of uniform diameter ranging in size from about 0.5 mm in the hummingbird to about 2.0 mm in the chicken and other species. Thus, they are grossly visible in the chicken lung.

Parabronchi differ significantly from the tertiary bronchi of mammals, which we would expect to continue branching on down to the "terminal" alveoli. Well, parabronchi actually have a whole network or mantle of minute air capillaries mixed with blood capillaries right in their wall (Figs. 6-13 & 6-14). The order of air spaces from the lumen is as follows: (1) **atria**-these are the largest chambers connecting directly with the main airway; (2) **infundibula**- which are funnel-shaped ducts that extend outward from the floor of the atria and lead to the air capillaries; (3) **minute air capillaries** that are closely intermeshed with the blood capillaries (Fig. 6-13 & 6-14).

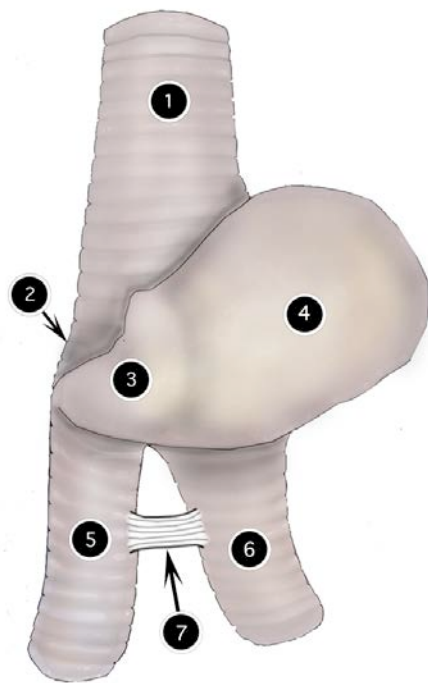


Figure 6-11. Syringeal bulla of drake, ventral view: (1) trachea; (2) syrx; (3) minor compartment of syringeal bulla; (4) major compartment of syringeal bulla; (5) right principal bronchus; (6) left principal bronchus; (7) interbronchial ligament. (Modified after McLelland, *A Color Atlas of Avian Anatomy*, WB Saunders Co., 1991: p. 103.)

As mentioned above, parabronchi measure about 2 mm, while the air capillaries, which are functional homologues

of the mammalian alveoli, are only about 5 μm in diameter. Obviously, the air capillaries have a distinct functional advantage in that they are not "terminal," but rather can receive air (oxygen) coming through from either direction.

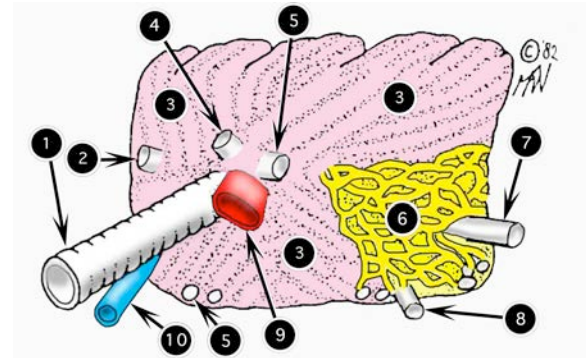


Figure 6-12. Right lung of chicken, septal surface: (1) principal bronchus; (2) connection with cervical air sac; (3) arch-like pattern of parabronchi in paleopulmo (old lung); (4) connection with clavicular air sac; (5) connection with cranial thoracic air sac; (6) net-like pattern of parabronchi of neopulmo (new lung); (7) direct continuation of principal bronchus with abdominal air sac; (8) connection with caudal thoracic air sac; (9) pulmonary vein; (10) pulmonary artery.

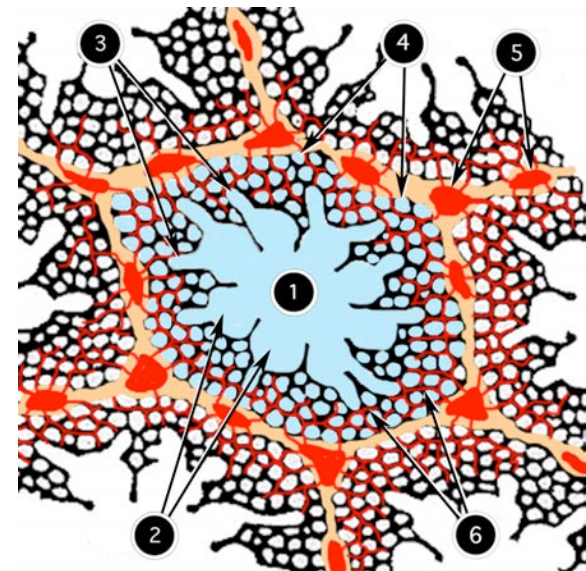


Figure 6-13. Schematic representation of adjacent parabronchi in cross-section: (1) lumen of parabronchus; (2) atria; (3) infundibula; (4) air capillaries; (5) interparabronchial blood vessels; (6) blood capillaries of lung.

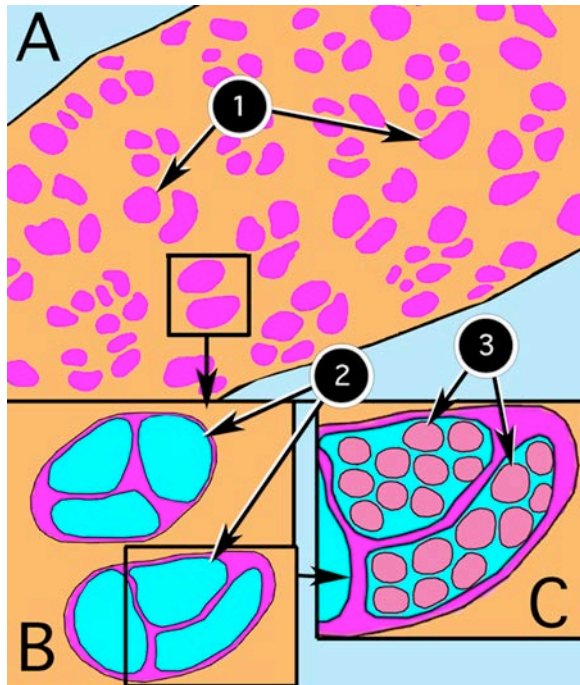


Figure 6-14. Schematic representation of the lumen of parabronchus in longitudinal section: (A) internal surface of parabronchus; (B) enlargement of two atria; (C) enlargement of two infundibula: (1) atria in wall of parabronchus; (2) infundibula in floor of atria; (3) air capillaries in floor of infundibula.

The air capillaries are highly tortuous tubes that branch and anastomose freely with one another. With their small, but uniform diameter, there is considerable resistance to airflow, which makes the pressure gradient for oxygen exchange in birds much higher than in mammals. As mentioned above, the air capillaries intermesh intimately with a high-volume network of blood capillaries, which is more extensive than in mammals. Also, the blood-gas barrier is significantly thinner in birds than in mammals. All of these features (and others not mentioned) give the bird a distinct respiratory advantage over the mammalian arrangement.

Air Sacs: Air sacs are thin-walled extensions of the respiratory system (Figs. 6-15 & 6-16). Diverticula from the air sacs invade just about everything in the area including bones. There are eight air sacs in

the chicken as follows: unpaired clavicular and cervical¹ air sacs (= 2); and paired cranial thoracic, caudal thoracic, and abdominal air sacs (= 6).

Although air sacs function in the overall plan of air movement for respiration, the lungs of bird account for almost all the actual gas exchange. On the other hand the air sacs provide "turn-around points" for the air so that it can make another run, back through the lungs. The cervical, clavicular, and cranial thoracic together form a functional unit referred to as the **cranial air sacs**. This group has been around longer and is associated with the paleopulmo. The caudal thoracic and abdominal air sacs comprise the **caudal air sacs**, which are relative newcomers and are associated with the neopulmo.

So how does all of this work? Well here goes. On inspiration, slight movements of the ribs and sternum pull air through the lungs and into the air sacs (Fig. 6-17). The caudal air sacs get a first-pass hit of fresh air because some of it takes an express way *via* a direct continuation of the principal bronchus. The cranial air sacs have to settle for "semi-used" air that has already been through a set of parabronchi. This means that we now have some reserve fresh air in the caudal air sacs that can be pushed back through the lungs on expiration. As you can see, birds are definitely on the cutting-edge of respiratory technology.

¹ I think all air sacs are paired developmentally; however, the right and left cervical and the right and left clavicular air sacs unite as they mature so that these two air sacs are now considered unpaired.

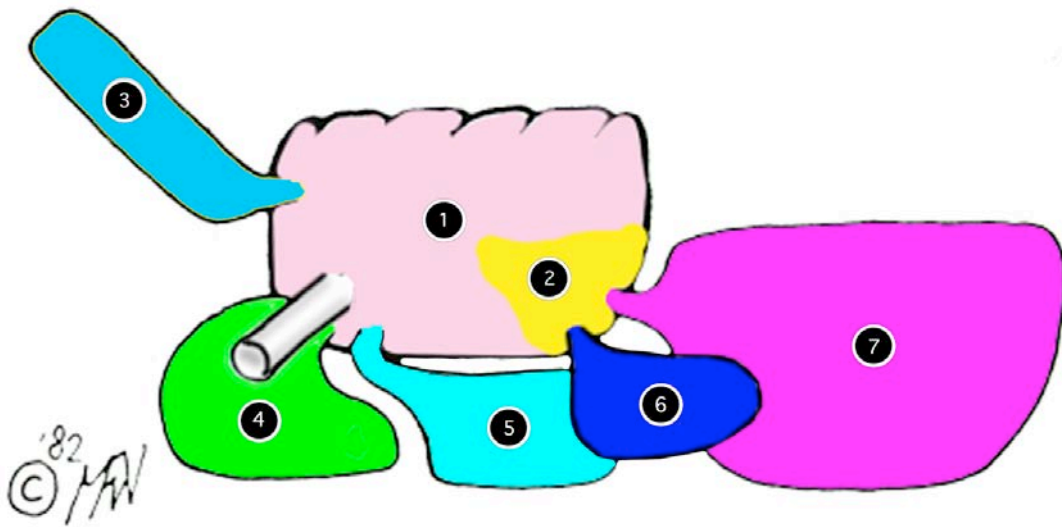


Figure 6-15. Schematic representation of right lung & air sacs of chicken: (1) right lung, paleopulmo; (2) right lung, neopulmo; (3) cervical air sac; (4) clavicular air sac; (5) cranial thoracic air sac; (6) caudal thoracic air sac; (7) abdominal air sac.

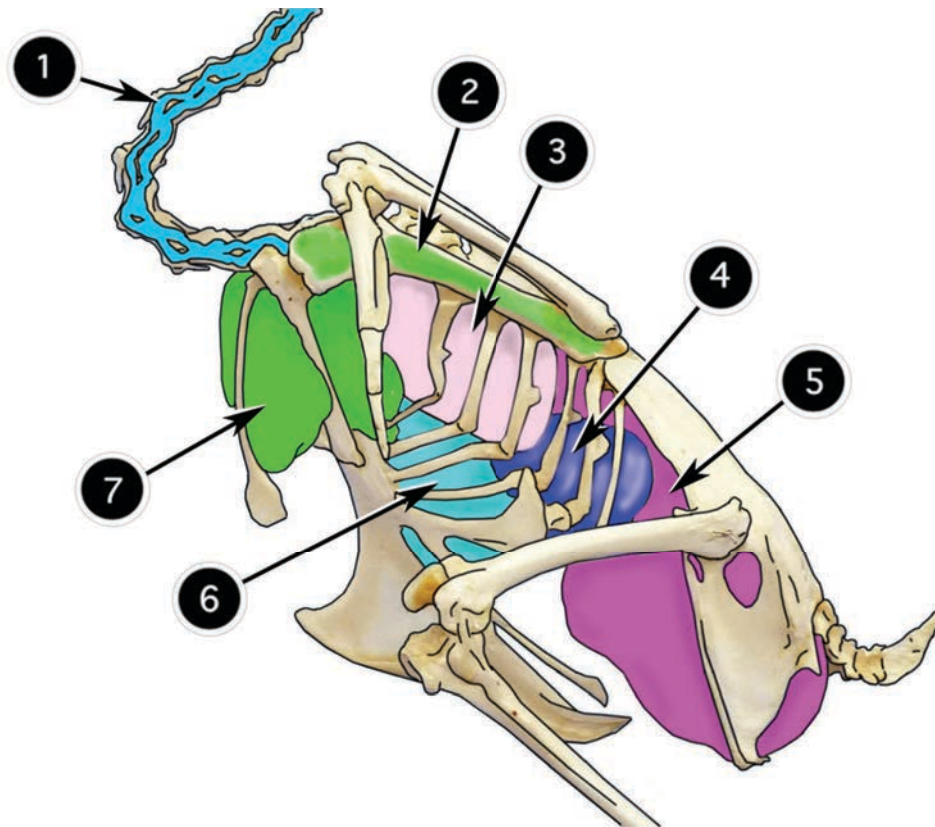


Figure 6-16. Lungs & air sacs of chicken: (1) cervical air sac; (2) extension of clavicular air sac into humerus; (3) lung; (4) left caudal thoracic air sac; (5) left abdominal air sac; (6) left cranial thoracic air sac; (7) clavicular air sac.

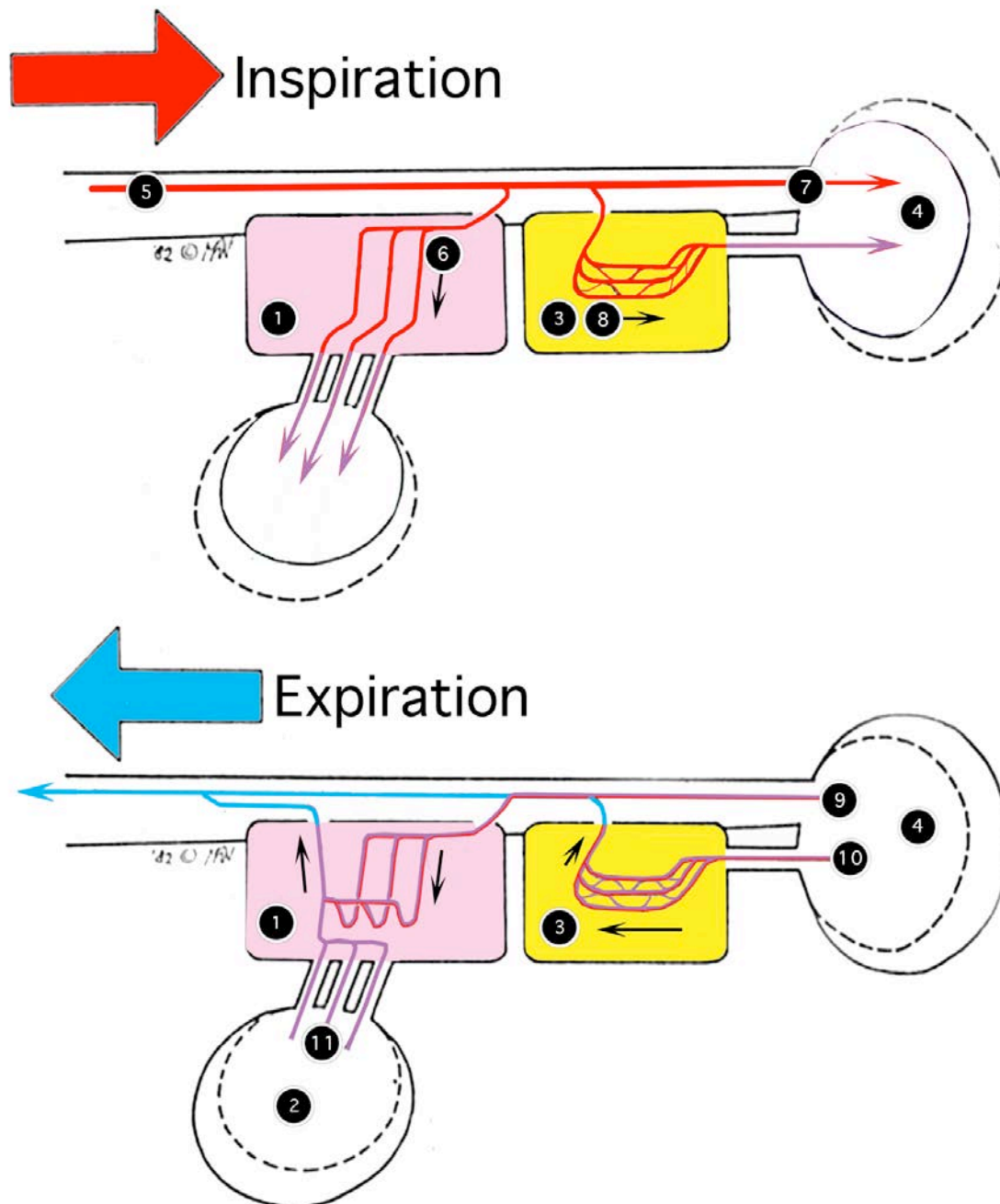


Figure 6-17. Schematic representation of air flow through lungs and air sacs of bird: (1) paleopulmo (one-way air flow in parabronchi); (2) cranial air sacs; (3) neopulmo (two-way air flow in parabronchi); (4) caudal air sacs; (5) inspired air in principal bronchus; (6) part of 5 is diverted through paleopulmo & to cranial air sacs; (7) part of 5 goes directly to caudal air sacs; (8) part of 5 goes through neopulmo to caudal air sacs; (9) part of air passes back through paleopulmo; (10) part of air is diverted back through neopulmo; (11) air in cranial air sacs is diverted back into principal bronchus.

Chapter 7 • Urogenital System

Kidneys: The kidneys of the bird are elongated, reddish-brown structures that are embedded for the most part in excavations of the ventral surface of the synsacrum. Although variable in relative size of each part, the kidney of the bird is typically divided by adjacent arteries into **cranial**, **middle**, and **caudal divisions** (not lobes). The **external iliac artery** marks the separation between the cranial and middle divisions, while the **ischiodic artery** passes between the middle and caudal divisions (Fig. 7-1). These divisions are not distinct in passerine birds such as the canary, and in both the canary and budgerigar, the caudal divisions appear to be fused.

As in mammals, the functional unit of the kidney is the **nephron**, but in birds they are of two distinct types. The **cortical nephrons** are the majority type in most birds and are similar in structure to those of reptiles in that they have no loop of the nephron (Fig. 7-2). The **medullary nephrons**, on the other hand, are more like those of mammals in that they do have a loop. The collecting ducts from clusters of nephrons group together forming cone-shaped bundles, which drain one **renal lobule**. Several bundles of these collecting ducts then unite to form the secondary branches of the ureter, which drain one **renal lobe**. (Although not really funnel-like, these secondary branches of the ureter would correspond roughly with the calix of the bovine kidney.) Likewise, several secondary branches come together to form a primary branch of the ureter. Obviously, using this small duct → bigger duct method dispenses with the need for a renal pelvis (Fig. 7-2).

The **ureter**, which originates in the cranial division of the kidney by union of

several primary branches, courses caudally along the ventromedial aspect of the kidney, receiving additional primary branches along the way. Once all of these branches have been collected, the ureter continues directly to the cloaca, where it empties its thick, white urine composed of semisolid urates *via* the ureteral orifice in the dorsal part of the **urodeum**.

The urine can then be moved by retrograde peristalsis back into the rectum and ceca, where water can be reclaimed. Following this little detour, the urine and feces are expelled together (in most species), sort of like Neapolitan ice cream- the chocolate fecal matter, being surrounded by the vanilla concentrate of uric acid. Conspicuously absent in the bird are a urinary bladder and a urethra.

Blood enters the avian kidney *via* several routes. Like in the mammal, the **cranial renal artery** is a direct branch of the aorta. The bird kidney, however, also receives arterial blood from the **middle and caudal renal arteries**, which are branches of the ischiadic artery (Fig. 7-1). Several generations of branches lead to small intralobular arteries that supply one renal lobule.

The major difference between blood flow through the avian kidney *vs.* that of the mammal is the presence in the bird of a **renal portal system**, which is capable of filtering in-coming venous blood on its way back from a capillary bed in other body tissues. Blood returning from the pelvic limbs *via* the **ischiodic veins** or from the pelvic area *via* the **internal iliac veins** can be partially diverted through renal portal veins (Fig. 7-1). Here it is filtered through the kidney just as if it were arterial blood.

The amount of venous blood diverted through the kidney is controlled by a **renal portal valve** located in the **common iliac vein** (Fig. 7-1). Closure of this valve

increases resistance to direct venous return and the blood follows the path of least resistance, which is through the kidney.

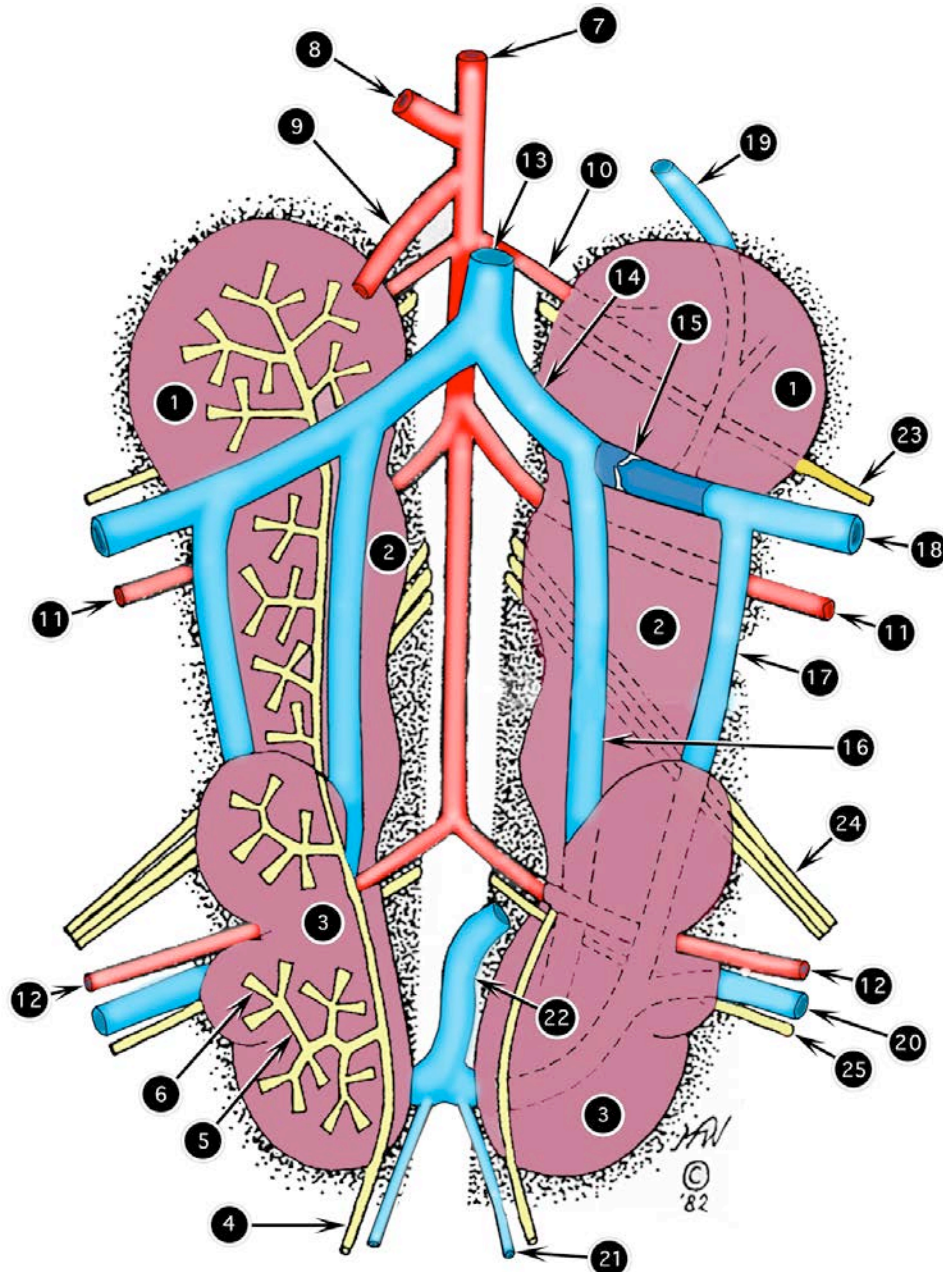


Figure 7-1. Schematic representation of kidneys of chicken, ventral view: (1) cranial division of kidney; (2) middle division of kidney; (3) caudal division of kidney; (4) ureter; (5) primary branch of ureter; (6) secondary branch of ureter; (7) aorta; (8) celiac artery; (9) cranial mesenteric artery; (10) cranial renal artery; (11) external iliac artery; (12) ischiadic artery; (13) caudal vena cava; (14) common iliac vein; (15) renal portal valve; (16) caudal renal vein; (17) caudal renal portal vein; (18) external iliac vein; (19) anastomosis of cranial renal portal vein with vertebral venous sinus; (20) ischiadic vein; (21) internal iliac vein; (22) caudal mesenteric vein; (23) femoral nerve; (24) sciatic nerve; (25) nerve to pudendal plexus.

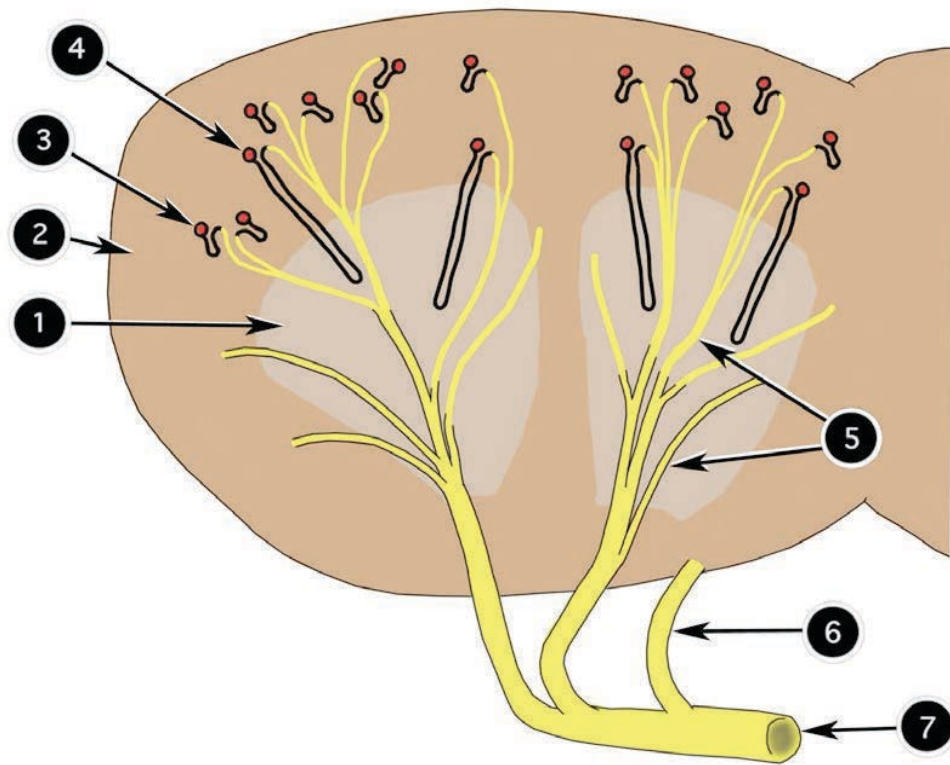


Figure 7-2. Schematic representation of bird kidney showing two adjacent lobes: (1) medulla of one lobe; (2) cortex of kidney; (3) cortical nephron (majority type); (4) medullary nephron with loop extending into medulla; (5) bundles of collecting ducts from groups of nephrons; (6) secondary branch of ureter draining one lobe; (7) primary branch of ureter

Although the percentage of blood from the pelvic limbs and pelvis that is filtered by the kidney varies with the closure-status of the renal portal valve, there are always "escape routes" (*i.e.*, caudal mesenteric vein, connection with vertebral venous sinus) around the kidney if renal portal pressure increases so that it is no longer the path of least resistance.

The presence of the renal portal system has **clinical significance** for the veterinarian in that injection of drugs in the pelvic limbs can have unpredictable results. If the absorbed drug is diverted through the kidney on its first pass, much of it may be excreted before it ever reaches general body circulation. **For this reason, the pelvic**

limbs are generally not a good site for injections.

Male Genital Organs: The male genital organs consist of paired testes, epididymes, and ducti deferentes, and the phallus or copulatory organ (Fig. 7-3). The absence of a urethra pretty much eliminates the home base for any accessory genital glands.

The size of the testes varies greatly with the reproductive activity level of the bird. During the breeding season, they more than double in size compared with the non-breeding period. The testes are typically located near the cranial extremities of the kidneys, where they are attached to the dorsal body wall by short mesorchia.

Castration of the young rooster has been done to produce a **capon** for eating purposes. The surgical procedure, which is not done routinely anymore due to the rapid growth of broilers, is known as **caponization**. It is performed through an incision near the last rib. Sex determination, which is not possible from external examination in some large pet birds, used to be done *via* laparoscopy, with direct visualization of the gonads using a fiber optic scope.

Knowing the sex of a large pet bird can increase significantly its monetary value. DNA testing is now the method of choice for use in sexing birds. As mentioned above, some broiler lines of chickens can be "feather sexed."

The testes of common domestic species appear yellow or whitish yellow in color, however, the presence of some dark pigmentation is not uncommon. The seminiferous tubules conduct the "spermakids" *via* the **rete testis** to the epididymis, which is not divided into a head, body, and tail as it is in mammals.

The **epididymis**, which contains also the **efferent ductules**, is formed primarily by the highly convoluted ductus epididymis. The latter is continuous with the tightly looped **ductus deferens** near the caudal extremity of the testis. The ductus deferens, which owing to its full load of spermatozoa appears white during the breeding season, courses caudally with the ureter to the urodeum. The terminal part of the ductus straightens out and is slightly enlarged in this segment.

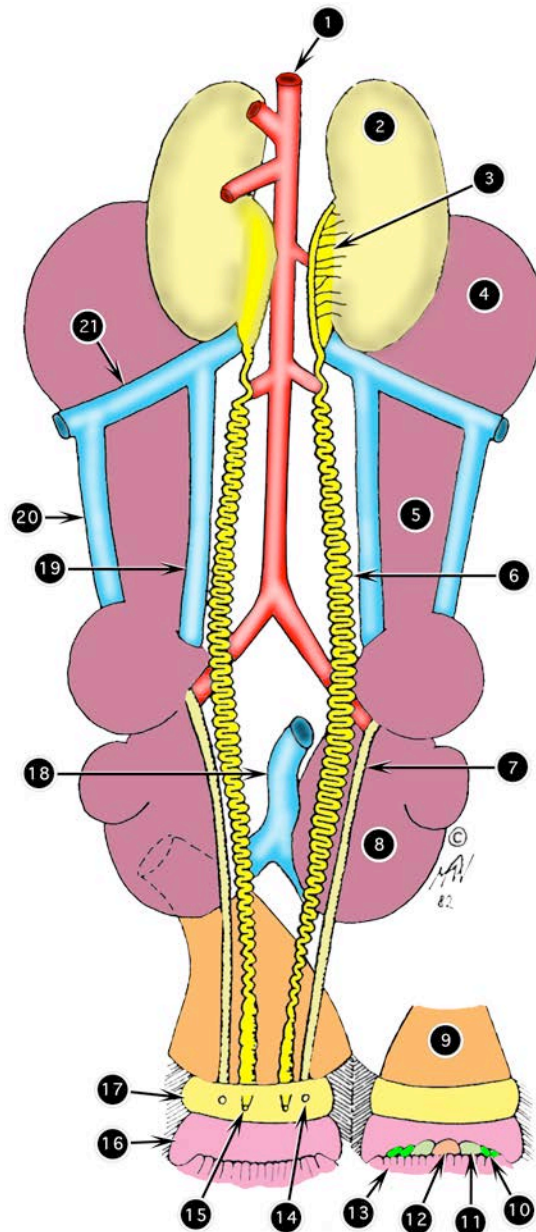


Figure 7-3. Genital organs of rooster, ventral view: (1) aorta; (2) testes; (3) epididymis; (4) cranial division of kidney; (5) middle division of kidney; (6) ductus deferens; (7) ureter; (8) caudal division of kidney; (9) coprodeum; (10) lymphatic folds; (11) lateral phallic body; (12) median phallic body; (13) vent; (14) ureteral orifice; (15) opening of ductus deferens on papilla; (16) proctodeum; (17) urodeum; (18) caudal mesenteric vein; (19) caudal renal vein; (20) caudal renal portal vein; (21) external iliac vein.

In some species (canaries), the more caudal part of the ductus becomes highly convoluted forming an enlarged mass, which has even been called (incorrectly) a seminal vesicle or sac. During the breeding season (nuptial phase) of these birds, this part of the ductus becomes so enlarged with spermatozoa that it produces a protrusion externally, which can be used to sex male passeriformes. The ductus deferens opens on a papilla in the dorsal wall of the urodeum (Fig. 7-3).

Along the ventral lip of the vent are located several structures that together form the **non-protrusible phallus** of many bird species, including the chicken and turkey. These consist of a **median tubercle**, which is flanked on either side by the **lateral phallic bodies**. These are supplemented with lymphatic folds that become involved with intumescence of the phallus.

When engorged during the tumescent state, the phallus protrudes slightly from the cloaca and the grooves formed between the median tubercle and lateral phallic bodies serve as "gutters" to direct the semen to the outside world. During copulation, the phallus is pressed against the cloacal mucosa of the female, an act commonly referred to as the "cloacal kiss." It's typically not a long, lingering kiss, but does last long enough for the semen to be transferred to the cloaca of the female.

Ducks, geese, ratites (ostrich, emu, rhea) and some other species are different. These birds have a **protrusible phallus**, which functions much like a penis (although it is not a penis) for cloacal intromission (Fig. 7-4). The phallus of the duck is an elongated, spiral structure several centimeters in length. The semen is conducted along the phallus *via* a *phallic groove*, which spirals around the organ.

Female Genital Organs: Embryologically birds have paired **ovaries** and oviducts; however, during development the right ovary and oviduct typically degenerate so that only the left develops to a functional state (Fig. 7-5). The term **oviduct** is no longer used correctly in veterinary nomenclature to describe the uterine tube of mammals. This term is now reserved for the female avian reproductive tube. The oviduct, which consists of several distinct segments, is a very large structure when fully developed, measuring about twice the length of the bird when straightened out.

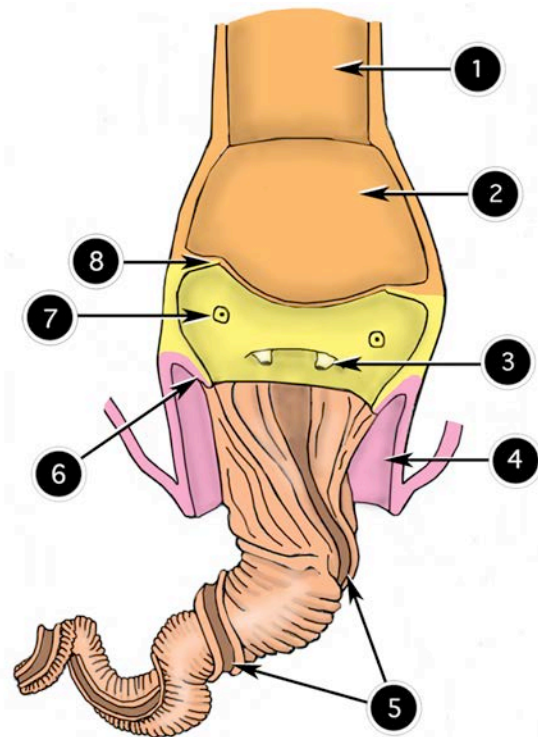


Figure 7-4. Genital organs of male duck, ventral view: (1) rectum; (2) coprodeum; (3) opening of ductus deferens on papilla; (4) proctodeum; (5) phallic groove spiraling around protrusible phallus; (6) uroproctodeal fold (7) ureteral orifice; (8) coprourodeal fold.

As the female bird matures to the state of reproductive competency, the **ovary** develops from a small infantile structure to one that is completely covered with follicles,

which then enlarge in sequence to a phenomenal size, reaching several centimeters in diameter in the chicken. Because the ovary becomes covered with these developing follicles, the ovary of the mature bird resembles a cluster of grapes (Fig. 7-5).

Each **follicle** contains a large yolk-filled **oocyte**, which is contained by a thin-walled follicle. The follicular wall is highly vascular, but as the time of ovulation approaches, a linear non-vascular zone, the **stigma**, develops. It is along this avascular stigma that the follicle ruptures to release the oocyte. The **oocyte**¹ contains the germinal disc, which lies on the surface of the large yolk component of the oocyte, which is now contained within a soft **yolk membrane**.

Immediately following ovulation, the oocyte is fertilized if viable spermatozoa are available for the job. These spermatozoa had been brought up the **oviduct**, by the female, from a storage facility located in her vagina. One insemination can be used for the daily fertilization of ova for up to 10 days or so (*a clutch*).

The oocyte is drawn immediately into the upper end of the oviduct, which is a large funnel-shaped segment known as the **infundibulum** (Fig. 7-5). The infundibulum is attached to the body wall near the last rib. During the approximately **15 minutes** the oocyte spends in the infundibulum, a stronger **outer yolk membrane**, consisting of a delicate fiber network, is added. It is then coated with a thin layer of very dense albumin known as the **chalaziferous layer**. This layer, which later forms a "twisted-

towel" wrapper known as the **chalaza**, extends from the yolk out toward the ends (poles) of the egg. The chalaza is important in keeping the germinal disc in the center of the egg. It becomes twisted by the rotation of the yolk around the longitudinal axis of the egg, and it prevents any end-to-end rotation of the yolk.

From the infundibulum, the oocyte now enters the **magnum**, which is the longest segment of the oviduct. During the next **3 hours** or so, large glands within in the thick wall of the magnum are busy pumping out more albumen, which is added on in layers around the slowly moving oocyte. The inner part of the albumen is thinner and more liquid than the more gel-like outer part, which is added in the lower part of the magnum and isthmus.

The **isthmus** is only about 8 cm long in the chicken, and the oocyte typically spends about **an hour or less** here. Besides adding more albumen, the inner and outer shell membranes are added to surface of the albumen layer.

Leaving the isthmus, the encapsulated albumen sac is ready for the outer hard shell, which is added to the oocyte in the **uterus**. Because of this function, the uterus has been unfortunately referred to as the "shell gland." The uterus of the chicken is only about 8 cm long, but the egg remains in this short segment for **approximately 20 hours**. First some more thin albumen is pumped in through the shell membranes to "plump" the egg, and then the real work begins.

Production of the hard outer shell takes a lot of work, and a good bit of time. After the shell is finished, it is top-coated with a thin glaze-like cuticle, which helps protect the egg (ovum) and its contents.

¹ Unfortunately, both the oocyte and the shelled egg of the bird are commonly referred to by the term, ovum. In this book, I have chosen to refer to the egg cell as the oocyte, and the shelled egg as the ovum.

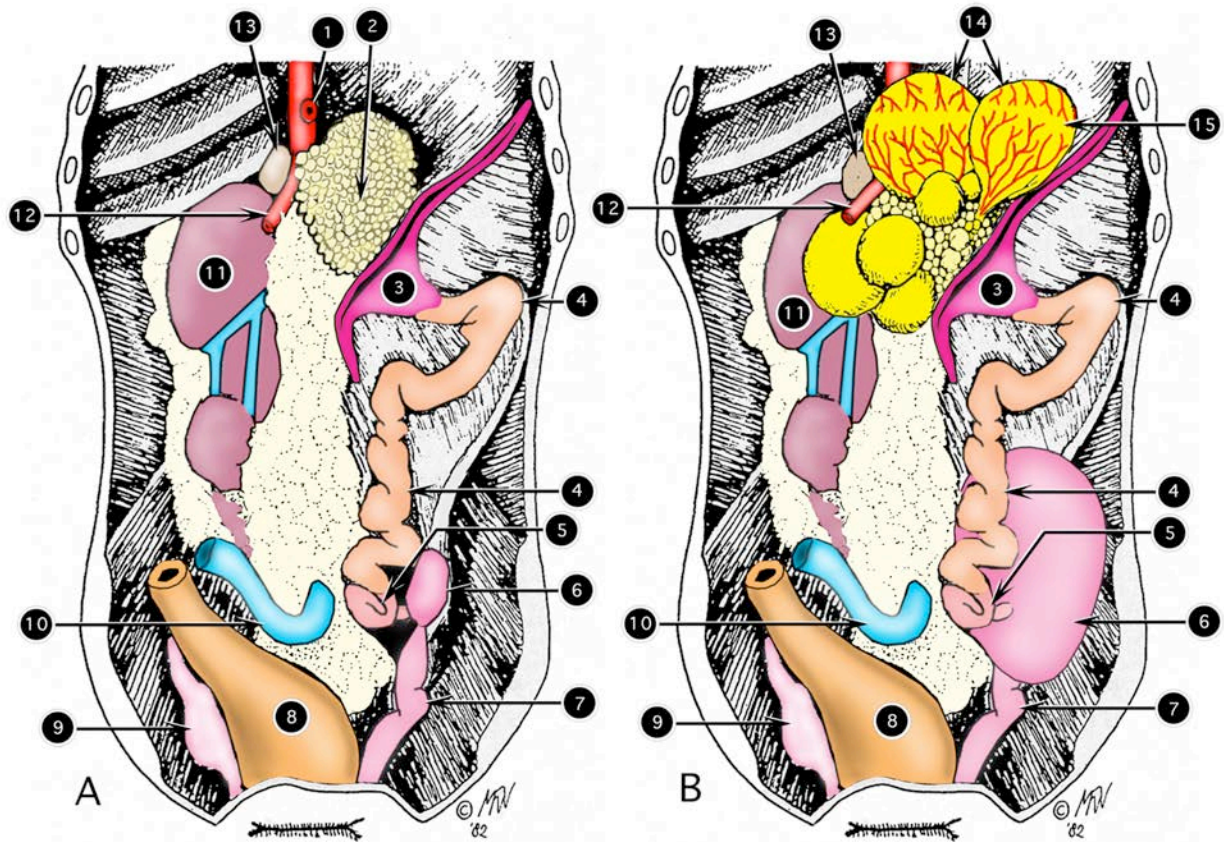


Figure 7-5. Genital organs of hen, ventral view: (A) Non-Laying hen; (B) Laying hen; (1) celiac artery; (2) ovary; (3) infundibulum; (4) magnum; (5) isthmus; (6) uterus (contains egg in B); (7) vagina; (8) coprodeum; (9) cyst in vestigial right oviduct; (10) caudal mesenteric vein; (11) right kidney; (12) cranial mesenteric artery; (13) right adrenal gland; (14) mature follicles; (15) stigma (avascular area along which follicle will rupture to release oocyte).

The **vagina** is a short, S-shaped muscular tube, through which the egg is expelled into the urodeum. The ovum is propelled through the vagina rapidly, where it continues through the cloaca and vent to the outside world.

Anatomy of an Egg: Now that we have followed the oocyte (now ovum) from the ovary to the vent, we should take a closer look at the ovum (egg) itself. In fact, the anatomy of the egg is more complex than one might think (Fig. 7-6). We will start

with the oocyte (yolk sphere), which is released from the follicle as the latter tears along the stigma. When the oocyte is released and captured by the infundibulum, the yolk sphere is already contained within a soft **yolk membrane**, which is produced by the ovary. The nucleus of the oocyte now rests on the **germinal disc**, which is a white spot on the surface of the yolk and is about 3 mm in diameter. If fertilized, the germinal disc becomes the **blastoderm**; if not fertilized, it is known as the **blastodisc** (Fig. 7-6).

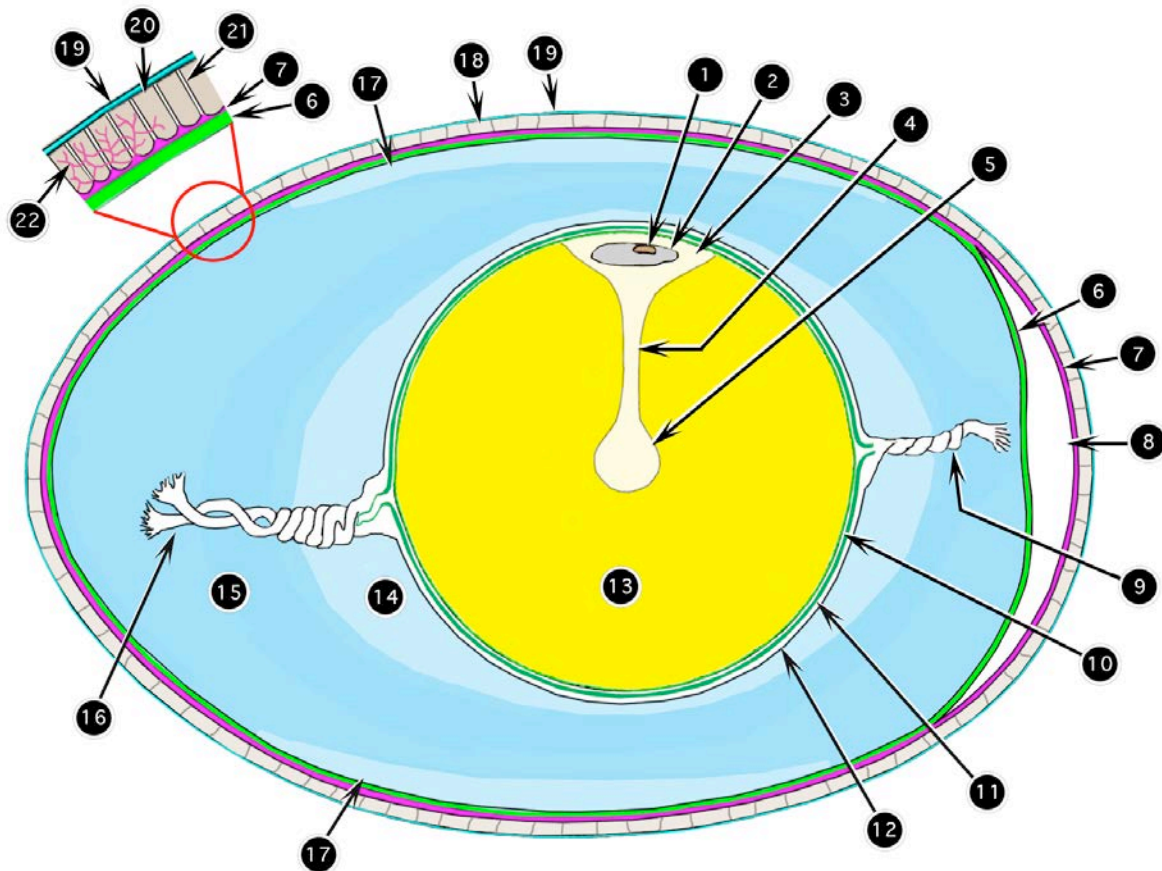


Figure 7-6. Schematic representation of an egg, longitudinal section, with magnified insert of shell: (1) nucleus of oocyte; (2) germinal disc; (3) white yolk forming latebral disc; (4) latebral neck; (5) centrum of latebra; (6) inner shell membrane; (7) outer shell membrane; (8) air cell; (9) single strand of chalaza toward blunt end; (10) yolk membrane; (11) outer yolk membrane; (12) chalaziferous layer of very dense albumin; (13) yellow yolk; (14) internal layer of liquid or thin albumen; (15) dense or thick albumen, extending to ends of egg; (16) ends of chalaza embedded in polar part of dense albumen; (17) external layer of liquid albumen; (18) calcified shell; (19) cuticle; (20) spherites of calcium carbonate; (21) air canaliculi through calcified shell between adjacent spherites; (22) organic matrix holding spherites together and giving strength to shell.

There are actually two types of yolk material. **White yolk** contains much more protein than fat and forms the **latebra**, which is a supporting pedestal for the germinal disc. The latebra consists of a central bulb, connected by a narrow neck to the **latebral disc**, which lies just beneath the germinal disc (Fig. 7-6). Most of the yolk is made up of **yellow yolk**, which contains much more fat than protein.

In the infundibulum, a thicker **outer yolk membrane** is added to strengthen the yolk on its journey through the oviduct. The semi-permeable yolk membranes allow

water from the albumen to enter the yolk and “plump” it to its definitive size. Also, within the infundibulum, the **chalaziferous layer** of very dense albumin is added to the surface of the outer yolk membrane. This chalaziferous layer will mature within the oviduct to form the definitive **chalaza** that we see in the fully formed egg. The chalaza extends toward the ends of the egg, and becomes twisted as the yolk moves through the oviduct.

The chalaza functions to keep the germinal disc centered in the egg, and because the side of the yolk away from the

germinal disc is heavier, the germinal disc consistently rotates to the top of the yolk. The twisted part of the chalaza extending toward the blunt end of the egg is a single strand, while that toward the pointed end consists of a double-twisted strand (Fig. 7-6). The ends of the chalaza are embedded in the dense (polar) albumen.

A less viscous layer of **liquid or thin albumen** is added to the egg in the upper part of the magnum, which accounts for about 50% of the total albumen production. The albumen produced in the more distal part of the magnum becomes more viscous or gel-like, forming the **dense or thick albumen** (Fig. 7-6).

In the isthmus, the **internal and external shell membranes** are added, and the remaining 50% of the albumen is produced. Part of this albumen forms the external layer of liquid albumen. In the uterus, water is pumped through the shell to “plump” the egg prior to production of the mineralized shell.

The calcified shell consists primarily of **calcium carbonate “spherites”** (spheres at the base, continued outwardly as cylinders), with a small amount of organic matrix holding these spherocylinders together. Without the organic matrix, the eggshell would be too brittle and subject to cracking. Between the spherites are thousands of tiny **air canaliculi** leading to **pores** on the egg’s surface (Fig. 7-6). It is *via* these “air ducts” through the calcified shell that there is gaseous exchange with the surrounding air. In fact, the **air cell** forms *via* this exchange after the egg has been laid and is surrounded by air.

Once the calcified shell is complete, the last step is the application of a thin, outer coating of organic material known as the

cuticle or “bloom.” This is typically, the final layer; however, in certain species, including some broiler breeds of chickens, there is another thin calcified layer called the “cover” added over the cuticle.

Loss of a certain amount of water during incubation is necessary for proper formation of the air cell. This is important during incubation because the air cell is penetrated by the fully developed embryo prior to hatching and provides a source of breathing air prior to “pipping” the shell as the first step in hatching. The amount of natural water loss from an egg during incubation varies among species. And it seems “parent nature” has taken this evaporative loss into account because in certain species, there must be a considerable loss of liquid ($\approx 15\%$ weight reduction in ostrich vs. 12% loss in chicken) from the egg or the embryo may drown prior to hatching.²

In addition to temperature, one of the most important factors affecting the amount of water loss is the ambient humidity within the incubator. Higher than optimal humidity during incubation and the resulting failure to lose sufficient water is a recognized cause of late embryonic mortality and weak, edematous chicks in ostriches.

More about Eggs: The longer an egg is exposed to air, the more evaporation of moisture from the egg occurs, and the larger the air cell becomes. By releasing an egg gently into a saucepan of water, you can perform a simple “freshness test.” Fresh eggs will sink to the bottom quickly; the older the egg, the more slowly it will sink as it contains more air. If the egg does not sink, don’t eat it.

² Ley DH, Morris RH, Smallwood JE, Loomis MR: Mortality of chicks and decreased fertility and hatchability of eggs from a captive breeding pair of ostriches. JAVMA 189 (1986): 1124-26.

Variation in the color of eggs is produced by the incorporation of pigments into the calcified shell. Egg color varies mostly with species and breeds of birds. In general, chicken breeds with white ear lobes lay white eggs, whereas chickens with colored ear lobes lay brown or colored eggs.

There are differences in the number of eggs a particular species can or will lay. With regard to laying behavior, birds are classified as either **determinate** or **indeterminate** layers. As these terms imply, determinate layers have a pre-programmed number of eggs for a particular “lay.” If one or more of the eggs is broken or removed, during the lay period, it will not be replaced. Thus, the total number of eggs for that lay will be reduced if an egg is lost or removed from the nest. Many wild bird species (*viz.*, Eastern bluebirds) are determinate layers.

Indeterminate layers have no pre-determined number of eggs in a laying period. If an egg is removed, it will be replaced. The domestic chicken is obviously an indeterminate layer, and so long as the eggs are removed, a single hen can lay more than 240 eggs during a laying period. In wild birds and many domesticated species, egg-laying ceases with the onset of **broodiness** (hormonal changes, which trigger incubation of the eggs). In the genetically altered, high egg-producing chicken lines, laying continues uninterrupted until the time of **molting**.

Molting in commercial laying flocks can be induced by changes in the diet and by adjustments in the daily light/dark periods to which the birds are exposed. In laying breeds, broodiness has been almost eliminated by genetic selection, and the molting period has been greatly reduced so

that birds come back into lay after a short molting period.

Embryogenesis in Birds: If the haploid oocyte (female gamete) is fertilized in the infundibulum, the resulting zygote rests on the germinal disc, which now becomes the **blastoderm**. In contrast with mammals, where the male determines the sex of the progeny by contributing either an X or Y gamete, it is the female bird that produces both **Z and W oocytes**. All avian **spermatozoa** contain the Z chromosome.

Because avian oocytes (zygotes) are associated with a large amount of yolk material, birds are classified as **macrolecithal** vs. placental mammals, which are micolecithal. The massive amount of yolk in birds prevents complete division of the zygote and initial cleavage is only partial (four or five cell divisions) or **meroblastic**. At that stage, cleavage is temporarily interrupted until the egg has been laid and incubation begins. With the initiation of incubation, cleavage proceeds through **gastrulation** and formation of the various germ layers- **ectoderm**, **mesoderm**, and **endoderm**.

Only part of the germinal material resulting from fertilization is used to produce the embryo itself- another portion is used to form the **embryonic membranes**. The **amnion** is formed from the ectoderm and outer (somatic) mesodermal layer, and forms a fluid-filled chamber, the **amniotic cavity**, surrounding the embryo (Fig. 7-7). The amnion is continuous with the ectoderm of the skin of the embryo at the umbilicus. The amniotic cavity, which contains amniotic fluid mixed with some albumen, serves to protect and float the embryo so that it can move freely.

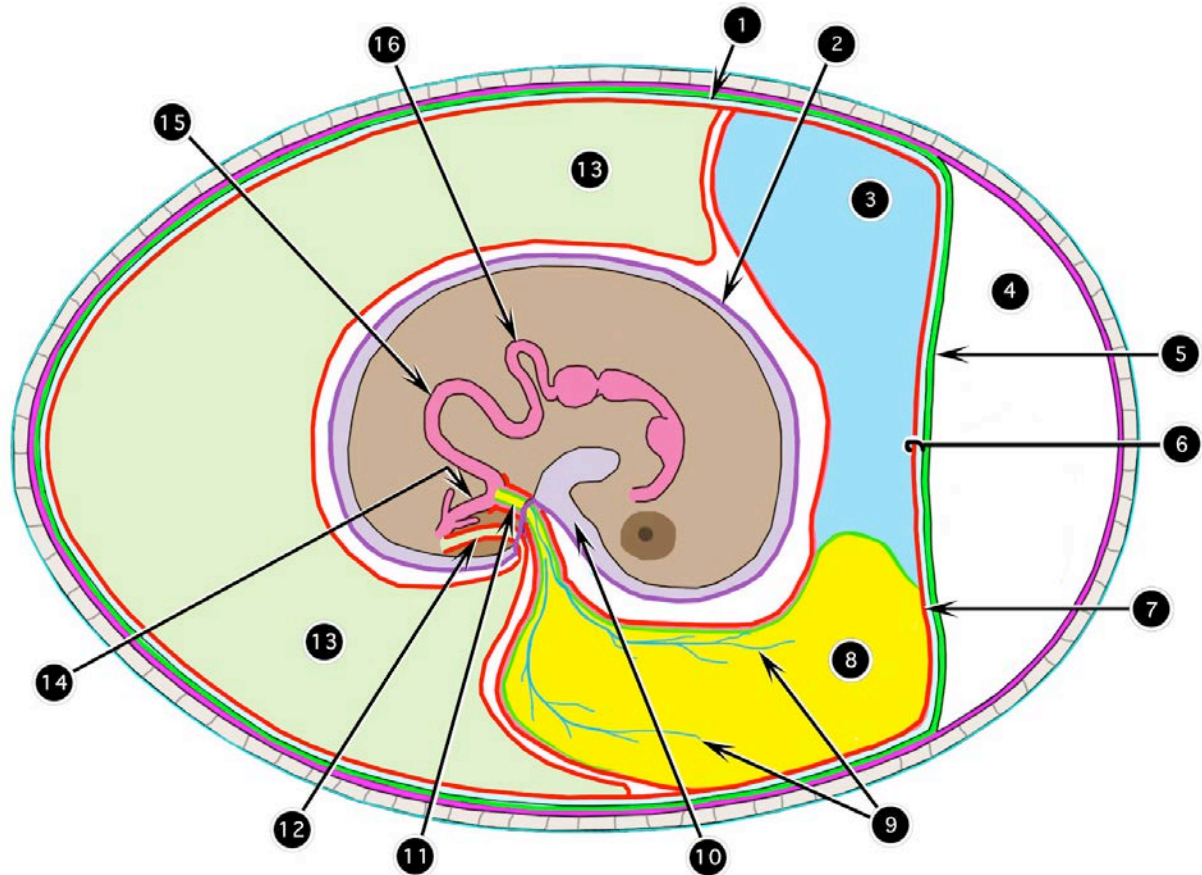


Figure 7-7. Schematic representation of egg with developing embryo and embryonic membranes, longitudinal section: (1) chorion fused with inner shell membrane; (2) amnion, continuous with ectoderm of skin at umbilicus; (3) albumen sac; (4) air cell; (5) inner shell membrane; (6) chorioallantois; (7) vascularized allantois; (8) yolk sac; (9) vitelline veins on surface of yolk sac; (10) amniotic cavity; (11) stalk of yolk sac entering gut; (12) connection of allantoic cavity with hindgut; (13) allantoic cavity containing uric acid waste; (14) ileum of small intestine; (15) jejunum; (16) duodenal loop.

The **chorion**, which is initially associated with amnion forming chorioamniotic folds, continues to expand so that it becomes closely associated with the inner shell membrane (Fig. 7-7). The **allantois** develops later from splanchnic mesoderm and endoderm and forms a diverticulum of the embryonic hindgut. As the allantois expands, it fuses with the splanchnic mesoderm of the yolk sac and with the chorion.

The **allantoic sac** collects the uric acid wastes as the embryo continues to grow. With the exception of the **vitelline veins**,

which are associated with the yolk sac, the allantois carries most of the blood vessels to and from the embryo.

Once the vascularized allantois fuses with the chorion, forming the **chorioallantois**, it is these vessels that allow for the gaseous exchange of oxygen and carbon dioxide through the porous calcified shell. As the embryo continues to develop and occupy more space within the egg, the yolk sac and albumen sac are drawn into the thoracoabdominal cavity. After hatching, the yolk sac persists for some days until it is drawn completely into the gut, leaving a

remnant of its stalk as the vitelline or Meckel's diverticulum. The vitelline remnant marks the junction of the jejunum with the ileum.

Similar to the situation with newborn mammals, not all birds have the same degree of development or parental independence at the time of hatching. In some avian species, particularly those that nest in trees, the chicks are hatched at a state of relative helplessness. That is to say, they remain in the nest for an extended period and require intensive parental nurturing to mature to the stage of independent activity. In other species (*viz.* chicken, ducks), the hatchlings are more mature and capable of walking and/or swimming, independent of parental care.

Incubation Periods: Not surprisingly, the state of maturity at hatching is related to the length of the incubation period. Table 7-1 gives the incubation periods of some common avian species. You might notice that the shortest incubation period on this list is that of the cowbird (Fig. 7-8). Having a very short incubation period is part of the strategy of this “parasitic” species of birds. Cowbirds lay their eggs in the nests of other birds and let the parent birds of the “host” species raise their young for them. Because the female cowbird typically deposits only one egg in the nest of the host species, she has the potential of “parasitizing” as many as 40 nests in a single breeding season.

Because of the short 10-day cowbird incubation period, their chick is the first to hatch in the nest of the target species such as the Eastern bluebird (11-19 days). As a result of this “brood parasitism,” host chicks are often so malnourished that they die or may be crowded out of the nest altogether.

In addition to the cowbird, many species of the **cuckoo**, mostly Old-World species, are brood parasites, laying their eggs in the nests of other birds.



Figure 7-8. Female and male brown-headed cowbirds (*Molothrus ater*). Photos by James E. Smallwood, Raleigh, NC.

Table 7-1. Some Incubation Periods

Bird Name	# Days
emu	49-50
ostrich	42
Muscovy duck	35-37
turkey	28
Guinea fowl	28
duck	28
goose (various species)	22-30
cockatoo	22-30
parrots (various species)	18-28
ring-necked pheasant	23-25
bobwhite quail	23
chicken	21
cockatiel	18-20
Eastern bluebird	11-19
budgerigar	18
pigeon	17-19
canary	13-14
cowbird	10

Gynandromorphism: Some strange things can happen during embryologic development of birds. One such event is known as **bilateral gynandromorphism**. This phenomenon is also seen in insects and crustaceans, but is thought to be quite rare in birds. On February 21, 2021, a long-time birder named Jamie Hill photographed a gynandromorphic Northern Cardinal in Warren County, Pennsylvania, about 55 miles southeast of Erie (Fig. 00-00).



Figure 7-9. : Gynandromorphic Northern Cardinal. (Photograph made February 20, 2021 by Jamie Hill in Warren County, Pennsylvania.) Arrows and letters added by JES.

Hill's photograph was not the first documentation of gynandromorphism in Northern Cardinals. In fact, a similar bird was photographed by Shirley Caldwell in January 2019, also near Erie, Pennsylvania. (See <https://www.nationalgeographic.com/animals/article/halfmale-half-female-cardinal-pennsylvania>).

So just how does this happen? Well, that's a good question, and it is believed that it happens like this. First you must understand that, unlike in mammals where the male determines the sex of the progeny by supplying either an X or Y chromosome, it is the female bird that has both Z and W chromosomes. The male can supply only Z

spermatozoa. For such a chimeric³ individual to result, the first mistake is that the female oocyte retains two nuclei, one with the Z, and one with the W chromosome. Now along come a couple of eager Z spermatozoa (the only kind), and each of the two nuclei are fertilized. Now you have both ZW and ZZ cells in the same individual resulting from this double fertilization. As the embryo develops, it tries to follow the genetic code, but receives "mixed messages." Thus one side of the chick contains female (ZW) cells and the other side contains male (ZZ) cells (Fig. 7-9).

Why are just cardinals affected? Well this rare phenomenon likely occurs in other bird species, perhaps with equal frequency, but just goes unnoticed. The chimeric cardinals stand out because of the distinct sexual dimorphism in this species. Another interesting question arises as to whether or not these gynandromorphic birds could be fertile. We'll have to get back with you on that one because I am not sure that fertility in these birds has ever been recorded.

³ A genetic chimera is a single organism composed of cells with more than one genotype. In animals, such an individual is derived from two or more zygotes, which can include possession of both female and male sex organs = gynandromorphism.

Chapter 8 • Cardiovascular System

With reference to the cardiovascular system, our attention will be directed toward some of the more important differences between birds and mammals. For example, you should know that the erythrocytes (RBCs) of birds retain their nuclei, and the bird has **nucleated red blood cells**.

Heart and Great Vessels: Birds have a four-chambered heart that is considerably larger than the mammalian heart relative to body size. In the domestic species (chicken, turkey, duck) the heart accounts for about 0.5-1.0% of their body weight, while in smaller birds, it may represent more than 1.5%. The high metabolic rate of birds demands a commensurate level of blood flow, which is reflected by their rapid heart rate. In domestic fowl the heart rate averages about 250 beats per minute, while it may exceed 1200 bpm in small, fast-flying birds (*viz.* hummingbirds).

As previously noted, the heart of the bird is located in the thoracic part of the thoracoabdominal cavity, ventral to the horizontal septum, and partly surrounded by the liver. (See Figs. 5-8 & 5-13.) It is also surrounded by a thin-walled pericardial sac, which is connected ventrally with the liver forming the **hepatopericardiac ligament**.

As we consider the avian heart and great vessels, we will focus primarily on the differences between the avian and mammalian structures. The interatrial septum of the avian heart **lacks a foramen ovale**. However, during early embryonic development, there are numerous, sieve-like perforations through the interatrial septum to allow blood to pass from right to left, thus bypassing pulmonary circulation. These small openings close off with the

commencement of pulmonary respiration, leaving no discernible remnant (fossa ovalis) of their presence.

In contrast with mammals, **it is the right, not the left, 4th aortic arch in the bird that persists to form the definitive aorta** (Figs. 8-1 & 8-2). Thus, the aorta and pulmonary trunk (right 6th aortic arch) of the bird pass to the right side of the esophagus and trachea.

The ascending aorta gives rise to both **left and right brachiocephalic trunks** (Figs. 8-1 & 8-2). The left trunk typically arises first, followed immediately by the right trunk. Each brachiocephalic trunk gives rise to its respective common carotid and subclavian arteries.

There are 3 venae cavae in the bird, the caudal vena cava, and the paired **right and left cranial venae cavae** (Figs. 8-1 & 8-2). The entrance of the caudal vena cava into the right atrium is flanked by two muscular flaps forming the **sinoatrial valve**, which functions to prevent regurgitation of blood into the caudal vena cava (Fig. 8-1). This valve also helps prevent backflow into the adjacent openings of the two cranial venae cavae.

The **left atrioventricular (AV) valve** is similar in structure to that of the mammalian heart, with the notable exception that it has three vs. two major cusps. Due to this 3-cusp structure, the left AV valve of the bird has sometimes been described as the so-called “tricuspid” valve, which is indeed unfortunate. This term should not be used in the bird because of the confusion it naturally generates between avian and mammalian nomenclature, and of course the term

“mitral” valve would not apply to the bird. The avian left AV valve has chordae tendineae associated with each of three papillary muscles (Fig. 8-2).

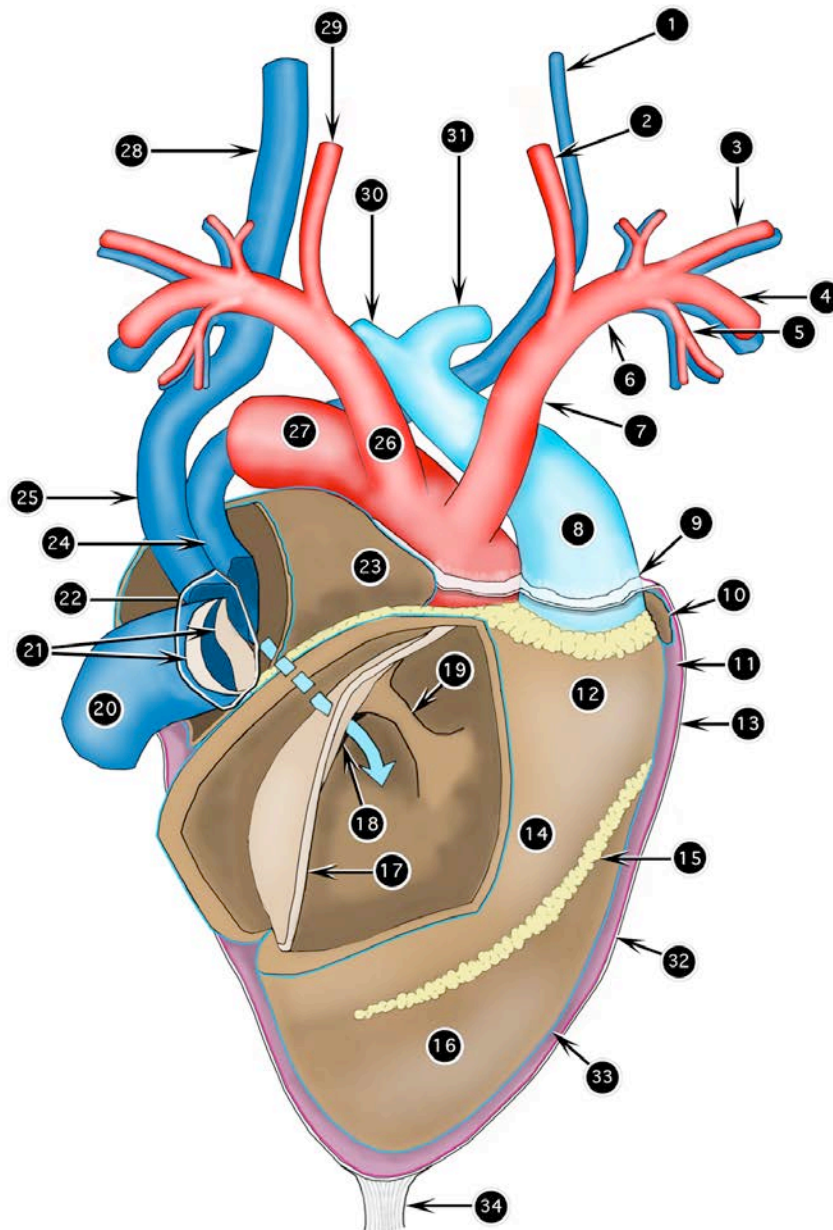


Figure 8-1. Semi-schematic drawing of avian heart & pericardium, ventral view: (1) left external jugular vein smaller than right); (2) left common carotid artery; (3) left axillary artery; (4) left pectoral trunk; (5) left internal thoracic artery; (6) left subclavian artery; (7) left brachiocephalic trunk; (8) pulmonary trunk; (9) line of pericardial reflection; (10) tip of left auricle; (11) pericardial cavity; (12) conus arteriosus; (13) fibrous pericardium; (14) right ventricle (opened); (15) paraconal interventricular groove; (16) left ventricle; (17) right AV valve; (18) right AV ostium; (19) attachment of right AV valve to interventricular septum; (20) caudal vena cava; (21) sinuatrial valve; (22) sinus venosus; (23) right auricle; (24) left cranial vena cava; (25) right cranial vena cava; (26) right brachiocephalic trunk; (27) aorta; (28) right external jugular vein; (29) right common carotid artery; (30) right pulmonary artery; (31) left pulmonary artery; (32) parietal serous pericardium; (33) visceral serous pericardium (epicardium); (34) reflection of 13 between lobes of liver forming hepatopericardiac ligament.

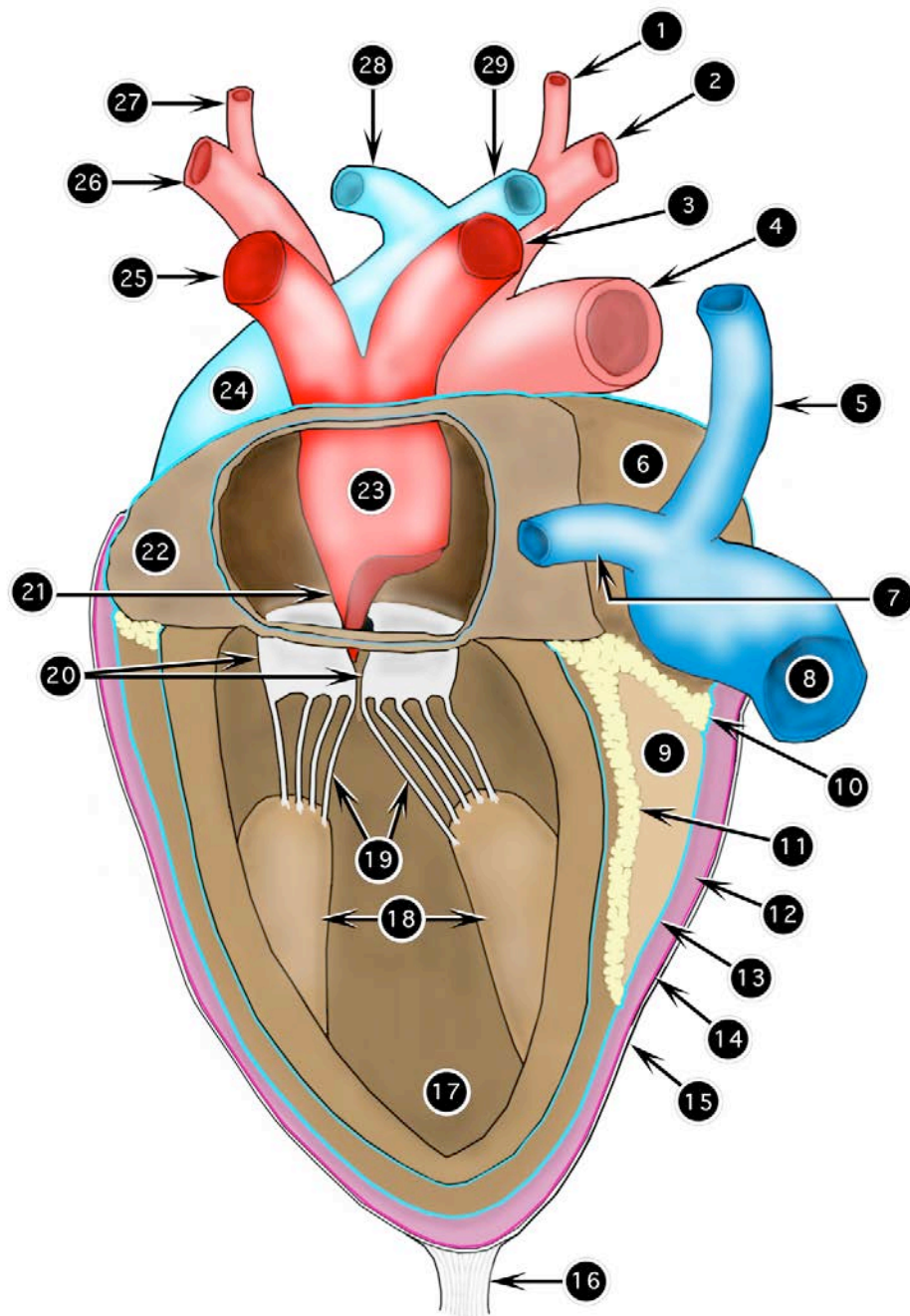


Figure 8-2. Semi-schematic drawing of avian heart & pericardium, dorsal view: (1) right common carotid artery; (2) right subclavian artery; (3) right pulmonary vein; (4) aorta; (5) right cranial vena cava; (6) right atrium; (7) left cranial vena cava; (8) caudal vena cava; (9) right ventricle; (10) coronary groove; (11) subsinuosal interventricular groove; (12) pericardial cavity; (13) visceral serous pericardium (epicardium); (14) parietal serous pericardium; (15) fibrous pericardium; (16) reflection of 15 between lobes of liver forming hepatopericardiac ligament; (17) left ventricle (opened); (18) 2 of 3 papillary muscles; (19) chordae tendineae; (20) 2 of 3 cusps of left AV valve; (21) left free margin of pulmonary chamber extending through AV ostium and forming valve to prevent back-flow into 23; (22) left auricle; (23) pulmonary chamber (camera pulmonalis) protruding into lumen of left atrium; (24) pulmonary trunk; (25) left pulmonary vein; (26) left subclavian artery; (27) left common carotid artery; (28) left pulmonary artery; (29) right pulmonary artery.

The right atrioventricular orifice is crescent-shaped (*vs.* round), and the **right atrioventricular (AV) valve** is much different, and perhaps more primitive in structure than that of mammals. It consists of a simple muscular flap, derived from both atrial and ventricular musculature (Fig. 8-1). There are no papillary muscles or chordae tendineae associated with the right AV valve; however, the flap is anchored to the interventricular septum by a thick strand of tissue (Fig. 8-1).

The **right and left pulmonary veins** typically join one another prior to entering the left atrium. The confluence of the two veins protrudes into the atrium forming a sub-compartment termed the **pulmonary chamber** (*camera pulmonalis*). The left wall of this invagination extends distally through the right AV ostium, and during atrial systole acts as a valve to prevent backflow from the left atrium into the pulmonary veins.

The pelvic limbs are supplied not only by the external iliac arteries, but also by the **right and left ischiadic arteries**. (See Fig. 7-1.) The ischiadic arteries exit the pelvic cavity *via* the ilioischiadic foramina with the sciatic (ischiadic) nerves. (See Fig. 2-12.)

As previously noted, birds have a **renal portal system**. (See Fig. 7-1.) Blood from the pelvic limbs may be filtered through the kidneys before reaching general, systemic circulation, which could certainly affect your decision for intramuscular injections of drugs (*i.e.*, in-one-leg and out-the-vent short-cut).

The **right external jugular vein** is typically much larger than the left (Fig. 8-1), and in some species, the left vein may be absent. The right external jugular vein is sometimes used as a **venipuncture site** in

the bird. The **superficial ulnar vein** and/or the **brachial vein**, which course subcutaneously along the ventral surface of the antebrachium and brachium respectively, can also be used as a venipuncture site in the bird (Fig. 8-3).

The principal blood flow to the pelvic limb is *via* the **ischiadic artery** rather than the femoral (Fig. 8-4). As previously mentioned, the ischiadic artery emerges through the **ilioischiadic foramen**.

Lymphatic System: Phylogenetically, birds are the first vertebrates to have valves in their lymphatic ducts to produce unidirectional flow toward the venous connection. Likewise, birds introduced the concept of consolidating lymphatic tissue into definitive structures we recognize as lymph nodes. Albeit a modest attempt, **cervicothoracic and lumbar lymph nodes** have been described in the duck and goose. Generally speaking though, lymph nodes are not routinely observed (or palpated for that matter) in birds.

Although short on lymph nodes, birds do have numerous collections of lymphoid tissue associated with the walls of the oropharynx and gut. Some of these **aggregated lymphoid nodules** are grossly evident, and are frequently termed “**tonsils**” (*viz.*, ileal tonsil, cecal tonsils, etc.) (See Fig 5-14.)

The age-dependent aggregation of lymphoid tissue associated with the wall of the **cloacal bursa** is important immunologically in the synthesis of circulating antibodies and is the site of differentiation of **B-lymphocytes**. This bursa, commonly referred to as the bursa of Fabricius, is obviously very active during early life, when the bird is developing a lot of antibodies. Once the early surge of

antibody synthesis subsides (about 5-6 weeks in the chicken), the bursa begins to atrophy, much like the thymus of mammals.

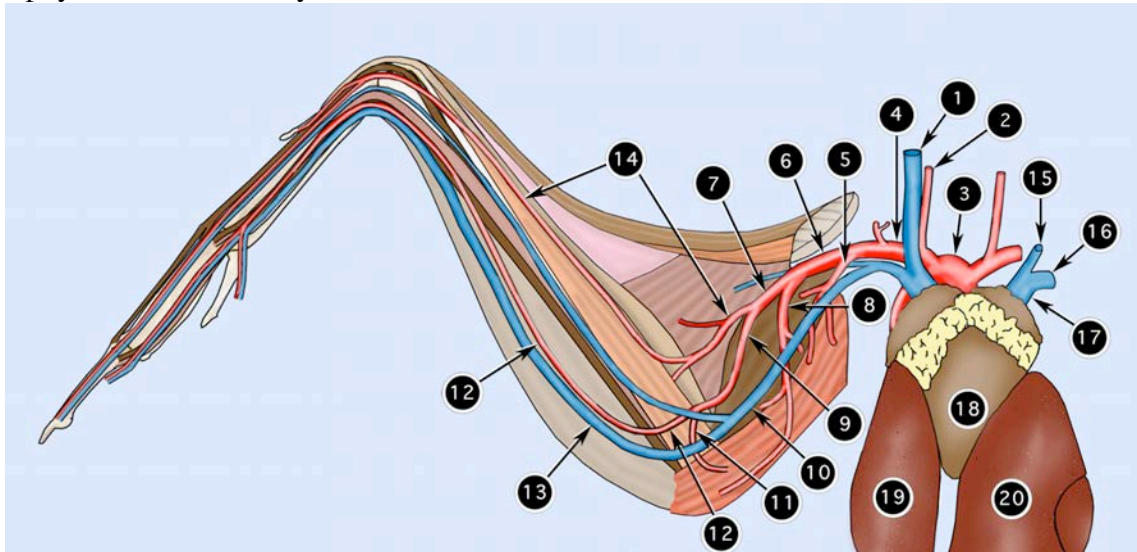


Figure 8-3. Selected vessels of wing, ventral view: (1) right external jugular vein; (2) right common carotid artery; (3) aorta; (4) right subclavian artery; (5) pectoral trunk; (6) axillary artery; (7) brachial artery; (8) collateral ulnar artery; (9) ulnar artery; (10) ulnar vein; (11) recurrent ulnar artery; (12) superficial ulnar artery; (13) superficial ulnar vein; (14) radial artery; (15) left external jugular vein; (16) left subclavian vein; (17) left cranial vena cava; (18) left ventricle of heart; (19) right lobe of liver; (20) right lobe of liver.

Solitary lymphoid nodules (not evident grossly) are also found in the walls of other organs (*viz.*, liver, pancreas, etc.).

Major Lymph Ducts: In the bird, there is no single lymphatic vessel comparable to the thoracic duct of the mammal. The thoracic duct is replaced in the bird by **paired (right and left) thoracoabdominal trunks**, which are formed in the renal part of the pelvic cavity. These paired ducts course cranially in the sublumbar region, to either side of the aorta. Numerous dilatations occur along their course, and there are numerous anastomotic connections between the left and right thoracoabdominal trunks.

Each trunk drains lymph from the pelvic limbs, and pelvic viscera. The trunks also receive mesenteric lymphatics from the gastrointestinal tract, and tributaries from other viscera (*viz.*, gonads, kidneys,

adrenals). There is no well-defined dilatation that would correspond with the cisterna chili of the mammal. Each thoracoabdominal trunk continues cranially along side the thoracic part of the aorta and terminates in its respective cranial vena cava, near the confluence of the external jugular and subclavian veins.

Lymph from the thoracic limbs arrives at the thoracic inlet *via* the right and left **subclavian lymphatic vessels**, while that from the head and neck is drained by paired **jugular lymphatic vessels**. Most of the lymph from the pelvic limbs is drained *via* the right and left **ischiodic and external iliac lymphatic vessels**. These vessels, join the **internal iliac lymphatic vessels**, which drain the pelvic viscera to form thoracoabdominal trunks within the pelvic cavity.

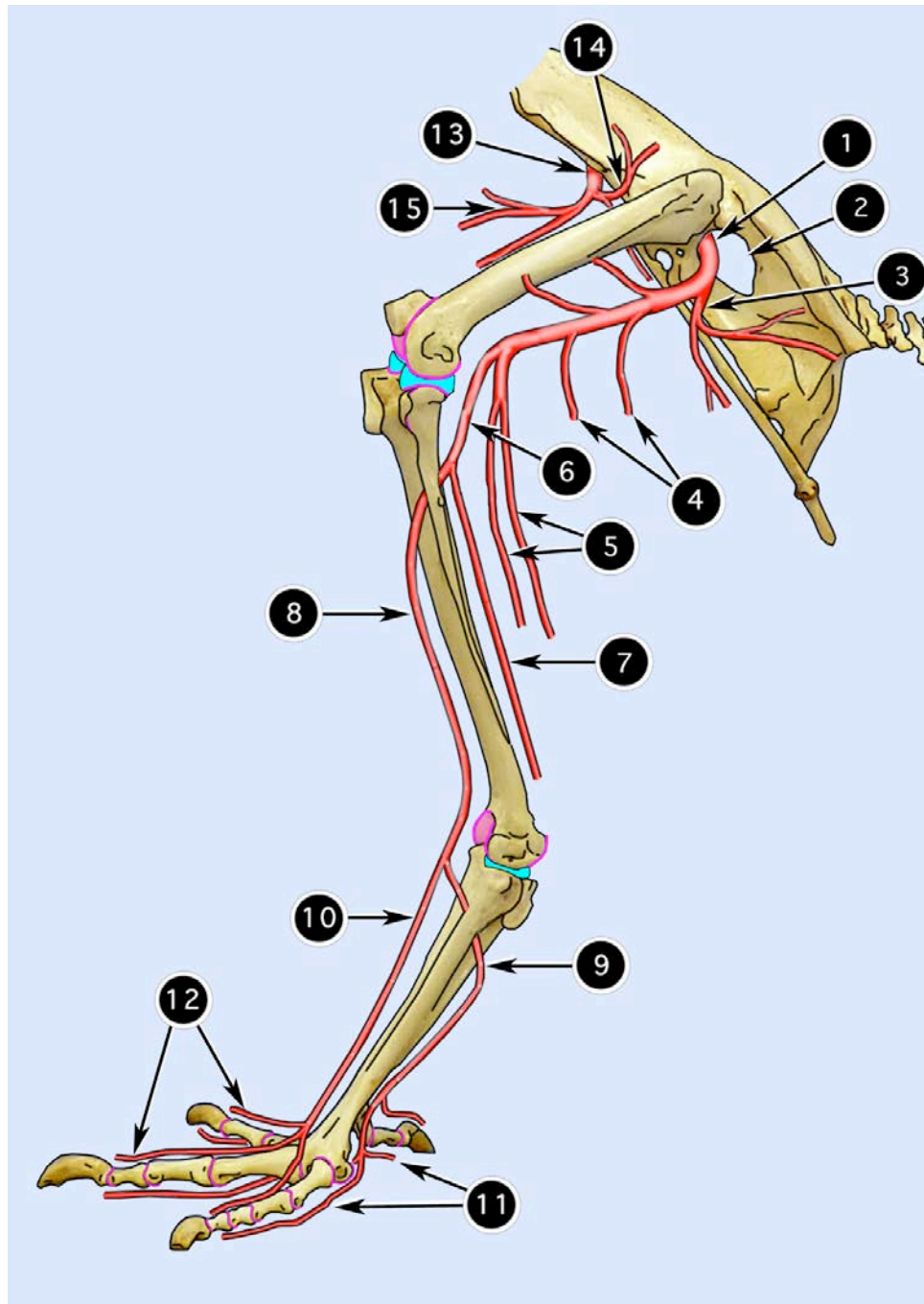


Figure 8-4. Selected arteries of pelvic limb, lateral view: (1) ischiadic artery; (2) ilioischiadic foramen; (3) caudal coxal artery; (4) caudal femoral arteries; (5) caudal sural arteries; (6) popliteal artery; (7) caudal tibial artery; (8) cranial tibial artery; (9) plantar metatarsal artery; (10) dorsal metatarsal artery; (11) plantar digital arteries; (12) dorsal digital arteries; (13) femoral artery; (14) cranial coxal artery; (15) cranial femoral artery.

Chapter 9 • Nervous System

Although one sometimes hears an intended derogatory comment about being a “bird brain,” this may actually be a complement in disguise. Birds, it turns out, are anything but mentally challenged. In fact, birds are highly intelligent animals, capable of not only using tools, but even completing multistep tasks. In case you doubt this statement, I refer you to the following video:

<https://www.youtube.com/watch?v=AVaITA7eBZE>

Cerebrum (telencephalon): One anatomic reason, birds might be considered less intelligent than mammals is the more or less smooth (lissencephalic) surface of their cerebral hemispheres (Fig. 9-1), which is considered a pathologic condition in mammals, except in rodents. Actually, the cerebral hemisphere of the bird is not without some external demarcation in that there is a groove on the dorsal surface known as the **cerebral vallecule**¹ (Fig. 9-1). This depression separates the cerebral hemisphere into two areas, the major part lying lateral to the vallecule, and a ridge medial to the

groove known as the **sagittal eminence**. (Note: in older references, this eminence is referred to as the “*Wulst*” or bulge).

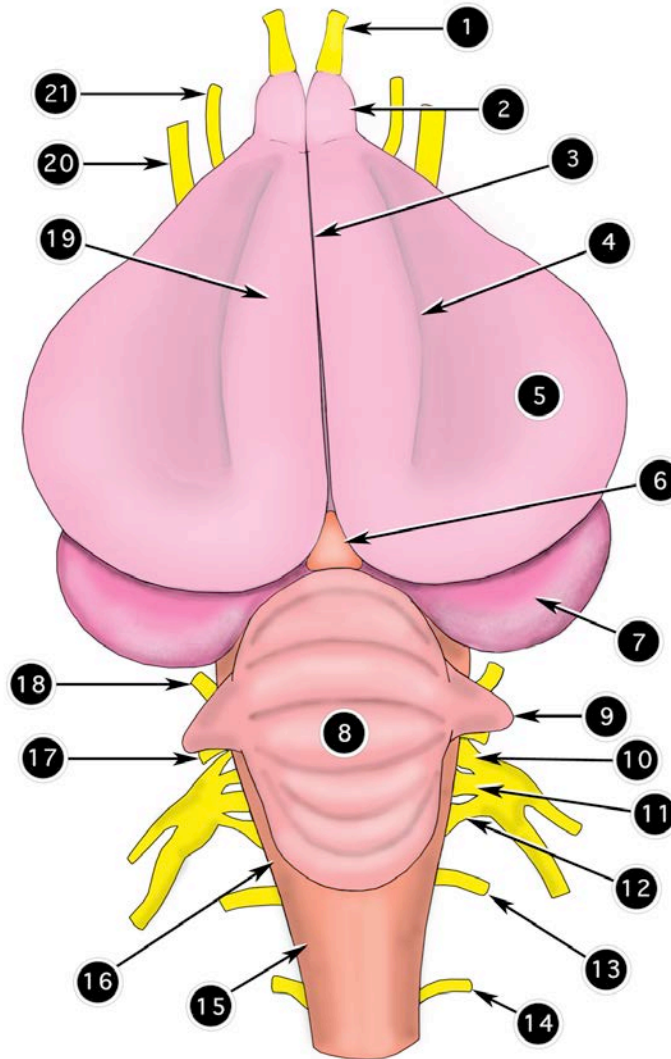


Figure 9-1. Brain and cranial nerves of chicken, dorsal view: (1) CN I- olfactory nerve; (2) olfactory bulb; (3) interhemispheric fissure; (4) cerebral vallecule; (5) cerebral hemisphere; (6) pineal body; (7) mesencephalic colliculus (optic lobe); (8) cerebellum; (9) cerebellar auricle; (10) CN IX- glossopharyngeal nerve; (11) CN X- vagus nerve; (12) CN XI- accessory nerve; (13) C1- first cervical spinal nerve; (14) C2- second cervical spinal nerve; (15) spinal cord; (16) myelencephalon (medulla oblongata); (17) CN VIII- vestibulocochlear nerve; (18) CN VII- facial nerve; (19) sagittal eminence; (20) ophthalmic nerve; (21) CN IV- trochlear nerve. (Modified after *Anatomy of the Domestic Birds*, R. Nickel, A. Schummer, E. Seiferle, Springer-Verlag, New York, 1977, page 116.)

¹ vallecule- *L.* little valley; any crevice or depression on the surface of an organ or structure.

As has been mentioned previously, birds, with few exceptions (*viz.*, kiwi), have essentially lost their sense of smell. Thus the **olfactory bulbs** are quite small (Figs. 9-1 & 9-2). We have also noted that birds have remarkable vision, and it should come as no surprise that the visual part of the brain is very well developed. The **optic nerves** are large, and the **optic tracts** lead directly to prominent bulbs just caudal to the cerebral hemispheres (Figs. 9-1 & 9-2). These so-called “**optic lobes**” are enlargements of the mesencephalic tectum forming the **mesencephalic colliculus**. Many or most of the fibers within the optic nerve decussate at the **optic chiasma**.

Although located more ventrally, the mesencephalic colliculus is homologous to the rostral colliculus of mammals, and there is no external evidence of a caudal colliculus in birds. In mammals, the rostral colliculus functions in visual reflexes. When one considers the many “split-second” corrections in wing, tail and body position of birds in flight, it seems reasonable that many of these rapid responses to the demands of flight, are almost reflexive as opposed to deliberate thought processes.

There is no time to think about what adjustments need to be made to avoid obstacles in rapid flight through tree branches, etc. The goshawk is an expert at flying through dense forests without colliding with the tree branches.

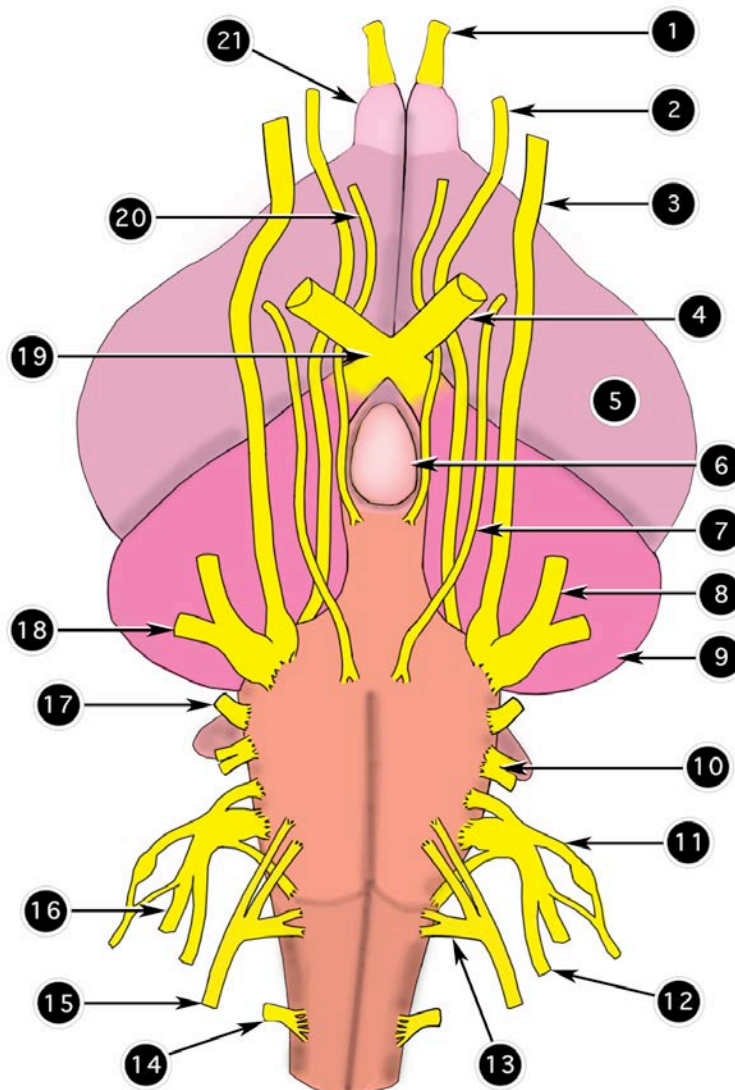


Figure 9-2. Brain and cranial nerves of chicken, ventral view: (1) CN I- olfactory nerve; (2) CN IV- trochlear nerve; (3) CN V- ophthalmic nerve; (4) CN II- optic nerve; (5) cerebral hemisphere; (6) hypophysis cerebri (pituitary gland); (7) CN VI- abducent nerve; (8) CN V- maxillary nerve; (9) mesencephalic colliculus (optic lobe); (10) CN VIII- vestibulocochlear nerve; (11) CN IX- glossopharyngeal nerve; (12) CN XI- accessory nerve; (13) C 1- first cervical spinal nerve; (14) C 2- second cervical spinal nerve; (15) CN XII- hypoglossal nerve; (16) CN X- vagus nerve; (17) CN VII- facial nerve; (18) CN V- mandibular nerve; (19) optic chiasma; (20) CN III- oculomotor nerve; (21) olfactory bulb. (Modified after *Anatomy of the Domestic Birds*, R. Nickel, A. Schummer, E. Seiferle, Springer-Verlag, New York, 1977, page 116.)

Another feature of the avian brain that is particularly well developed is the **pineal body** (Fig. 9-1). The pineal body of birds is a neuroendocrine gland responsible for the production of melatonin. Because of its largely secretory function in most birds, it is frequently referred to as the pineal gland. The pineal is believed to be sensitive to light, which reaches it *via* the optic nerve or directly through the thin-walled skull of the bird. The pineal is generally believed to be strongly influential on the reproductive behavior in birds in response to the light/dark photoperiod. Thus reproductive behavior increases during the spring, when days are getting longer, and is diminished in the fall, when the daylight period is shortening. The role that the pineal actually plays in reproductive activity is somewhat controversial, in that there is no conclusive

scientific evidence that confirms its function in this regard.

Adnexa of Eye

The adnexa of the eye include the eyelids, the conjunctiva, the lacrimal apparatus, the bulbar muscles, and other structures associated with the eyeball. The eyelids function to protect and clean the exposed surface of the eye. The anatomically correct terms for the upper and lower eyelids are the **superior** (dorsal) and **inferior** (ventral) **palpebrae**, and the opening between them, through which the eye is visible, is the **palpebral fissure** (Fig. 9-3). The upper and lower eyelids come together at the medial and lateral **palpebral commissures**, and the medial (nasal) and lateral (temporal) **angles** of the eye.

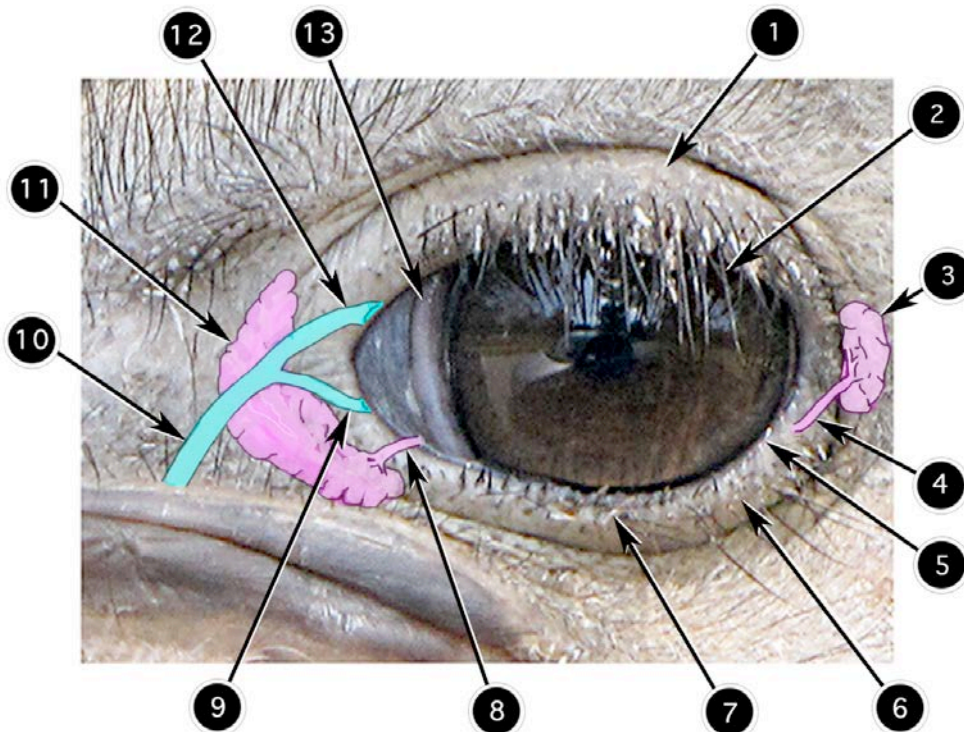


Figure 9-3. Left eye of ostrich showing eyelids and associated structures: (1) superior (dorsal) eyelid; (2) superior cilia; (3) lacrimal gland; (4) single duct of 3; (5) plicated margin of eyelid; (6) inferior (ventral) eyelid; (7) inferior cilia; (8) duct of gland of nictitating membrane; (9) inferior lacrimal ostium & canaliculus; (10) nasolacrimal duct; (11) gland of nictitating membrane; (12) superior lacrimal punctum & canaliculus; (13) free edge of nictitating membrane reinforced with connective tissue band. (Original photo courtesy: <http://tulsagentleman.blogspot.com/2011/01/macro-monday-high-as-ostrichs-eye.html>).

The inferior eyelid of birds is typically thinner and much more moveable than the upper lid. When the lids are closed, it is the lower eyelid that does most of the movement resulting in a closed palpebral fissure taking the form of an arch, well above the middle of the pupil. Only the lower eyelid is reinforced by a fibrous plate or **tarsus**. Relative to that of mammals, the open palpebral fissure is small and completely hides the sclera, leaving only the cornea exposed. Movements of the eyelids are produced by several skeletal muscles, including the **levator palpebrae superioris**, the **depressor palpebrae interioris**, and the **orbicularis oculi**.

Unlike the situation in mammals, the **lacrimal gland** is not the largest tear producer. In fact, it is relatively small and is associated with the lateral commissure of the eyelids. Its single duct empties into the conjunctival sac on the bulbar surface of the inferior eyelid (Figs. 9-3 & 9-4). The much larger **gland of the nictitating membrane** (third eyelid) is located on the ventral and caudomedial surfaces of the eyeball, and its single duct empties into the conjunctival sac between the nictitating membrane and the eyeball (Fig. 9-4). This gland is not the homologue of the superficial gland of the third eyelid in domestic mammals, but is comparable to the **deep (Harderian) gland**, which is well developed in some domestic mammals (*viz.* pig). This gland contains plasma cells, which are derived from the cloacal bursa, and it plays a role in the immunologic response to antigens introduced into the conjunctival sac.

Distribution of the **tear film** across the cornea is primarily effected by movement of the **nictitating membrane** (third eyelid), which pushes the fluid to the medial (nasal) aspect of the conjunctival sac. Here it is aspirated into the **superior and inferior**

lacrimal ostia (punctae). These punctae are located on the bulbar surface of the eyelid margins a few mm from the medial commissure. The superior punctum is several times larger than the inferior one, and each ostium is continued by their respective **superior and inferior lacrimal canaliculi** (Fig. 9-3). These canaliculi converge within a few mm to form a single **nasolacrimal duct**, which passes through the dorsal and medial walls of the infraorbital sinus, conducts the “used” tears to the nasal cavity just dorsal to the **choana**. Thus, the tears continue through the choanal cleft to the oropharynx. (See page 102.)

One unique feature of the nictitating membrane of the bird *vs.* the mammal is the presence of the **marginal fold** along the free edge of the nictitating membrane (Fig. 9-4). When the nictitating membrane is pulled across the eye, the marginal fold lies flat against the anterior surface of the membrane, but as the membrane retracts toward its home medial to the eyeball, this fold lifts away from the membrane, acting much like a “squeegee” to push the tear film toward the lacrimal ostia located near the medial angle of the eye.

Unlike the more or less passive excursion in mammals, movement of the nictitating membrane across the cornea is accomplished by two skeletal muscles, the **pyramidalis** and the **quadratus** (Fig. 9-5A), which develop from the same primordial tissue as the retractor bulbar muscle of mammals. These muscles are innervated by CN VI (abducent nerve). The pyramidalis and quadratus muscles lie flat against the posterior aspect of the sclera, and have a unique relationship to one another. The aponeurosis of the quadratus muscle forms a fibrous canal or trochlea for the cylindrical tendon of the pyramidalis muscle to pass

through as it arches up and over the optic nerve (Fig. 9-5A).

The tendon of the pyramidalis muscle continues ventrally, then passes along the ventrolateral aspect of the eyeball to reach the ventral part of the free edge of the nictitating membrane (Fig. 9-5B). Because the dorsal part of the free edge of this membrane is attached to the eyeball,

contraction of the pyramidalis and quadratus muscles pulls the nictitating membrane across the cornea from medial (nasal) to lateral (temporal). Although there is species variation, the nictitating membrane moves across the cornea about every 2 seconds, which spreads and redistributes the tear film. It also moves across the eye in a reflex action whenever any object approaches the eye.

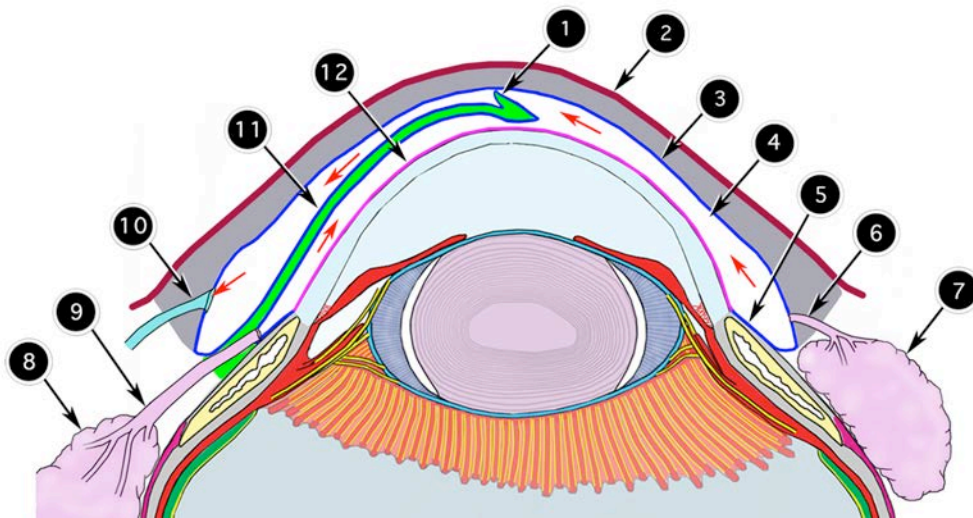


Figure 9-4. Dorsal section through right eye through inferior eyelid: (1) marginal fold; (2) skin of lower eyelid; (3) palpebral conjunctiva; (4) conjunctival sac; (5) bulbar conjunctiva; (6) duct of lacrimal gland; (7) lacrimal gland; (8) gland of nictitating membrane; (9) duct of 8; (10) inferior lacrimal ostium & canaliculus; (11) nictitating membrane; (12) anterior epithelium of cornea. Red arrows → show direction of tear film flow. (Modified after Slonaker, 1918).

Other muscles of the Eyeball (Fig. 9-5A): The large eyeball of the bird completely fills the orbit, leaving little room for retrobulbar fat and/or extraocular muscles as we see in mammals. Therefore, there is **no retractor bulbar muscle** because pulling the eyeball back in the orbit is not possible in the bird. The remaining bulbar muscles consist of three antagonistic pairs of muscles, designed to rotate the eyeball around three axes, vertical, horizontal, and optic (anteroposterior).

The **dorsal, ventral, medial, and lateral rectus**, and the **ventral oblique muscles** of the eyeball resemble those of the

mammalian eye, both in structure and innervation. The lateral rectus muscle is innervated by CN VI (abducent nerve), while the other rectus muscles and the ventral oblique are innervated by CN III (oculomotor nerve). The dorsal oblique muscle is innervated by CN IV (trochlear nerve).

One notable difference in the avian eye is that the **dorsal oblique muscle** is similar in design to that of the ventral oblique, such that it originates directly from the medial wall of the orbit, and does not require a trochlea to change the direction of its tendon.

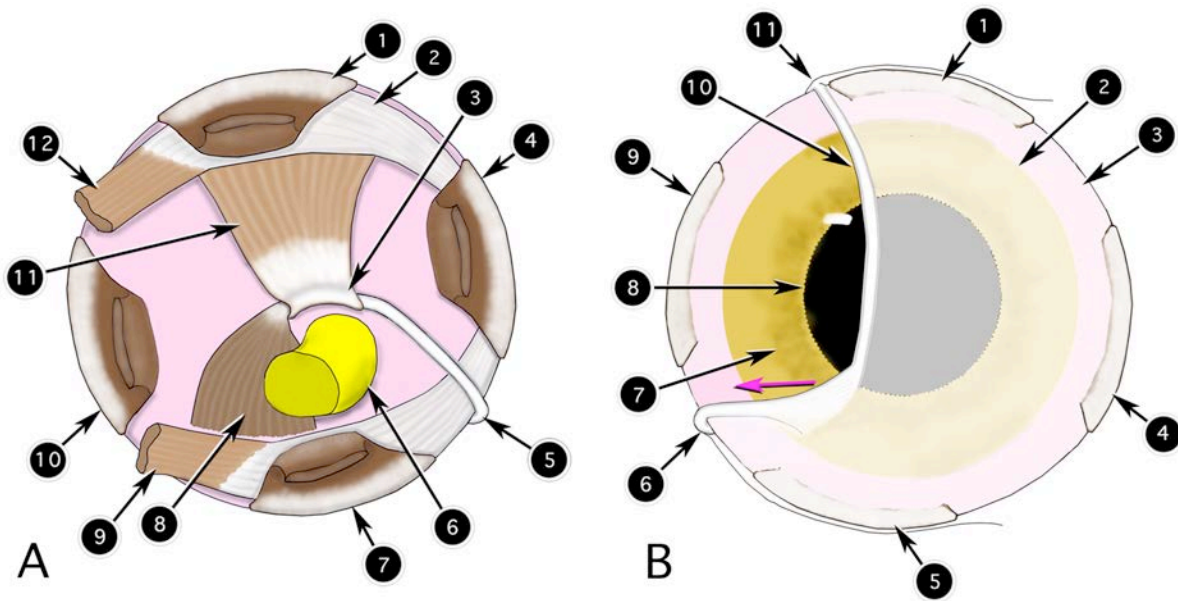


Figure 9-5. Posterior view of right avian eyeball (A): (1) dorsal rectus muscle; (2) tendon of dorsal oblique muscle; (3) aponeurosis of quadratus muscle forming a sleeve-like trochlea for the tendon of the pyramidalis muscle; (4) lateral rectus muscle; (5) tendon of pyramidalis muscle; (6) optic nerve; (7) ventral rectus muscle; (8) pyramidalis muscle; (9) ventral oblique muscle; (10) medial rectus muscle; (11) quadratus muscle; (12) dorsal oblique muscle, originates from medial side of orbit. **Anterior view of right avian eyeball (B):** (1) tendon of dorsal rectus muscle; (2) corneoscleral junction; (3) sclera; (4) tendon of medial rectus muscle; (5) tendon of ventral rectus muscle; (6) continuation of tendon of pyramidalis muscle in free edge of nictitating membrane; (7) iris; (8) plicated margin of pupillary border; (9) tendon of lateral rectus muscle; (10) free edge of nictitating membrane, reinforced by connective tissue band; (11) dorsal aspect of nictitating membrane attached to the sclera. The magenta arrow → indicates movement of nictitating membrane from medial to lateral.

Avian Eyeball (bulbus oculi)

The eye of the bird is an amazing structure. The difference between what we see and what birds see is, at the very least, the difference between regular television (720p) for mammals and HD (1080p) TV for birds. The eyes of the bird are so large that there is only a thin **interorbital septum** between them. (See Fig. 2-17.) In fact, the eye of the ostrich is the largest eye of any terrestrial vertebrate, measuring some 5 cm along its optic axis from cornea to retina. In most birds the weight of the two eyes is equal to or heavier than the brain.

The shape of the eye also shows considerable variation among avian species. In most bird species, the eye is compressed

from anterior to posterior forming a more or less “flattened” structure. The eye of other birds is more globe-like, while the large eye of owls (Strigiformes) and some eagles (Falconiformes) is elongated in the anterior-posterior dimension forming a “tubular” shape. (See Fig. 2-3.) The poorest vision among birds is likely that of the kiwi. The kiwi has relatively small eyes, but to compensate, they have retained a keen sense of smell, which is not present in most other avian species.

The anatomy of the avian eyeball is in many ways similar to that of mammals in that it consists of the same three tunics or coats- fibrous, vascular, and nervous (Fig. 9-6). There are, however, some marked differences in the avian eye. The **fibrous**

tunic consists of the cornea and the **sclera**, which is reinforced by the **scleral ossicles**. It is further reinforced in many birds by a wrapper of cartilage, forming a **cartilaginous lamina**, external to the fibrous part of the sclera (Fig. 9-6). Within the posterior part of the cartilaginous lamina, there may also be additional islands of ossification forming one or more **posterior scleral ossicles**.

The anterior segment of the fibrous coat is formed by the transparent **cornea** (Figs. 9-6 & 9-7). The refractive power of the cornea of birds is about equal to or even greater than that of the lens, depending on the species. The layers of the avian cornea are similar to those of mammals and consist of the anterior epithelium, the anterior limiting (Bowman's) membrane, the substantia propria or stroma, the posterior limiting (Descemet's) membrane, and the posterior epithelium (Fig. 9-7). The posterior limiting membrane, as in mammals, may be very thin or even absent in some birds.

The **ciliary body** is the anterior continuation of the choroid, and is primarily formed by the **ciliary processes** (Figs. 9-6 & 9-7). Associated with the ciliary processes are the **zonular fibers**, which attach to the lens capsule. Also associated with the ciliary body are **ciliary muscles**, which function in accommodation. There are several differences between the ciliary muscles of mammals and those of birds. The smooth ciliary muscles of mammals are composed of both meridional and circular components. In contrast, all ciliary muscles of birds are meridionally oriented, and most remarkably, they are composed of **striated muscle fibers**. Being striated would imply some voluntary accommodation ability in birds, but I doubt that is the case. I would reason that the striated muscle allows for

more rapid accommodation, but that it most likely occurs automatically, without conscious control. Birds would certainly benefit from an "auto focus" setting that would enable them to change focus for rapidly approaching objects (prey or obstacle) using "split-second timing."

The ciliary muscles of birds also work differently in the accommodation process, affecting not only changes in lens curvature (as in mammals), but they also have the ability to alter the curvature of the cornea. The **anterior ciliary muscle** (Crampton's m.) extends from the sclera to the internal part of the cornea. Contraction of this muscle can alter the curvature of the cornea (Fig. 9-7). The **posterior ciliary muscle** (Brücke's m.) also attaches near the cornea, but probably has less effect on the cornea than on the lens as far as accommodation.

The mechanism of lenticular accommodation may also be different than in mammals. Rather than just pulling the ciliary body anteriorly to release tension on the zonular fibers, it is thought that contraction of the posterior ciliary muscle causes the ciliary processes to push against the annular pad of the lens, thus causing active compression of the entire lens structure. This would increase the convexity of the central lens making it more convergent for near-vision accommodation. It might also be a logical deduction that the vesicular fluid between the annular pad and central lens would serve to evenly distribute and transfer the compressive forces of the ciliary process from the annular pad to the central lens.

Continuous with the ciliary body anteriorly is the **iris**, which controls the aperture of the pupil (Figs. 9-6 & 9-7). The iris of birds is highly mobile, and the diameter of the circular **pupil** can change

quickly. The peripheral part of the iris is thin near its attachment with the ciliary body; however, it thickens in the middle part, before thinning again near the pupillary margin. Unlike the situation in mammals, the pupillary margin of the iris is in direct contact with the anterior lens capsule. The anterior epithelium of the iris is a single layer of cells, while the posterior surface is covered by several layers of pigmented cells, which constitute the *pars iridica retinae*.

Similar to the avian ciliary muscles, and in contrast to those of mammals, the constrictor and dilator muscles of the avian iris are **striated**. Again, striated muscles would imply voluntary control, but this is not something the bird needs to think about. The iris (pupil diameter) is adjusted automatically in response to the amount of ambient light. The two muscles that control iris mobility are the **constrictor pupillae muscle** and the **dilator pupillae muscle** (Fig. 9-7).

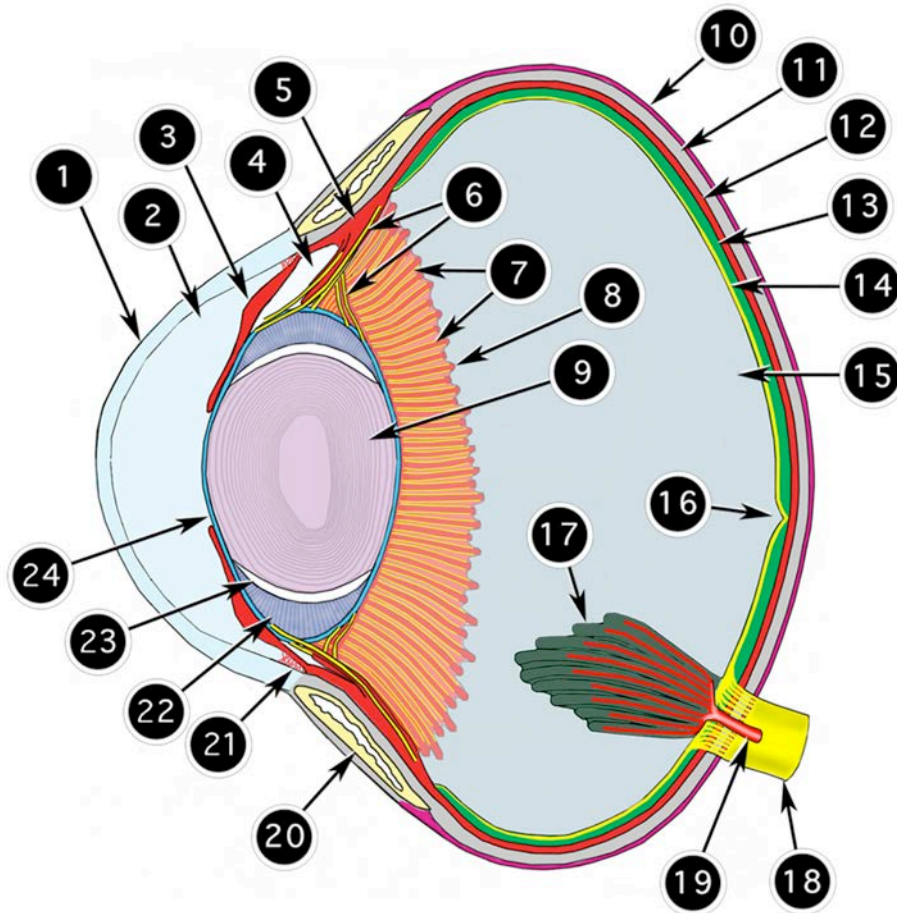


Figure 9-6. Semischematic drawing of avian eye, meridional section: (1) cornea; (2) anterior chamber; (3) iris; (4) posterior chamber; (5) ciliary body; (6) zonular fibers; (7) ciliary processes; (8) ora serrata; (9) central lens body (concentrically arranged lens fibers); (10) cartilaginous lamina of sclera; (11) fibrous lamina of sclera; (12) choroid; (13) pars optica retinae; (14) axons of photoreceptive cells converging to form optic nerve; (15) vitreous chamber; (16) fovea centralis; (17) pecten oculi; (18) optic nerve; (19) blood supply to pecten *via* ophthalmotemporal artery; (20) sclera ossicles forming scleral ring; (21) iridocorneal angle containing pectinate ligament (reticulum trabeculare); (22) annular pad of lens with radial fibers; (23) lens vesicle containing fluid; (24) lens capsule.

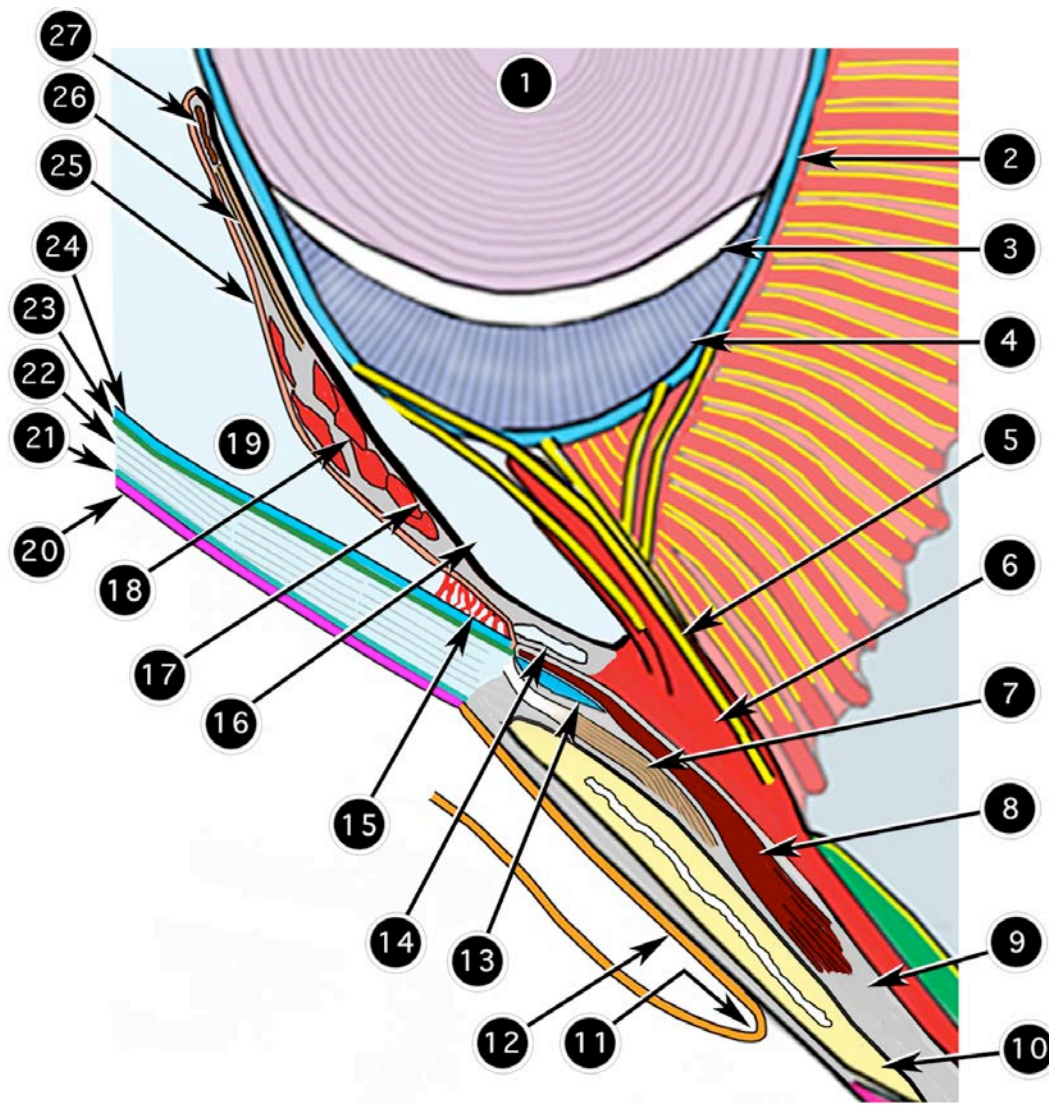


Figure 9-7. Semischematic drawing of iridocorneal angle of avian eye, meridional section: (1) central lens body with concentrically arranged lens fibers; (2) lens capsule; (3) lens vesicle containing fluid; (4) annular pad of lens with radial fibers; (5) zonular fibers; (6) ciliary processes; (7) anterior part of ciliary muscle (Crampton's m.); (8) posterior part of ciliary muscle (Brücke's m.); (9) sclera; (10) sclera ossicles forming scleral ring; (11) conjunctival fornix; (12) bulbar conjunctiva; (13) scleral venous sinus; (14) ciliocleral sinus; (15) pectinate ligament (reticulum trabeculare); (16) posterior chamber; (17) pigmented layer of iris combined with pars iridica retinae; (18) iridocyte body; (19) anterior chamber; (20) anterior epithelium of cornea; (21) anterior limiting (Bowman's) membrane of cornea; (22) substantia propria (stroma) of cornea; (23) posterior limiting (Descemet's) membrane of cornea; (24) posterior epithelium of cornea; (25) anterior epithelium of iris; (26) dilator pupillae muscle; (27) constrictor pupillae muscle.

Pigmentation of the iris is highly variable among avian species, including blues, browns, greens, yellows, and reds. In some species the color of the iris displays seasonal variation, and iris color may be different in males vs. females. Another

peculiarity of the avian iris is seen in Columbiformes (pigeons & doves). In these species, there are collections of refractive cells within the iris known as iridocytes, which may be scattered or collected into a definitive **iridocyte body** (Fig. 9-7). The

reflective layer formed by these cells is referred to as the *tapetum lucidum iridicum*.

The **nervous tunic** of the eyeball consists of the retina. The **retina** is further subdivided into the optic part, which covers the choroid and contains the photoreceptive cells, and the non-visual parts covering the ciliary processes (*pars ciliaris retinae*), and covering the posterior surface of the iris (*pars iridica retinae*). The ***pars optica retinae*** covers the **fundus** (deepest part) of the eye, and extends anteriorly to the posterior border of the ciliary process at the ***ora serrata*** (Fig. 9-6). As in the mammal, the retina is truly an extension of the brain, which develops as an embryonic outgrowth of the neural tube. It assumes the form of a “double-walled cup on a stalk.” The inner and outer walls of this optic cup meet at what will become the pupillary border. Thus, parts of the retina extend anteriorly over the ciliary body and iris. The difference between the ciliary and iridic parts vs. the much thicker optic part is that the latter has more layers of cells, including the photo receptive cells (*i.e.*, the rods and cones).

The axons from the **rods** and **cones** extend inward to synapse onto second-level neurons, which synapse again onto third-level neurons or **ganglion cells**. The axons of the ganglion cells reach the inner surface of the retina and turn immediately toward the optic disc, forming a fiber layer on the inner surface of the *pars optica retinae* (Fig. 9-6). Axons from the entire *pars optica* converge to the **optic disc**, where they turn outward to penetrate the choroid and sclera to form the optic nerve. The optic disc is technically the beginning of the optic nerve. Because there are no photoreceptive cells at the optic papilla, there is no image formation over this area, which accounts for the so-called “blind spot” in each eye. However,

when an image is formed by both eyes (binocular vision), each blind spot is negated or cancelled out by the image formed in the opposite eye. There are several differences between the *pars optica retinae* of the bird compared with that of our common domestic mammals. Although our domestic mammals have at least one *area centralis*, where there is a concentration of photoreceptive cells for higher resolution imaging, they do not typically have a distinct *fovea centralis* as is found in the human eye. In addition to an *area centralis*, many birds, like the human, have at least one fovea, and some species have two. The **fovea centralis** (Fig. 9-6) is positioned along the optic axis, while some bird species (*viz.*, owls, kingfishers, hummingbirds) also have a **fovea temporalis**.

The most remarkable difference between the retina of mammals vs. birds is the presence of the avian **pecten oculi** (Fig. 9-6). This structure projects from the *pars optica retinae* into the vitreous body. There is considerable variation in the development of the pecten across avian species, and its function has been the subject of much study and some debate. Most contemporary authors believe that the pecten functions in nourishment of the retina, **which in birds lacks retinal vessels**.

The pecten is a highly vascular structure, but its blood supply is not derived from the choroid. Blood flow to the pecten comes from the ophthalmotemporal artery (Fig. 9-6), which gives rise to numerous arterioles that open into a rich capillary network. At least three types of pecten oculi have been described in birds, ranging from a simple conical type in the kiwi, a vaned type in the ostrich, rhea, and tinamous, and the pleated type found in most other avian species. If the pecten oculi does serve a nutrient function, one would expect that nutrients

would diffuse out of the pecten into the vitreous body, and be transferred to the retina. This idea is supported by the two fundic photographs in figures 9-8 & 9-9.



Figure 9-8. Photograph of barred owl ocular fundus showing pleated nature of the pecten oculi. The highly vascular pecten projects into the vitreous body from the area of the optic disc (hidden by pecten in this photograph).

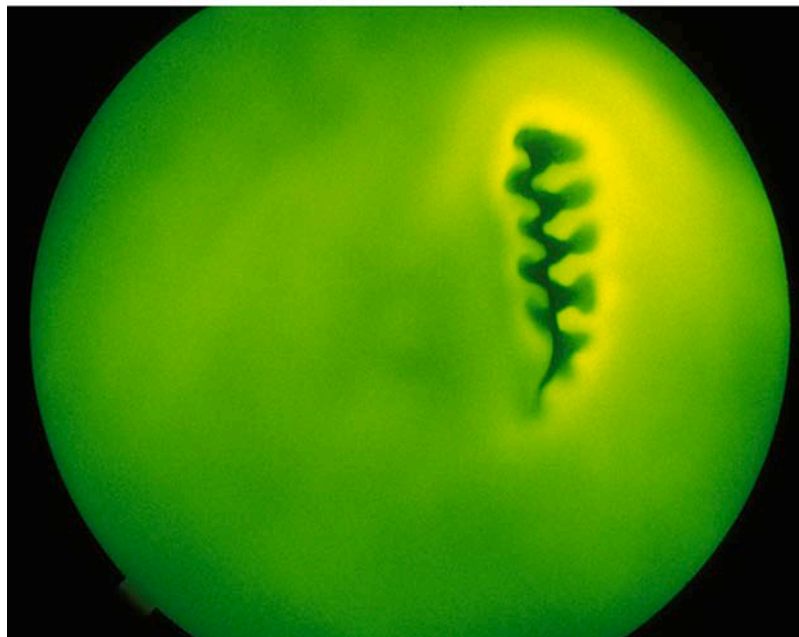


Figure 9-9. Photograph of barred owl ocular fundus following IV injection of fluorescein dye. Effusion of the dye (yellow color) from the pecten into the vitreous body is compatible with its proposed nutritive function of the pecten oculi.

Avian Ear and Hearing

Second only to vision, the sense of hearing is typically very well developed in birds. Birds use their keen sense of hearing in: (1) avoiding predators; (2) in the complex vocal communication with members of their own species; and (3) in the detection and location of prey. In fact, owls have all but perfected localization of sounds coming from potential prey. Not only can owls determine the horizontal direction, from which the sound is coming, but also can detect the origin of that sound in the vertical plane; *i.e.*, owls have a more developed “three-dimensional hearing.”

The external opening of the ear canal may be obvious in a few avian species such as the rhea (Fig. 9-10) or more likely inconspicuous as it is in many avian species. In most avian species the external acoustic meatus is a short opening concealed by small covert feathers, which form the **pinna** of the ear.



Figure 9-10. Head of American rhea showing an obvious external ear opening (red arrow). (Photo courtesy: [http://en.wikipedia.org/wiki/File:Greater_rhea_pair_arp.jpg](http://en.wikipedia.org/wiki/File:Greater_rhea_pair arp.jpg)).

These feathers are specialized and help, not only to funnel sound into the meatus, but also to protect the ear from the turbulence of

airflow across the meatus. Some birds, such as the chicken, have a fold of skin, termed an **earlobe**, associated with the external opening of the ear canal. (See Fig. 3-12.) Diving birds can diminish or even close the external ear canal when going under water.

The **external acoustic meatus** is a short tube located just caudal the quadrate bone (Fig. 9-11). Owls can even alter the shape of the meatus for better sound localization by manipulating a feathered skin fold or **operculum** (concha, pre-aural flap) located rostral to the meatus. Using striated muscles, the operculum can be moved rostrally or caudally to alter the size and shape of the external acoustic meatus. To make things even more interesting, some owls show asymmetry of their external ear structures, which may even be accompanied by asymmetry of their skull. For example, in the Boreal owl, the right ear is actually located at a more dorsal level in the skull than the left, which is believed to further assist these owls in sound localization, especially in the vertical plane.

Similar to mammals, the **middle ear** of the bird consists of an air-filled tympanic cavity. Unlike that of mammals, there is no malleus, stapes, and incus, and the tympanic membrane tends to protrude outward rather than inward. Air within the tympanic cavity communicates with air spaces in the surrounding bones, and *via* the auditory tube with the oropharynx. Transmission of eardrum vibrations to the vestibular window of the inner ear is accomplished *via* a single auditory ossicle, the **columella**, which is homologous to the mammalian stapes (Fig. 9-11). The mammalian malleus and incus are homologous to the articular and quadrate bones respectively.

Tension on the eardrum is accomplished by the **columellar muscle**, which originates from the occipital bone. This muscle is derived from the second branchial arch and is innervated by the CN VII, which would indicate that the columellar muscle of birds is homologous morphologically to the stapedius muscle of mammals. Interestingly, it is functionally similar to the tensor tympani muscle. The avian **cochlea** does not form a spiral as it does in mammals, but consists of a slightly curved tubular structure. The **cochlear duct** is much shorter than that of mammals and the **scala vestibuli** is greatly reduced in birds.

The organs of hearing and balance (inner ear) are housed within a complex of osseous elements forming the **ossa otica**, which

become incorporated with one another and adjacent parts of several bones, including the squamous temporal and exoccipital bones.

Olfaction and Taste

As mentioned elsewhere, with some notable exceptions (vultures, kiwis, and some marine birds (albatrosses, petrels) most birds have essentially lost their sense of smell in favor of vision and hearing. Similarly, taste, which is closely related to olfaction, is generally considered to be of little importance in birds. However, some species of birds, including the chicken, duck and pigeon, do respond to certain tastes, particularly salt and acids. Even in those species, the sense of taste is considered to be less than that of mammals.

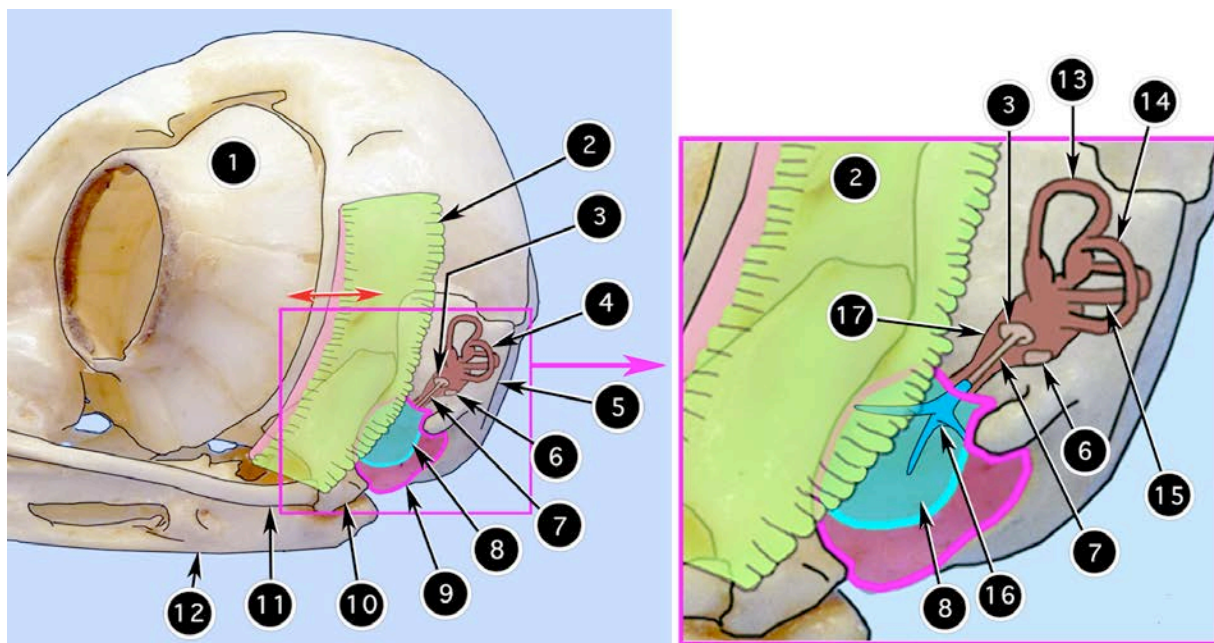


Figure 9-11. Skull of a barred owl, with superimposed structures of the ear, lateral view: (1) scleral ossicles; (2) operculum, consisting of skin fold covered with short feathers; (3) vestibular fenestra; (4) semicircular canals, surrounded by osseous canals; (5) ossa otica, incorporated into adjacent parts of several other bones; (6) oval fenestra; (7) columella; (8) tympanic membrane; (9) external acoustic meatus; (10) quadrate bone; (11) zygomatic (jugal) arch; (12) mandible; (13) rostral semicircular canal; (14) caudal semicircular canal; (15) horizontal semicircular canal; (16) extracolumellar cartilage- attaches 7 to 8; (17) cochlea. The **red arrow** indicates the rostrocaudal movement of the operculum, which alters the shape & size of the external acoustic meatus.

References:

1. *A Color Atlas of Avian Anatomy*, John McLelland, W. B. Saunders Company, Philadelphia, 1991.
2. Evans, H. E.: Anatomy of the Budgerigar and Other Birds, In *Diseases of Cage and Aviary Birds*, Roskopf and Woerpel, eds, Williams & Wilkins Company, Baltimore, 1996.
3. *Nomina Anatomica Avium*, an annotated Anatomical Dictionary of Birds, Baumel, King, Lucas, Breazile, and Evans, eds, Academic Press, New York, 1979.
4. *Form and Function in Birds*, A. S. King and J. McLelland, eds. Academic Press, New York, Vol. 1, 1979; Vol. 2, 1981; Vol. 3, 1985; Vol. 4, 1989.
5. *Textbook of Veterinary Anatomy*, 2nd ed., K. M. Dyce, W. O. Sack, and C. J. G. Wensing, W. B. Saunders Company, Philadelphia, 1996.
6. *Anatomy of the Domestic Birds*, R. Nickel, A. Schummer, E. Seiferle, Springer-Verlag, New York, 1977.
7. *The Embrology of Domestic Animals; Developmental Mechanisms and Malformations*, D. M. Noden and A. de Lahunta, Williams & Wilkins, Baltimore, 1985.
8. A physiological study of the anatomy of the eye and its accessory parts in the English sparrow (*Passer domesticus*), J. R. Slonaker, *J. Morph.* **31**: 351-459.
9. *Birds, their structure and function*, 2nd ed., A. S. King and J. McLelland, Baillière Tindall, London, 1984.
10. *Smithsonian Nature Guide, Birds*, D. Burnie, Dorling Kindersley, London, 2012.

Smallwood's Axioms of Learning & Teaching

- 1. Learning is more important than teaching. There is no single best method of teaching.***
- 2. Learning occurs by bridging the gap from the familiar to the less familiar. The most effective teachers are those who are best able to help the learners bridge this gap.***
- 3. The most important single element in determining how effectively learners learn is the "teacher." A good teacher serves as a living conduit for the information.***
- 4. The only thing more contagious than enthusiasm is apathy. Effective teachers are hopelessly infected with a contagious enthusiasm for their subject.***
- 5. Ignorance is relative, so don't take yourself too seriously. The most effective teachers are those who take their subject, but not themselves too seriously.***
- 6. The more actively you can get the students involved with the learning process, the better.***
- 7. Ninety percent of what students learn in a given course is directly related to how we test them. Good teachers emphasize the more important points, and their examinations accurately reflect differences in relative importance.***
- 8. Students are people too; they respond to positive and negative reinforcements just like we do. Honesty, fairness, and consistency are absolutely essential to establishing and maintaining the trust of your students.***
- 9. Organization and direction are important, but too detailed directions may actually impede learning.***
- 10. You can tell more about how much a student is learning by the questions they ask than you can by the answers they give.***
- 11. Good teachers emphasize the applied aspects of the subject matter.***
- 12. Being a laboratory instructor is a lot like being a tour guide.***
- 13. Forgetting is part of learning.***
- 14. One of the major rewards of teaching is learning. Every teacher is a learner and every learner is a teacher.***
- 15. A good teacher is part benevolent dictator, part coach, part noxious stimulus, and part cheerleader.***