

# Liberty Wildlife Medical Services

Medical Services  
Training Program

• Section Three •

Skeletal System and Feathers

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# **Introduction to the Avian Skeletal System and Avian Feathers**

Probably the most envied adaptation of birds is flight. This gift is owed to one of the simplest laws in aerodynamics – you have to be light enough to get off the ground! Many unique features of birds work together to make this possible. In this section, you will be introduced to two important components of avian structure: the avian skeletal system and the avian outer covering of feathers.

This part of your training will begin with an overview of vocabulary terms that are used in the Medical Services program. Next, the avian skeletal system, a critical foundation for future sections of this program will be discussed in detail. X-rays, common tools that are used to help identify irregularities in the skeletal system, will be viewed. This section also provides an overview of feathers, their structure and types. And, we'll end with an activity to diagram some of the parts and structures that you have learned.

Let's begin!

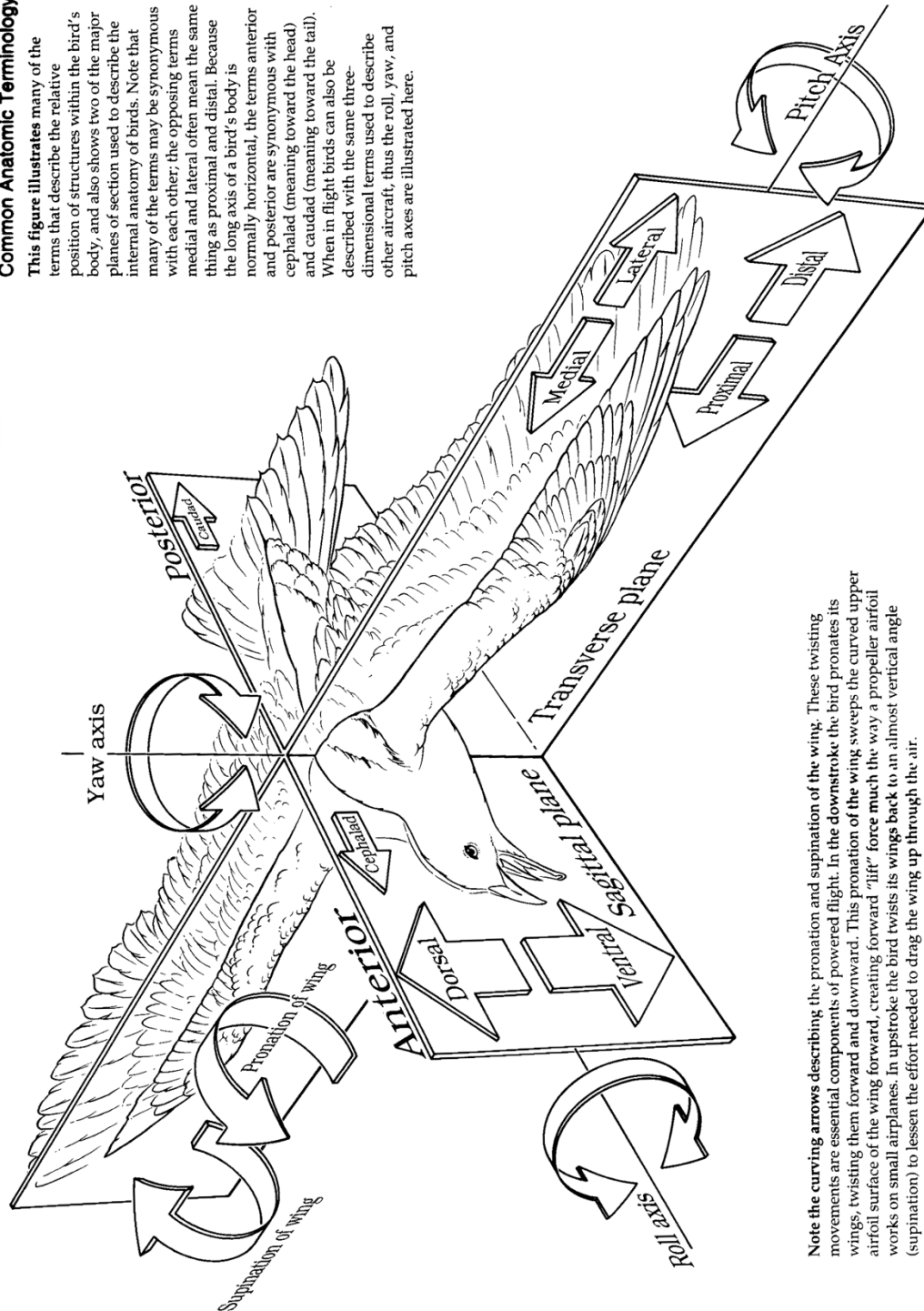
# **Vocabulary**

The following terms will help you to describe avian anatomy by function or position. Many of these words have an opposing term that is listed in brackets.

Abdominal	Pertaining to the region between the thorax and pelvis
Air sacs	Air-filled sacs that are part of the respiratory systems
Anterior [Posterior]	Directed toward the head
Apterygium	Area bare of contour feathers
Axillary	Pertaining to the armpit or axilla
Brachial	Upper arm, area supported by the humerus
Buccal	Cheeks, the lateral walls of the oral cavity
Carpal	The wrist or wrist area
Caudal [Cephalic]	Toward the tail
Celiac	Pertaining to the abdomen or stomach
Cephalic [Caudal]	Toward the head
Cervical	Pertaining to the structures of the neck
Costal	Ribs or ribcage
Cranial	Pertaining to the head
Digital	Pertaining to the fingers
Distal [Proximal]	Away from the point of attachment
Dorsal [Ventral]	The top side or back
Inferior [Superior]	Ventral or bottom
Lateral [Medial]	Farther away from the midline
Leading [Trailing]	Front (anterior) edge of the wing as the bird flies
Medial [Lateral]	Pertaining to or situated toward the midline
Occipital	Area where the spinal column meets the skull
Patagium	Tissue that connects shoulder area to the wrist
Pectoral	Ventral chest area, between the sternum and shoulder
Pelvis	Caudal portion of the trunk or torso
Pneumatic	Pertaining to air or respiration
Posterior [Anterior]	Directed toward the tail
Proximal [Distal]	Nearest to the point of attachment
Sacral	Region between crests of the pelvis, fused synsacrum
Synsacrum	Fused section of pelvic and caudal vertebrae
Sternal	Pertaining to the sternum
Superior [Inferior]	Dorsal or top
Tarsal	Area of the lower leg containing the tarsometatarsus
Thorax	The part of the body between the neck and abdomen
Trailing [Leading]	Back (posterior) edge of the wing as the bird flies
Ventral [Dorsal]	Bottom, toward the abdominal side
Vertebral	Referring to the spinal column

**Common Anatomic Terminology**

This figure illustrates many of the terms that describe the relative position of structures within the bird's body, and also shows two of the major planes of section used to describe the internal anatomy of birds. Note that many of the terms may be synonymous with each other; the opposing terms medial and lateral often mean the same thing as proximal and distal. Because the long axis of a bird's body is normally horizontal, the terms anterior and posterior are synonymous with cephalad (meaning toward the head) and caudad (meaning toward the tail). When in flight birds can also be described with the same three-dimensional terms used to describe other aircraft, thus the roll, yaw, and pitch axes are illustrated here.



Note the curving arrows describing the pronation and supination of the wing. These twisting movements are essential components of powered flight. In the downstroke the bird pronates its wings, twisting them forward and downward. This pronation of the wing sweeps the curved upper airfoil surface of the wing forward, creating forward "lift" force much the way a propeller airfoil works on small airplanes. In upstroke the bird twists its wings back to an almost vertical angle (supination) to lessen the effort needed to drag the wing up through the air.

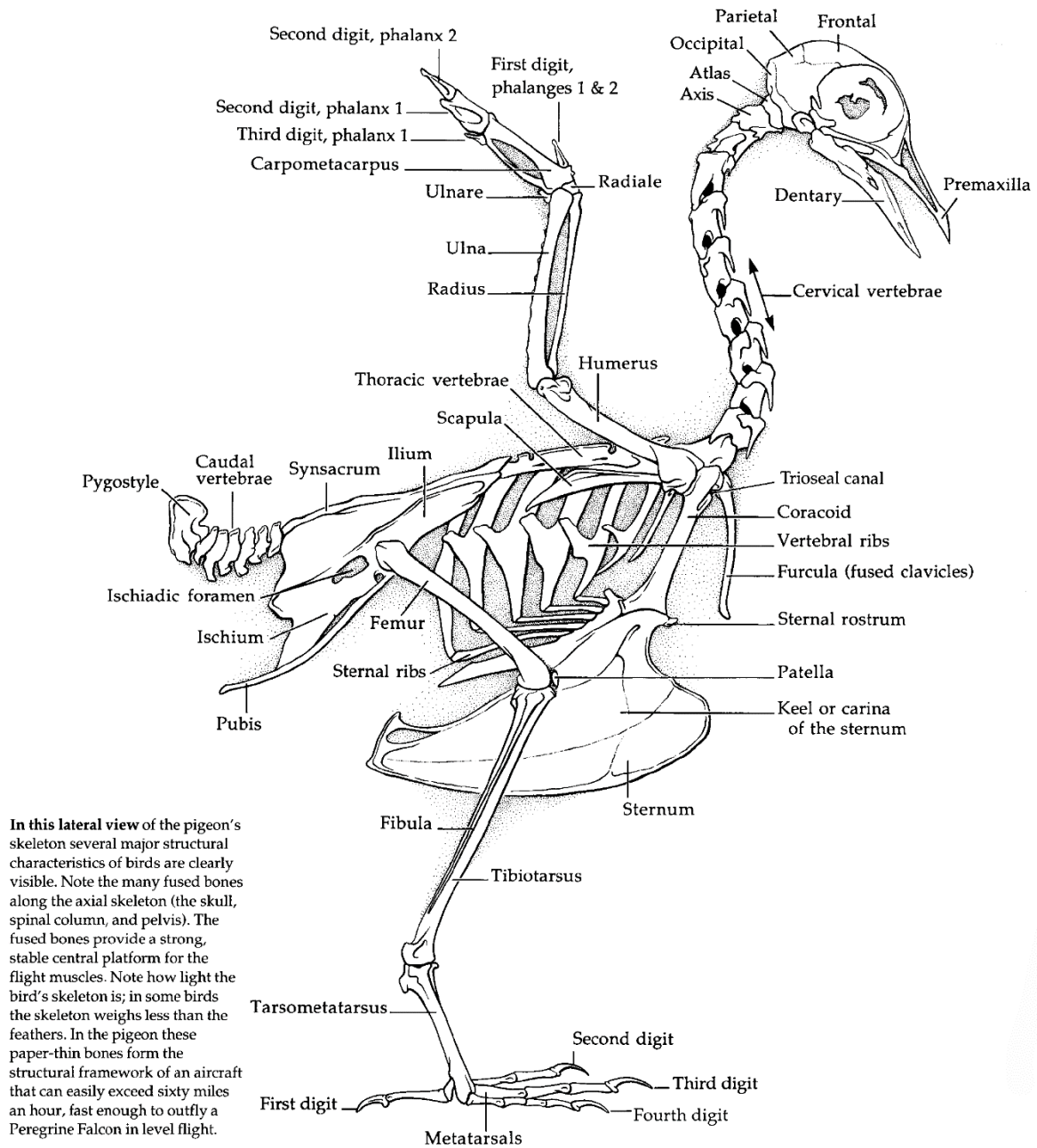
# **The Avian Skeletal System**

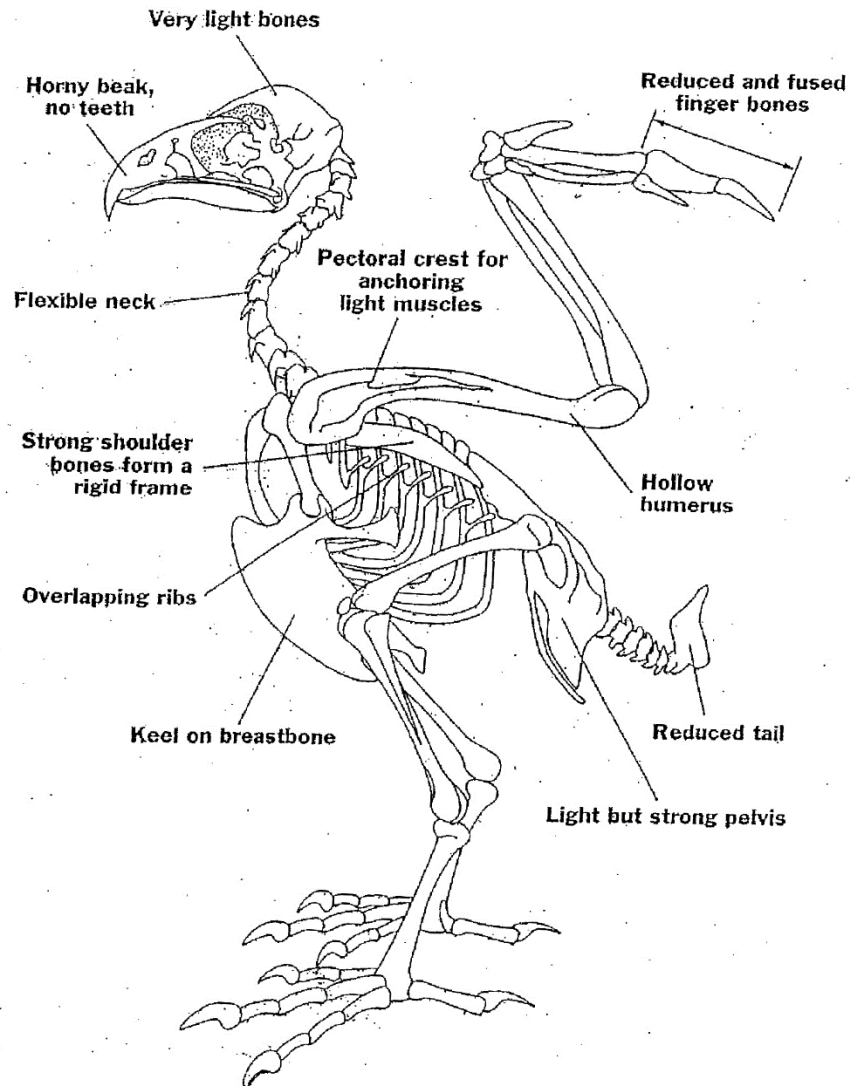
The avian skeletal system is a rigid framework containing bones that are often fused or reduced in number from the mammalian skeletal system. This rigidity is necessary as a foundation for the attachment of the limbs and large flight muscles. The make-up and location of the skeletal structure centralizes the avian body mass that supports flight.

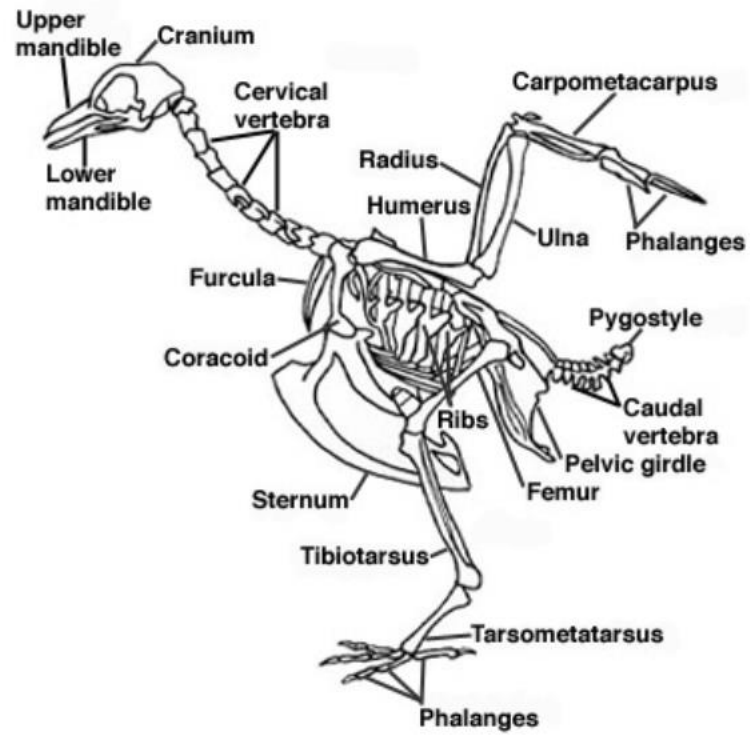
The avian skeletal system is divided here into four recognizable sections: the thoracic limbs (wings), the pelvic limbs (legs), the head, and the torso (thorax, pelvis, and tail).

## OVERVIEW OF THE SKELETON

### Lateral View of the Skeleton Rock Dove (*Columba livia*)



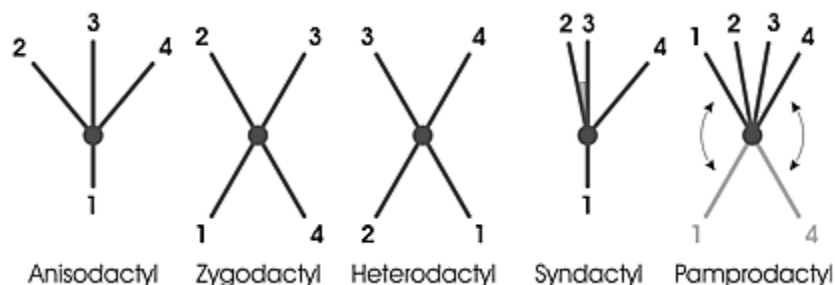






## Avian Skeleton Facts

- The total number of bones in a bird's body is lower than for mammals or reptiles. That comes in handy when a bird wants to take to the air.
- The bird skeleton is extremely lightweight, but strong enough to withstand the stresses that a bird experiences when taking off, flying, and landing. The bird's hollow bones make the skeleton lighter for flying, and allow more oxygen to be absorbed from the air into the blood for that extra energy a bird needs.
- Bird bones usually contain air. Many bird bones are hollow, with struts or trusses (cross walls) that crisscross for structural strength. Some flightless birds – like penguins – have only solid bones, however.
- Bird skull bones have air cavities that are continuous with the nasal cavities.
- Trunk bones – including the vertebrae, breastbone and pelvic bones – also contain air sacs invading from the lungs. These are all called pneumatic bones.
- The number of hollow bones in a bird's body will vary from species to species, though large gliding and soaring birds tend to have the most.
- Birds have more neck (cervical) vertebrae (back bones) than many other animals. Most birds have 13 to 25 of these very flexible bones. Thanks to this bone structure, birds are better able groom their feathers.
- Birds are the only vertebrate animals to have a fused collarbone (the furcula or wishbone). They're also the only vertebrate animals to have a keeled breastbone
  - a breastbone that's long and has a structure on it shaped like a ship's keel.
- The keel part of a bird's breastbone extends outward from the top of the bone and down the breast area and acts as an anchor for a bird's strong wing muscles. The keel is a feature of strong flying or swimming birds.
- Most birds have only four toes. Some have only three. The ostrich has just two toes. Most perching birds have four toes, with three that point forward and one that points back. However a few groups – including cuckoos, cockatoos and parrots, and owls, clutch the branch with two toes forward and two back.



Examples: anisodactyl (songbird), zygodactyl (woodpecker, osprey), heterodactyl (only trogons), pamprodactyl (swift), syndactyl (kingfisher)

- In most cases, a bird's entire skeleton weighs less than all of its plumage – and you know how light feathers are!
- Birds have knees. They're often under the feathers and not easily visible. A bird's knees bend the same way your knees bend. The part of a bird's leg that you see bending backwards when the bird walks is its ankle.

- On an owl's foot, the outer toe is reversible so that the owl can perch in the usual owl way, with two toes forward and two back, or it can perch as perching birds do, with three toes forward and one toe back. The owl also uses its versatile outer toe to get a better grip on its prey.
- Bird fossils are rare because bird bones are hollow and fragile

## **The Thoracic Limbs**

The thoracic limbs are the wings of a bird. They attach to the body at the shoulder and contain the humerus, elbow, radius, ulna, wrist, and the manus (carpus and metacarpus).

**Shoulder:** The shoulder is the joint or point of articulation between the wing and the body. At this joint the proximal end of the humerus articulates with the glenoid fossa, a cavity formed by the scapula and coracoid.

**Humerus:** The humerus is the bone of the wing located between the shoulder and the elbow. As in many other avian bones, the humerus is hollow, specialized for strength and lightness. The proper movement, including rotation, of the humerus is necessary for correct flight. Although the humerus is a bone, it is also part of the respiratory system in birds as it is connected to the air sacs. When this pneumatized bone has open or compound fractures there is a danger to waterfowl (or other birds in water) as liquid entering the bone through the fracture site could actually cause the animal to drown.

**Elbow:** The elbow is the joint or point of articulation between the distal end of the humerus and the radius and ulna.

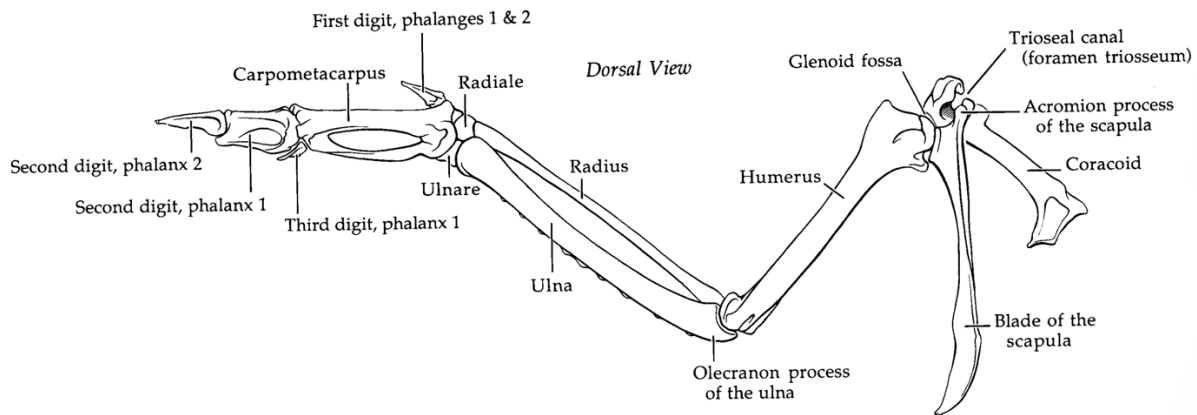
**Radius and Ulna:** The radius and ulna are the bones of the wing located between the elbow and the wrist. As in many other avian bones, the radius and ulna are hollow, specialized for strength and lightness. The proper movement, including rotation, of these two bones are critical for correct flight. The ulna is the larger of the two bones. The secondary wing feathers attach directly to the ulna. The radius is the smaller bone and is located closest to the patagium.

**Wrist joint:** The wrist joint is the point of articulation between the distal ends of the radius and ulna and the carpometacarpals.

**Carpus, metacarpus:** The manus (hand) bones of a bird are the bones at the distal end of the wing. This area contains both separate and fused bones, including the phalanges or digits. The carpus consists of the radial carpal bone and the ulnar carpal bone. The radial carpal bone is cranial and the ulnar carpal is caudal.

The minor and major metacarpals fuse, both distally and proximally, to form an opening called the intermetacarpal space. These bones support the alular digit or thumb (digit one). The remaining two digits are the proximal and distal bones of the second phalanx (digital two) and the small phalanx minor digit (digit three). Most of these bones are extensively fused and modified to support flight.

Superior View of the Left Wing Skeleton  
Rock Dove (*Columba livia*)



The wing plan seen from above is remarkably simple, yet it is structured for maximum efficiency and light mass. The flight muscles of the breast attach to the short, powerful humerus, which bears the main stresses during both the upstroke and the downstroke. The radius and the heavier ulna support the mid-wing area. As in the human forearm, the two bones are designed to allow some twisting (pronation and supination) of the wing during flight. Note the row of tiny dimples along the trailing edge of the ulna; these bony knobs show where the secondaries are fixed to the wing along the ulna. Farther out on the wing the primaries attach to the carpalometacarpus and the phalanges of the second and third digits.

## **The Pelvic Limbs**

The pelvic limbs are the legs of a bird. They attach at the hip and contain the femur, knee, tibiotarsus, fibula, ankle, tarsometatarsus, and the digits or toes.

**Hip:** The head of the femur articulates with the ilium of the pelvis at a cup-shaped structure on the ilium called the acetabulum. This point is usually located within the trunk of the body.

**Femur:** The long proximal bone of the leg is the femur

**Knee:** The knee is the point of articulation between the femur and the tibia.

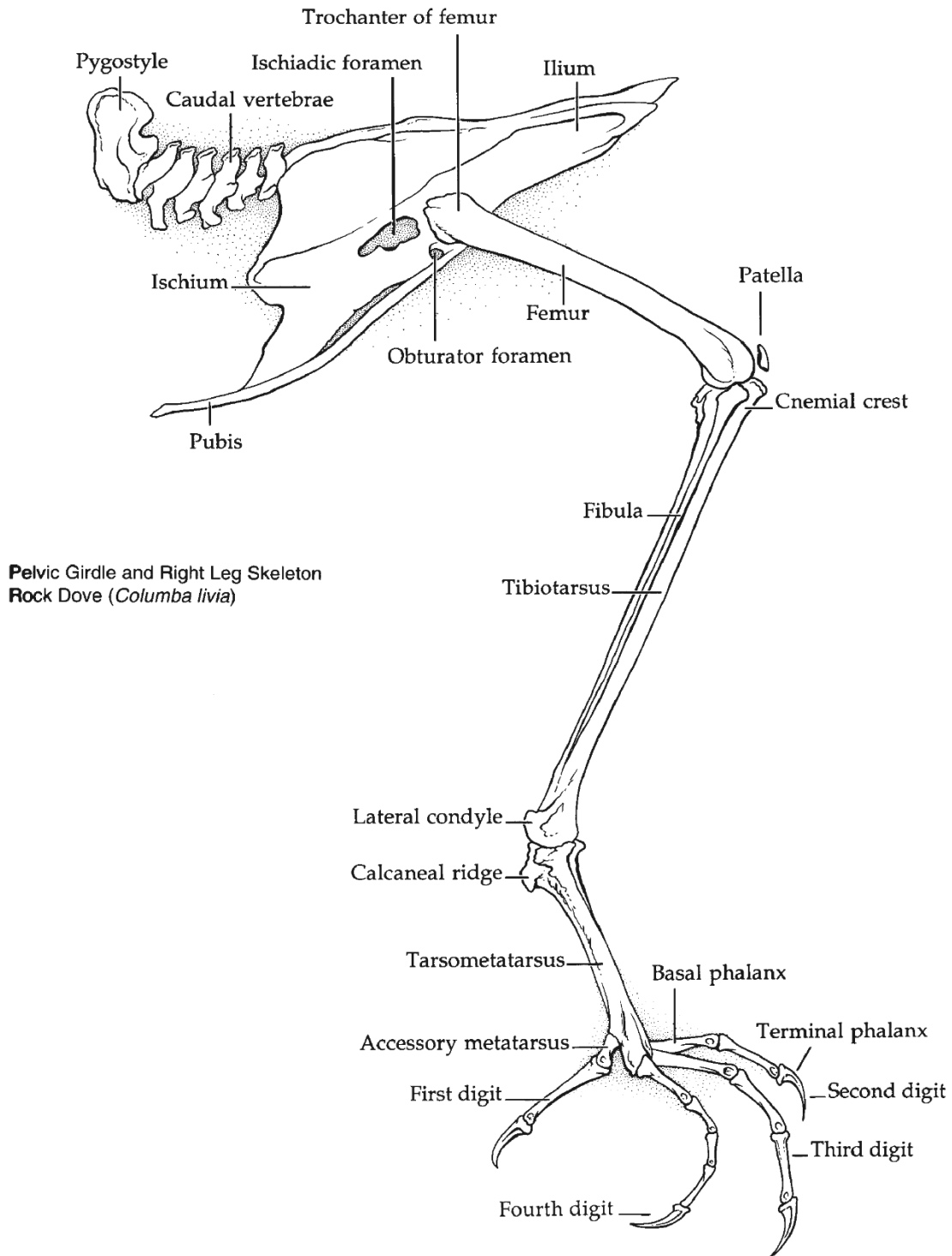
**Tibiotarsus/fibula:** The tibiotarsus is the long bone that is distal to the femur. It is a fused bone containing the tibia and upper bones of the foot. The fibula is a small bone that runs parallel to the tibiotarsus on the lateral side of the leg.

**Ankle:** The ankle is the point of articulation between the tibiotarsus and the tarsometatarsus.

**Tarsometatarsus:** Distal to the tibiotarsus, the lower bones of the foot are fused and stretched to form the tarsometatarsus.

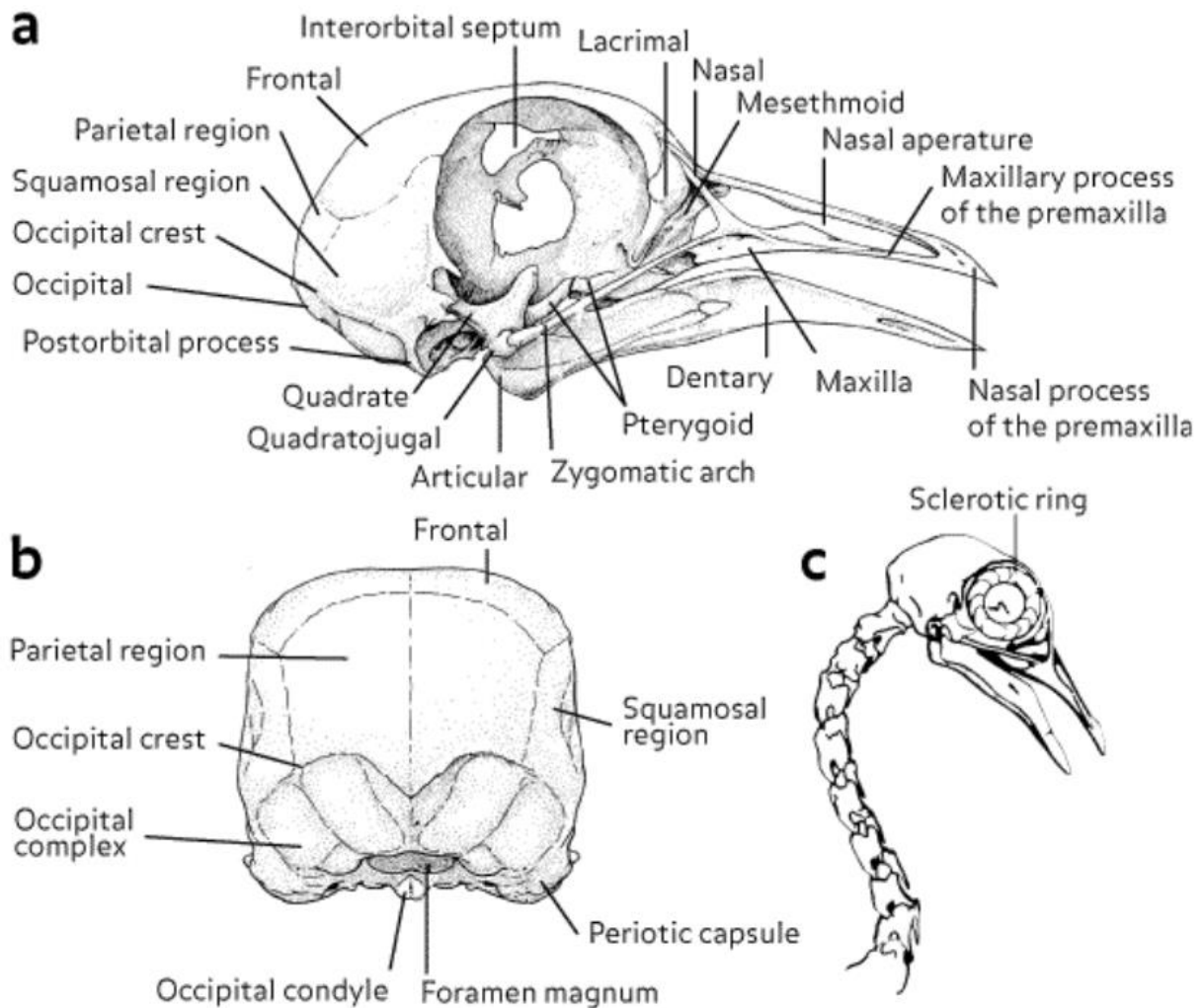
**Digits:** The digits, metatarsals, are the toes of the foot. The digits fall into specific arrangements known as toe configuration which vary according to species. The first digit of the foot, the hallux, is similar to the human big toe. On toes with raptorial arrangement, the hallux is the back toe. With the hallux as the first toe, the other digits are numbered with the inner toe as number two, the center forward toe as number three, and the outer toe as number four.

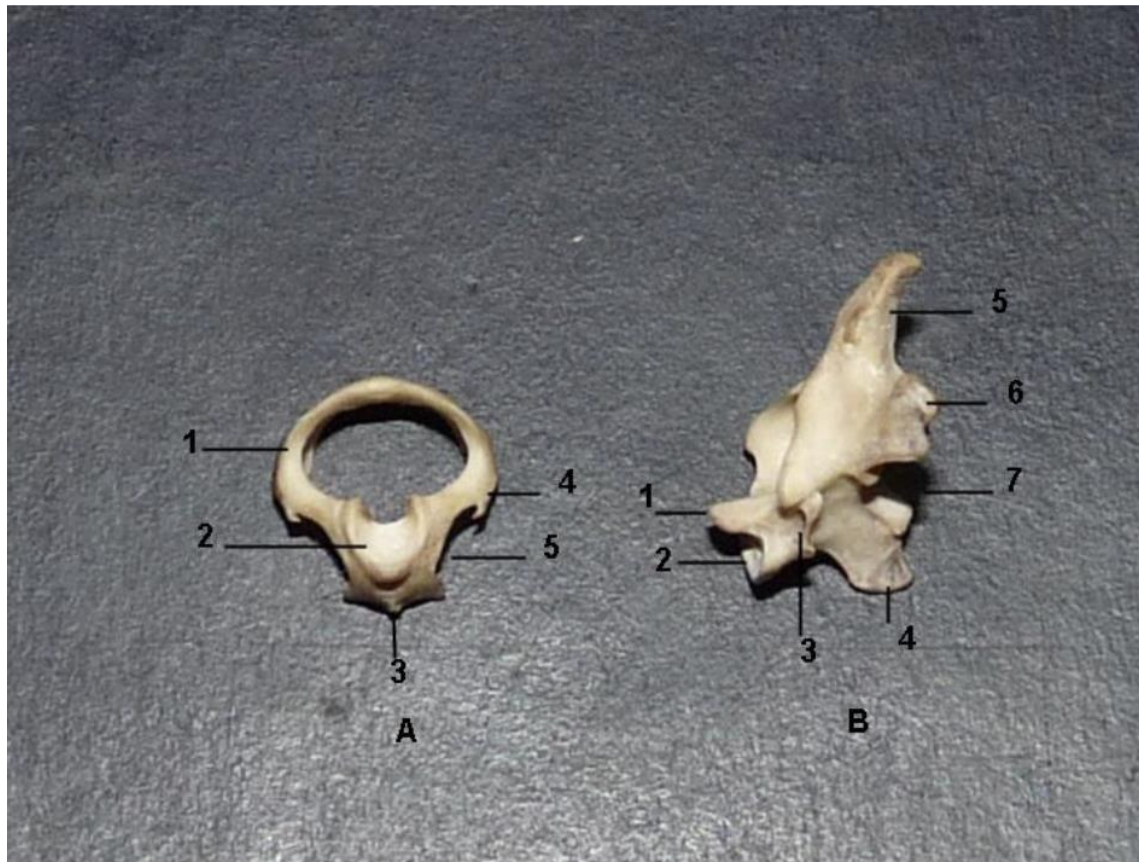
# THE BONES OF THE LEG AND FOOT



## The Head

In the avian skull most of the bones are fused. Others allow for flexibility with the upper and lower mandibles. Huge spaces are available for the eyes. Facial bones are reduced to a network of struts that support the beak. Additional bones are located in the tongue.





Atlas (A) and axis (B) of a Common Buzzard (*Buteo buteo*). A: 1 - vertebral arch, 2 - glenoidal cavity for occipital condyle of skull, 3 - ventral process, 4 - transverse process, and 5 - lateral vertebral notch. B: 1 - dens, 2 - articular facet for atlas, 3 - vertebral foramen, 4 - transverse process, 5 - spinous process, 6 - postzygapophysis, 7 - vertebral canal

## **The Torso or Trunk**

The torso of the bird's body contains all structures exclusive of the head and limbs.

### **Vertebral Column and Rib Cage**

The vertebrae are the bones of the spine and are grouped by location in the spine:

- The neck or cervical area has from 13 to 25 vertebrae, depending on the species – as compared with the seven vertebrae found in people
- The thorax or thoracic area has five vertebrae which are fused.
- The lumbar or abdominal vertebrae (three) are fused with the pelvic or sacral vertebrae (four) and six of the anterior caudal or tail vertebrae to form a fused spinal column of 13 vertebrae called the *synsacrum*.
- The remaining six free caudal vertebrae form the tail and end with the *pygostyle*, a fusion of final caudal vertebrae which form a flat blade of bone that supports the muscle and connective tissue of the tail.

### **Thorax and Sternum**

The thorax contains the sternum and the ribs. The sternum is the breastbone. On most avian species the sternum has a bony keel, a special adaptation found on flying birds. There are seven ribs on either side of the vertebral column, two of which are tiny and do not attach to the sternum. The remaining five are composed of two pieces which helps to strengthen the rib cage for flight.

### **Pectoral Girdle**

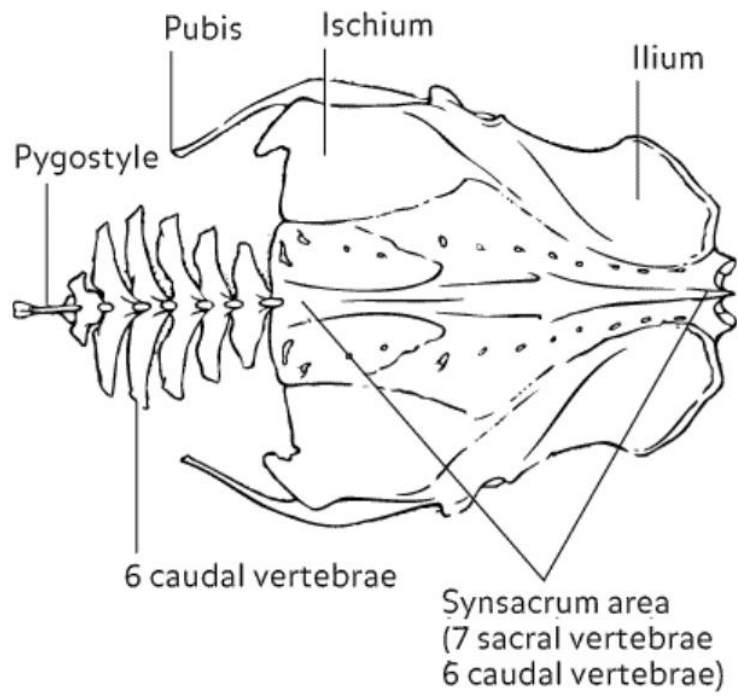
The pectoral girdle contains the sternum, the coracoids, the scapulas, and the clavicles. The sternum is the breastbone. The coracoid links the sternum with the shoulder area. The scapula extends posteriorly from the superior end of the coracoid and provides for attachment of the shoulder muscles. The two fused clavicles descend from the superior end of the coracoid and provides for attachment of the breast muscle.

A very important structure, the *trioseal canal*, is formed by three bones: the clavicle, the coracoid, and the scapula. The trioseal canal enables the bird to lift its wing using the muscles of the breast. This keeps its body mass centralized, an important adaptation for flight.

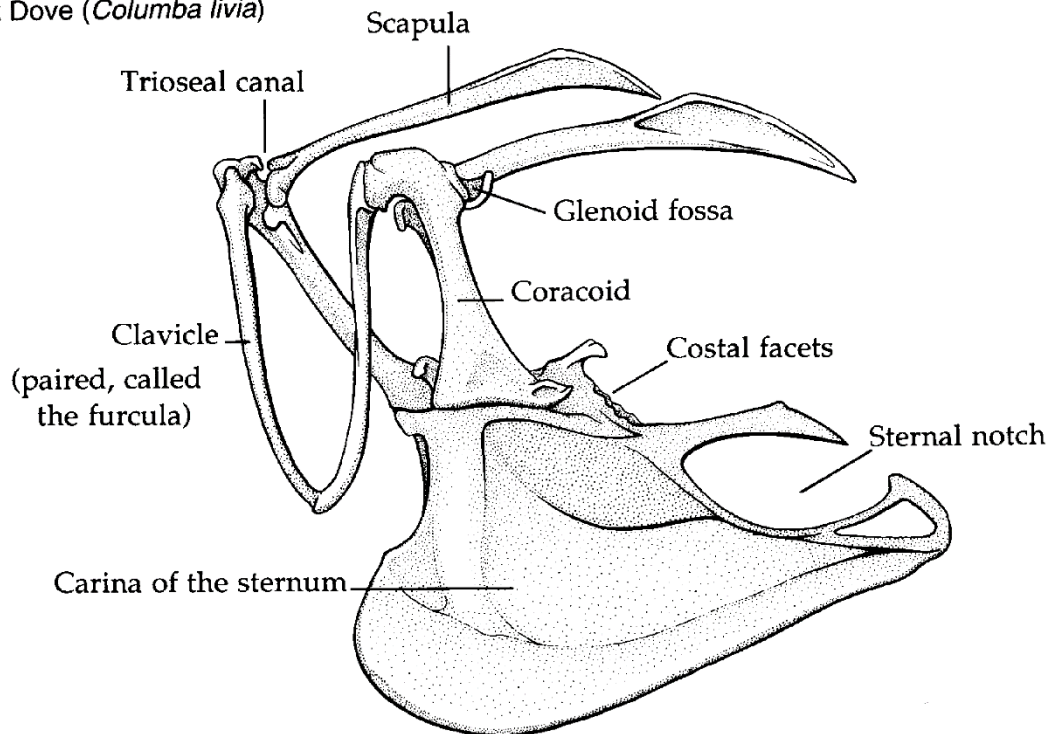
### **Pelvic Girdle**

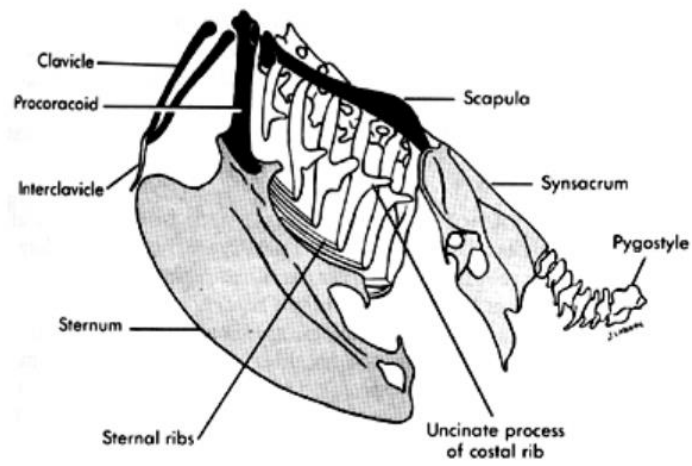
The pelvic girdle contains three principal bones called the ilium, the ischium, and the pubis. The fused spinal column, the *synsacrum*, joins with these extensively fused bones to form one unit of bone that makes a strong foundation for attachments of the legs. The pelvis also protects the contents of the abdomen.



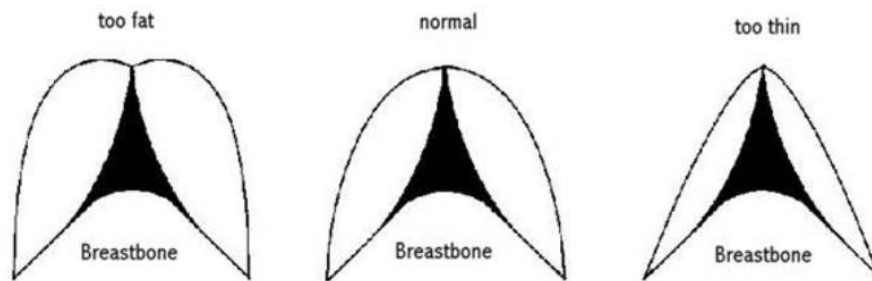


Pectoral Girdle  
Rock Dove (*Columba livia*)

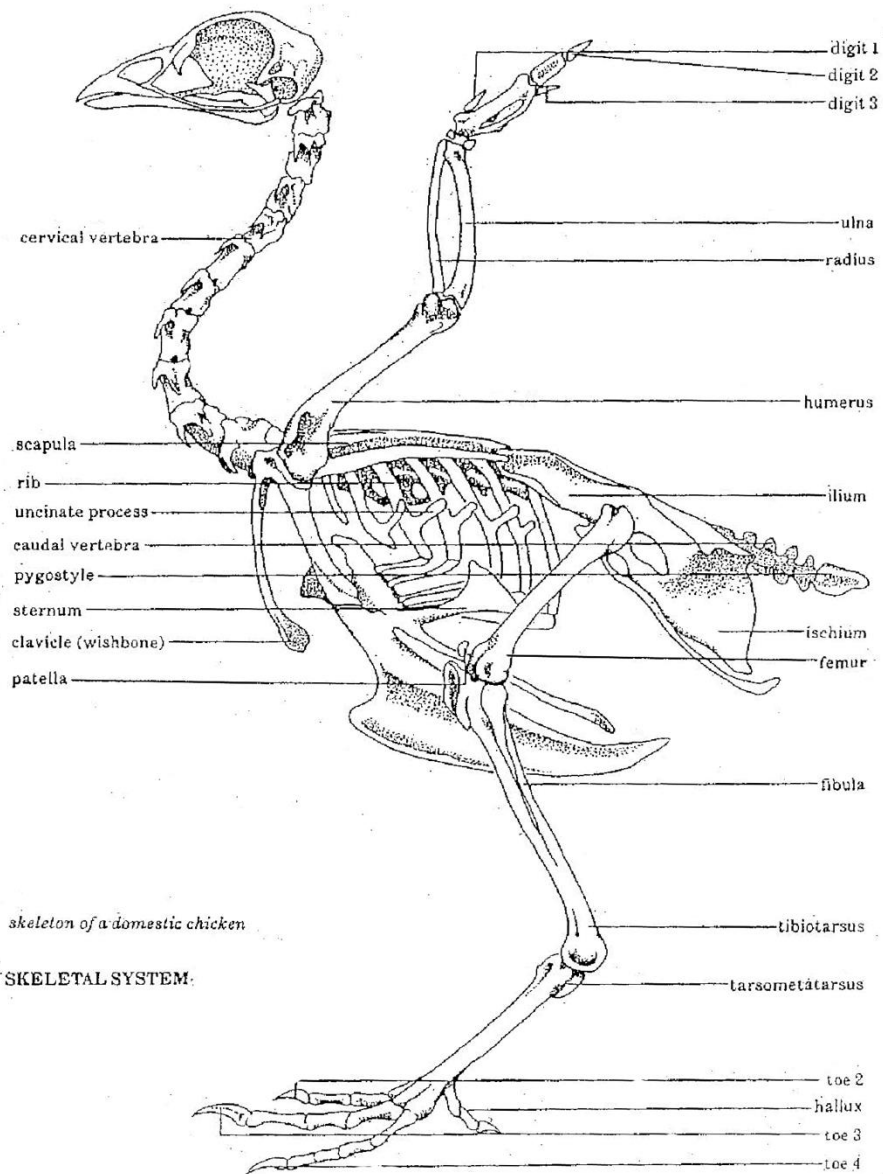
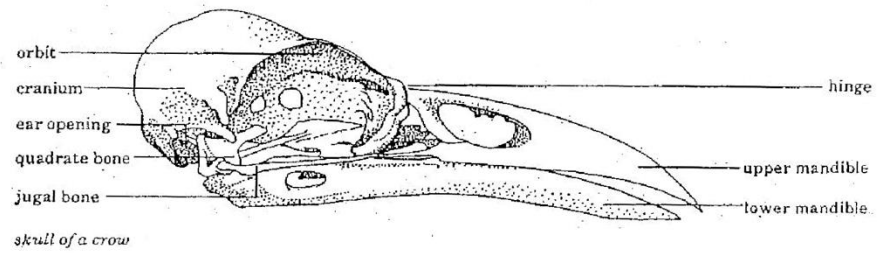




## Keel



# SKELETON



SKELETAL SYSTEM:

# **Feathers**

Feathers are another unique adaptation of birds. They are made of keratin. Feathers shield the skin from damage, protect the bird from extremes in temperature, and aid in flight.

## **The Parts of a Feather**

**Shaft:** The shaft is the supporting structure in a feather. It runs lengthwise through the feather.

**Vane:** A broad flexible vane extends from either side of the shaft.

**Barbs:** The vane contains barbs which extend from the shaft. The barbs contain other small structures which hook together and help the feather maintain its shape.

**Quill:** The quill is the exposed end of the shaft which is not covered.

**Sheath:** The feather emerges from a feather follicle in a sheath which provides protection.

**Molt:** The process of replacing worn feathers is called a molt. Most feathers are molted a few at a time so that the bird can still fly, but sometimes feathers are molted all at once leaving them flightless for a short period of time.

**Plumage:** The feather covering worn between molts is called the plumage. A bird's plumage can vary by age and season.

## **Types of Feathers**

There are many types of feathers on a bird. They can vary by location and species. They vary in number, too. A Trumpeter Swan may have over 25,000 feathers and yet a Hummingbird may have less than 1,000.

**Contour feathers:** Vaned feathers of the body and wings.

**Remiges:** Flight feathers of the wing. They include primaries, secondaries, and tertiaries.

*Primary* feathers are the large flight feathers located on the distal end of the wing. These are the largest feathers. Most birds have ten primary feathers (songbirds have nine) which are attached at the carpus and metacarpus. The first primary feather is located at the wrist. The primaries continue laterally in number. For example, the number ten primary is usually the first feather found on the distal end of the wing.

*Secondary* feathers are the flight feathers proximal to the primaries. They attach at the ulna. The first feather at the distal end of the ulna is the first secondary.

*Tertiaries* are the three or four feathers proximal to the secondaries which lie between the wing and the body.

### **Other body and wing feathers**

- Scapulars are the small contour feathers that cover the scapula.
- The *alular quills* are the feathers (usually three) that extend from the alular or first digit.
- The *wing coverts* cover the wings and the axillar region. The *crurals* are the feather coverings on the legs.
- *Crest* feathers extend from the crown of the head.

**Rectrices:** are the large, vaned flight feathers of the tail.

**Semiplumes:** lie under the surface of feathers providing insulation and aerodynamic contouring.

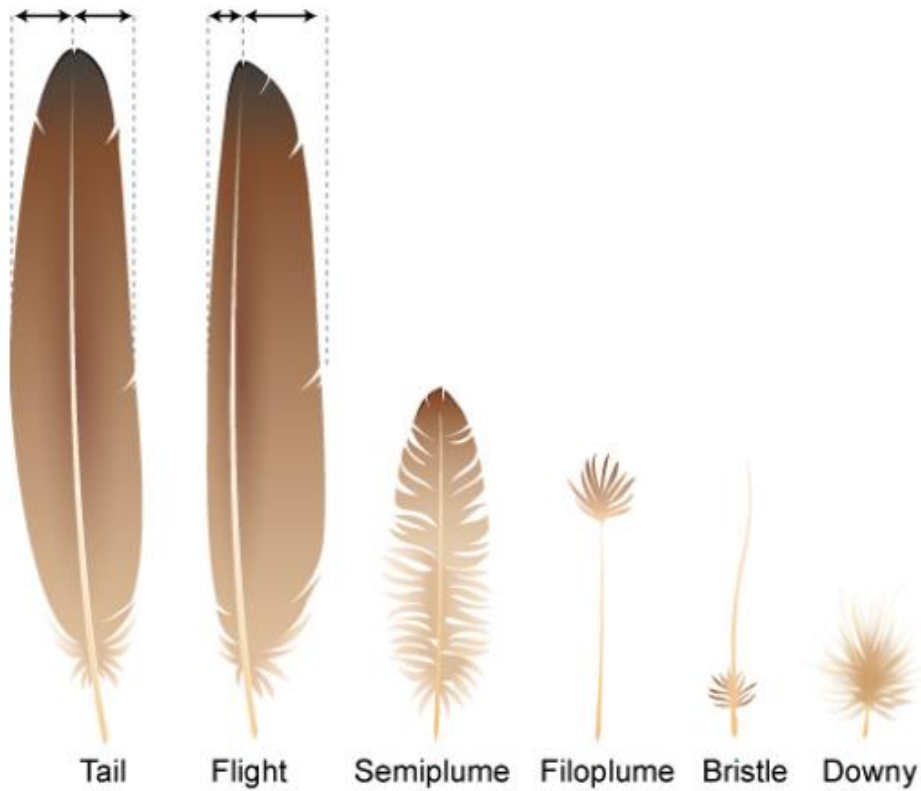
**Down:** Adult down provides a layer of insulation under other feathers. Natal down, which covers hatchlings, provides insulation. Natal down is often pushed out by other plumage and can appear as tufts at the tips of new feathers.

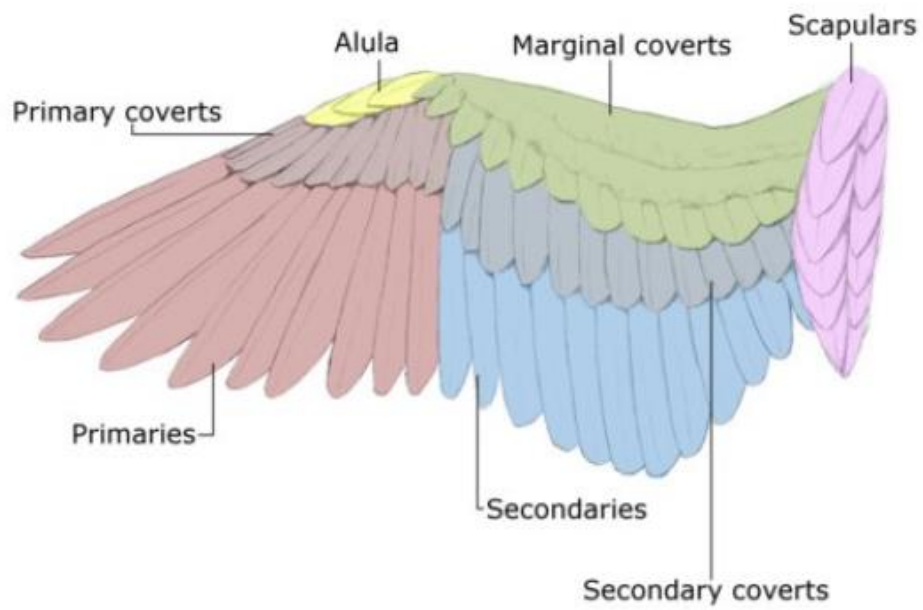
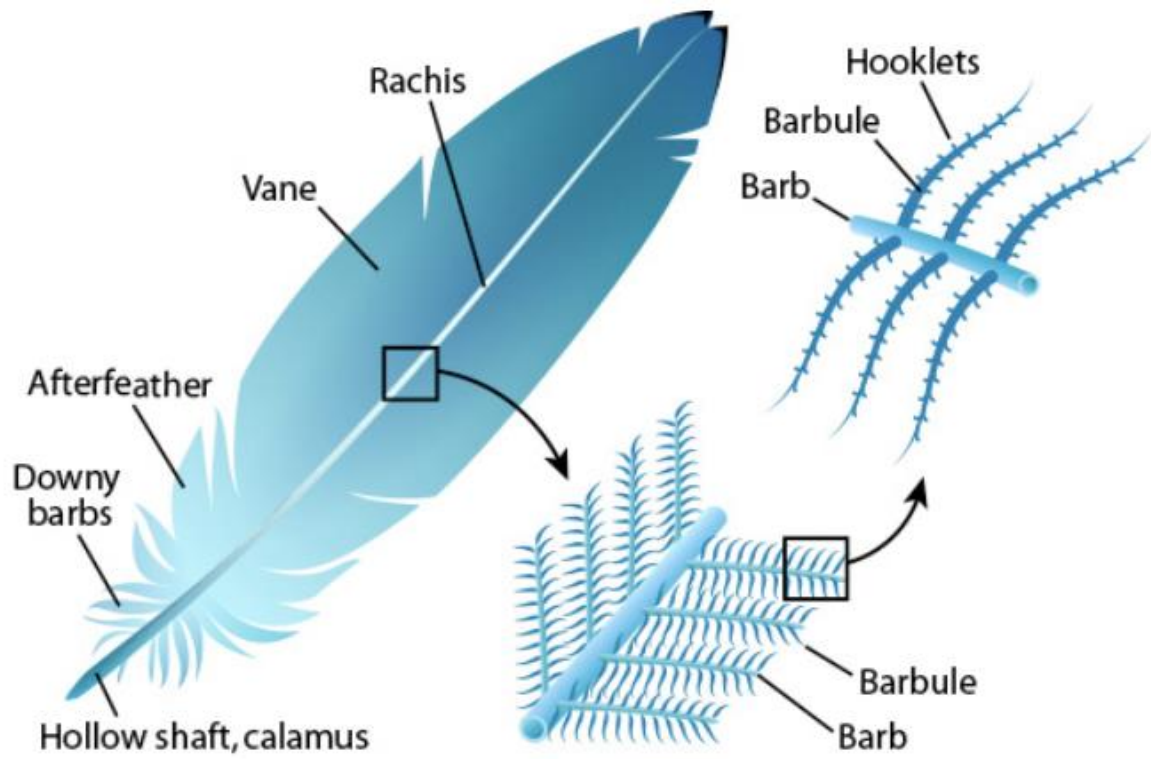
**Powder down:** Special feathers with barbs that shed at the tips. This shed feather is powder-fine and provides waterproofing.

**Bristles:** Bristles are contour feathers without vanes. Not all birds have bristles. They are usually found on the head near eyes, nares, and around the mouth.

**Filoplumes:** Long hair-like feathers that are throughout the plumage. They help determine the location of feathers and provide a sense of touch in the plumage.

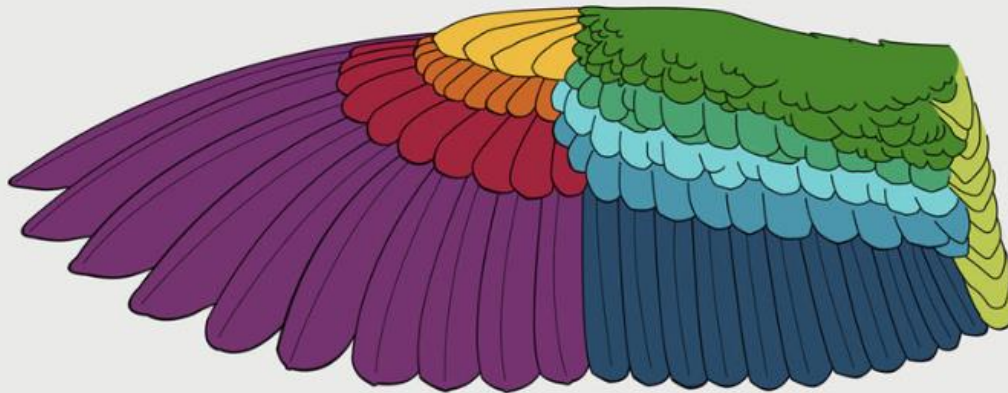
# Feather Types and Structure





# DORSAL WING TOPOGRAPHY

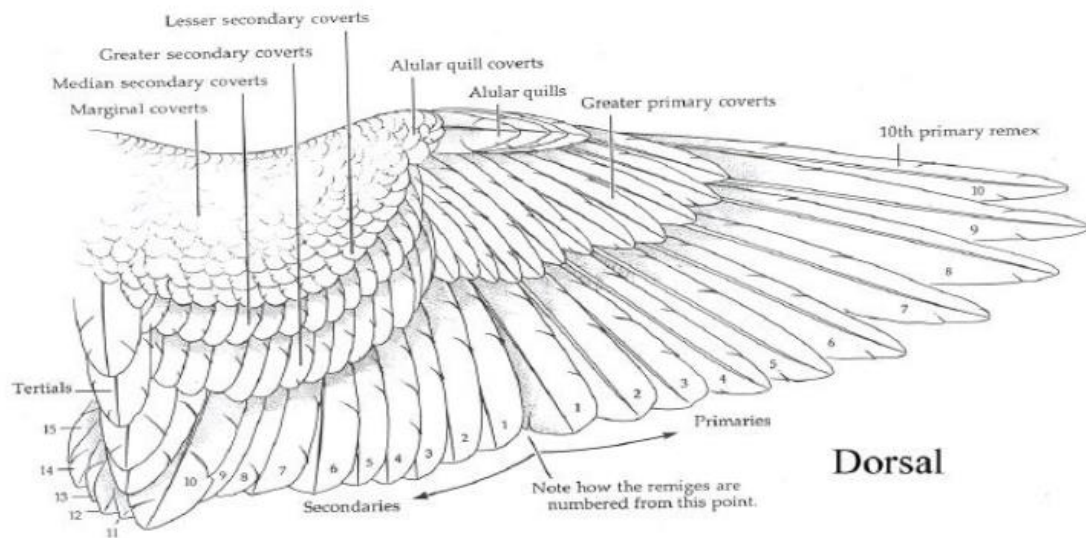
Barn Owl (*Tyto alba*)



- |                         |                            |          |
|-------------------------|----------------------------|----------|
| Alular Quills           | Marginal Secondary Coverts | Tertials |
| Lesser Primary Coverts  | Lesser Secondary Coverts   |          |
| Greater Primary Coverts | Median Secondary Coverts   |          |
| Primary Remiges         | Greater Secondary Coverts  |          |
|                         | Secondary Remiges          |          |

Hermione Osmer

Proctor, N.S. & Lynch, P.J. 1993. Manual of Ornithology: Avian Structure & Function. Yale Univ. Press.





# THE AVIAN WING

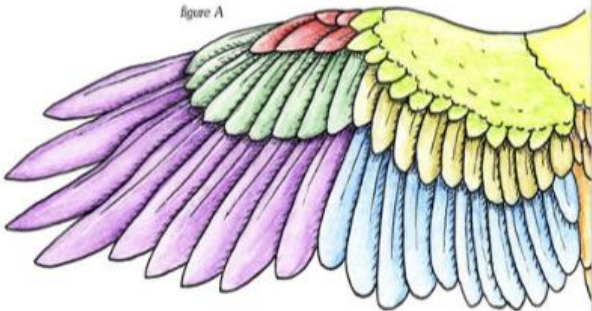


Figure A: Feather Types

- |                   |                  |
|-------------------|------------------|
| Primaries         | Alulae           |
| Secondaries       | Marginal coverts |
| Primary coverts   | Scapulars        |
| Secondary coverts | Tertiaries       |

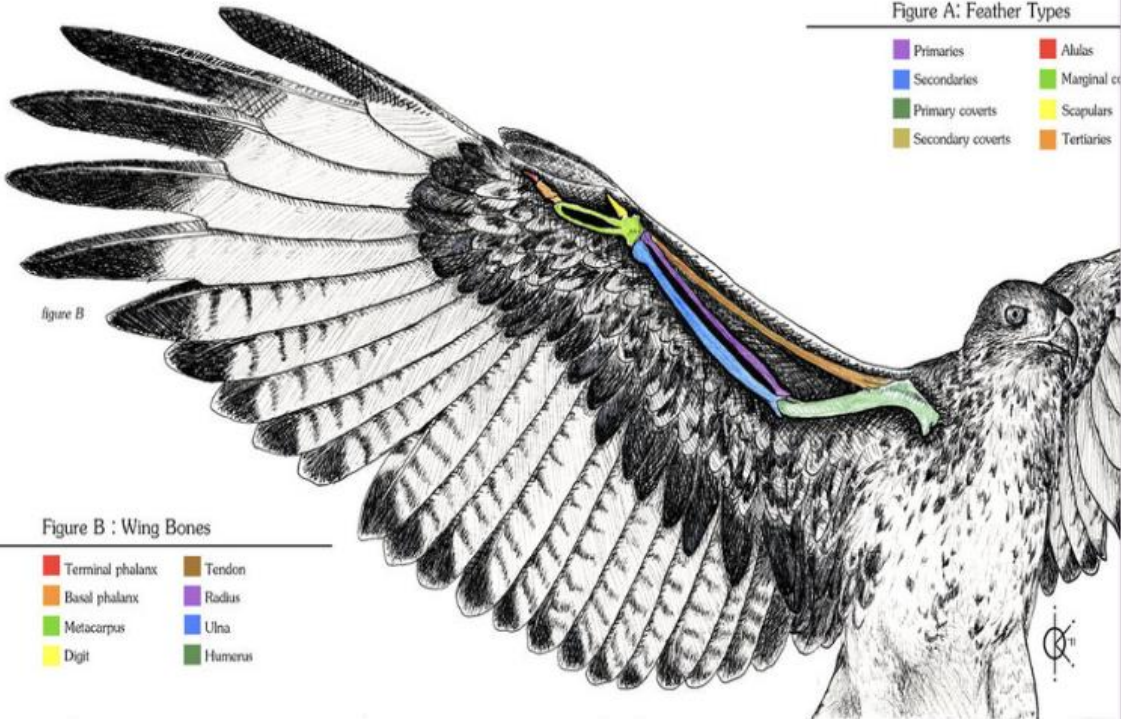
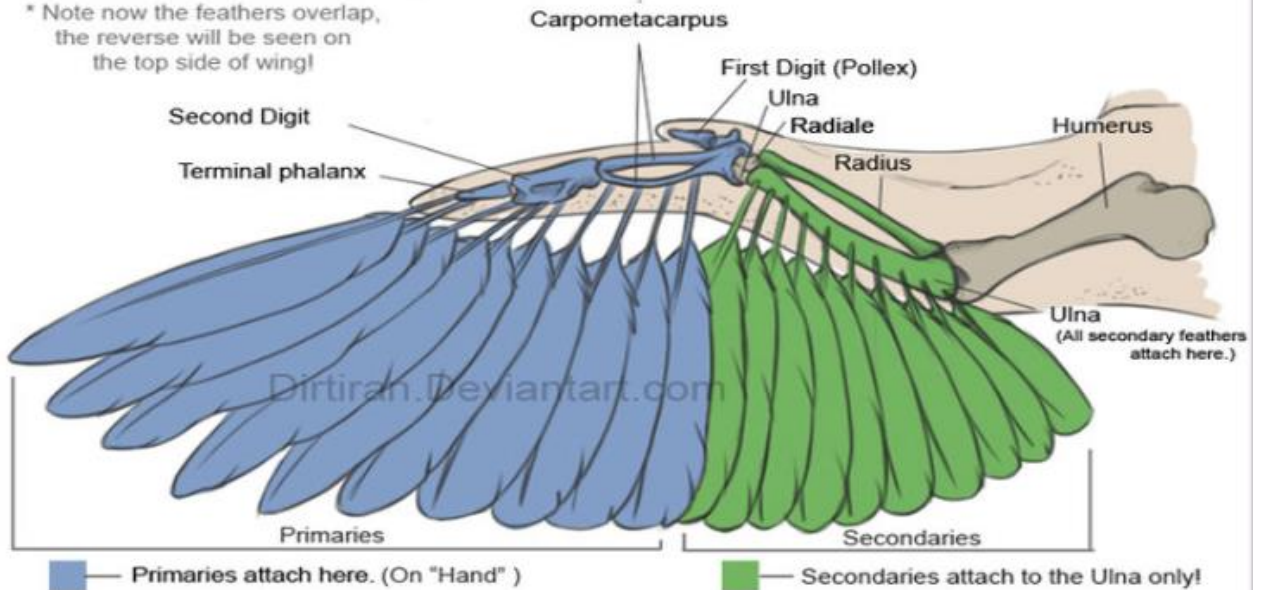


Figure B : Wing Bones

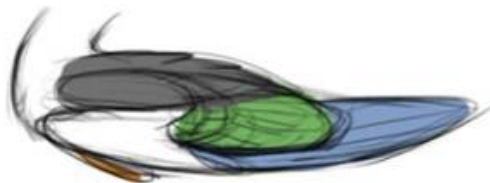
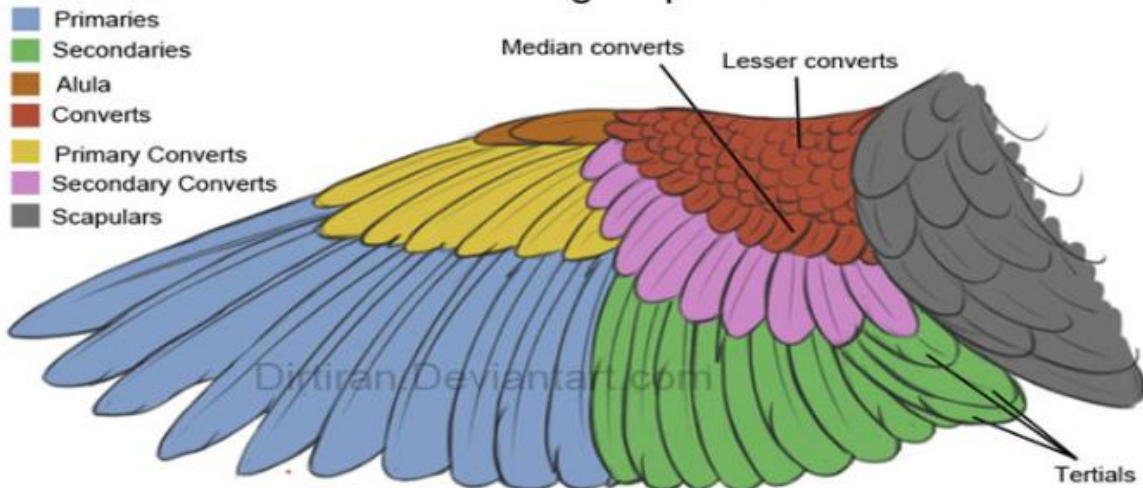
- |                  |         |
|------------------|---------|
| Terminal phalanx | Tendon  |
| Basal phalanx    | Radius  |
| Metacarpus       | Ulna    |
| Digit            | Humerus |

## Primary & secondary feathers - Underside.

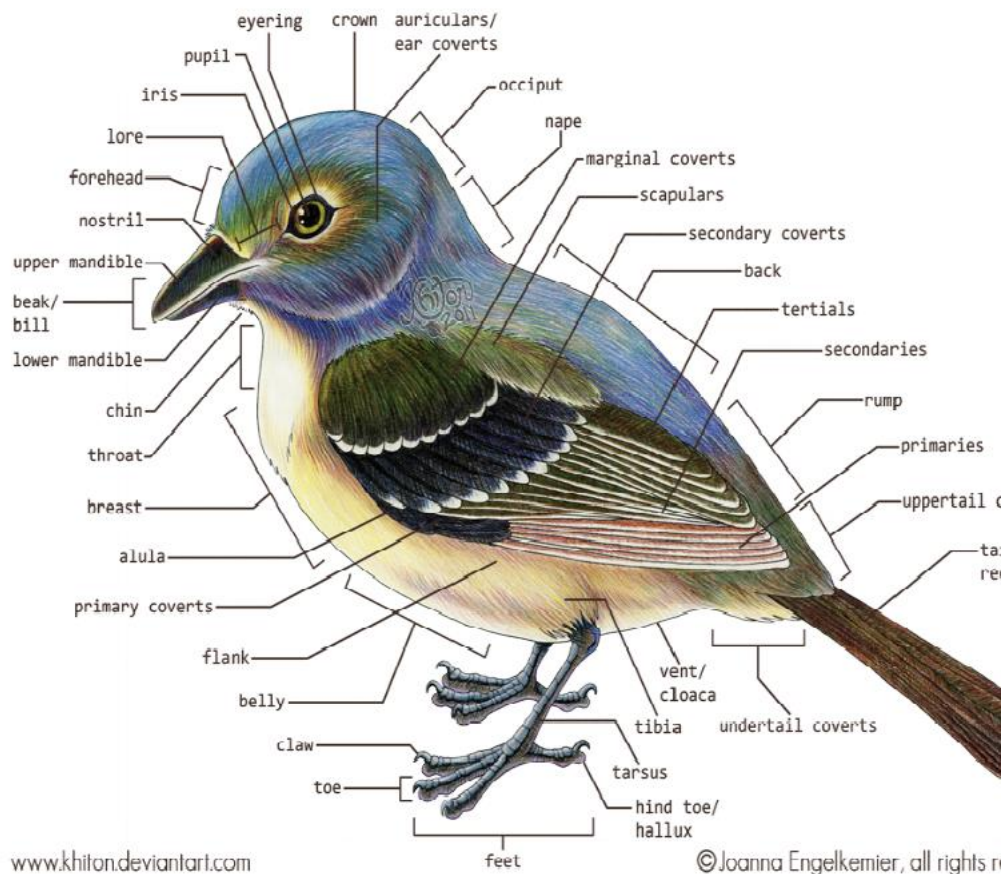
\* Note now the feathers overlap, the reverse will be seen on the top side of wing!



## Wing: Top View



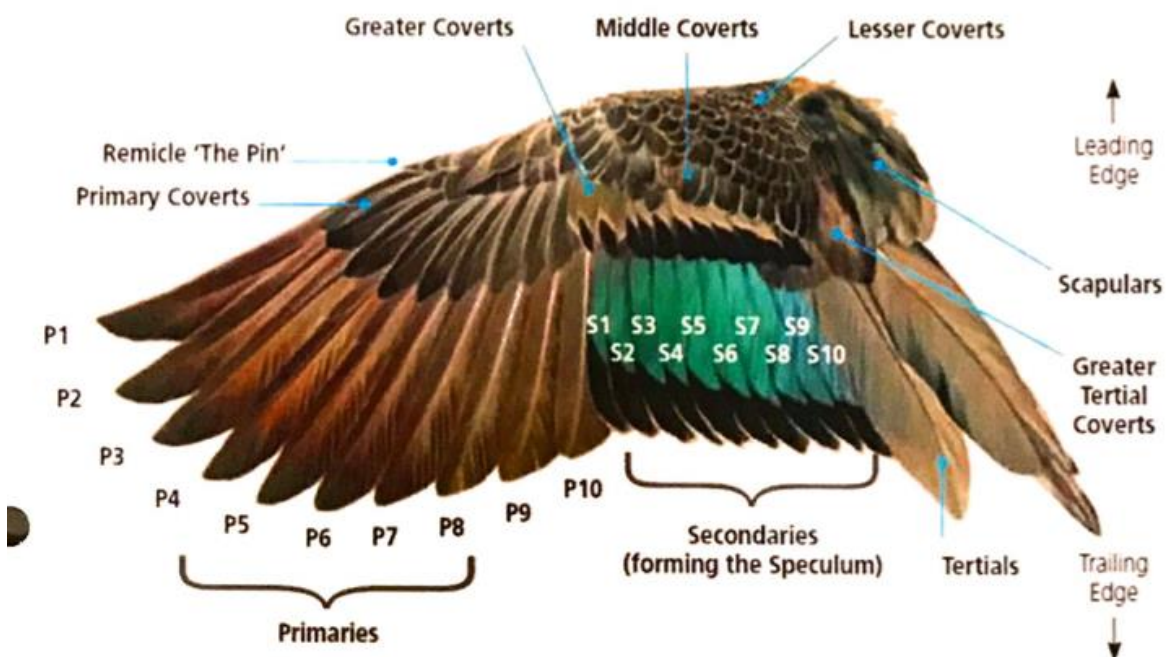
\* When folded, secondaries **COVER** the primaries.  
If you map out how the bones pose first, by recalling where the primary and secondary feathers attach, you can't go wrong



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## **Avian Skeletal System Humerus X-Ray Study**

*This self-study program uses x-rays in the packet labeled “X-Ray study – Humerus #1 thru #19.” Using an X-ray viewer, study each x-ray as you read the information listed below.*

#1 On this first x-ray, learn the location of the humerus in relation to the head and tail of the animal. Where is your humerus?

#2 Positioning is often the key to success for your observations! It’s hard to distinguish bones when they are “on top” of each other.

#3 It can be difficult to examine the humerus when the wings are folded. However, it would take a big x-ray to show extended wings on this Bald Eagle baby! Can you see something in the x-ray that might cause this bird problems?

(Hint: Remember bald eagles like to eat fish!)

#4 Can you find the humerus on this Barn Owl?

#5 How about on this Swainson’s Hawk?

#6 Can you find the humerus on this Harris’ Hawk?

#7 Note the long humerus on this Great Blue Heron.

#8 Can you find the small humerus on this Cardinal?

#9 Same birds, two positions. The left half shows a front view. The right half

shows a side (lateral) view with the wings pulled back. Can you locate the remains of this bird's last meal?

#10 Red-tailed Hawk, lateral view with both wings pulled back. Can you locate both humerus bones?

#11 Sometimes X-rays are very light or very dark, making them difficult to read.

#12 Can you find the humerus fracture on this Flicker? Note the location of the fracture. This would be identified as a mid-shaft fracture as the break is located about halfway along the length of the bone.

#13 Can you find the humerus fracture on this Flicker? It is probably the result of being shot. Can you see the shot in the X-Ray? This fracture has a poor prognosis because the break is close to the joint and the bone is broken into many pieces or *comminuted*.

#14 Can you find the multiple fractures of the humerus on this Kestrel?

#15 Can you find the multiple fractures on this Great Horned Owl?

#16 What do you think caused these fractures on this Cooper's Hawk?

#17 How would you describe the type and location of this fracture?

#18 This humerus has been pinned to help stabilize the fracture until it heals.

#19 Yeah! A good view of an intact humerus.

#20 When you have finished this exercise, return the x-rays to the envelope, leaving them in numerical order for the next person.

# **Medical Services Practice Worksheet**

## **Section Three • Avian Skeletal System and Feathers Vocabulary March**

Write the number of the term next to the appropriate description.

- |               |  |
|---------------|--|
| 1. Buccal     | ___ Pertaining to the structures of the neck                 |
| 2. Cephalic   | ___ Pertaining to the eye sockets                            |
| 3. Orbital    | ___ The wrist or wrist area                                  |
| 4. Synsacrum  | ___ Pertaining to the armpit                                 |
| 5. Pneumatic  | ___ Area bare of contour feathers or axilla                  |
| 6. Brachial   | ___ Pertaining to the head                                   |
| 7. Abdominal  | ___ Area where the spinal column meets the skull             |
| 8. Vertebral  | ___ Directed toward the head                                 |
| 9. Costal     | ___ Referring to fingers                                     |
| 10. Lateral   | ___ The top side or back                                     |
| 11. Air sacs  | ___ Ventral or bottom  |
| 12. Tarsal    | ___ Pertaining to or situated toward the midline             |
| 13. Patagium  | ___ Farther away from the midline                            |
| 14. Leading   | ___ Upper arm, area supported by the humerus                 |
| 15. Superior  | ___ Ventral chest area, between the sternum and shoulder     |
| 16. Sternal   | ___ Tissue that connects shoulder area to the wrist          |
| 17. Apterium  | ___ Toward the head  |
| 18. Inferior  | ___ Pertaining to the abdomen or stomach                     |
| 19. Celiac    | ___ Ribs or rib cage   |
| 20. Pelvis    | ___ Caudal portion of the trunk or torso                     |
| 21. Medial    | ___ Front (anterior) edge of the wing as the bird flies      |
| 22. Occipital | ___ Cheeks, the lateral walls of the oral cavity             |
| 23. Anterior  | ___ Air-filled areas that are part of the respiratory system |
| 24. Caudal    | ___ Away from the point of attachment                        |
| 25. Pectoral  | ___ Toward the tail  |
| 26. Cranial   | ___ Nearest to the point of attachment                       |
| 27. Trailing  | ___ Pertaining to the sternum                                |
| 28. Posterior | ___ Directed toward the tail                                 |
| 29. Distal    | ___ Pertaining to the region between the thorax and pelvis   |
| 30. Sacral    | ___ Referring to the spinal column                           |
| 31. Dorsal    | ___ Pertaining to air or respiration                         |
| 32. Proximal  | ___ Fused section of pelvic and caudal vertebrae             |
| 33. Digital   | ___ Region between crests of the pelvis                      |
| 34. Cervical  | ___ The part of the body between the neck and abdomen        |
| 35. Thorax    | ___ Area of the lower leg containing the tarsometatarsus     |
| 36. Axillary  | ___ Bottom, toward the abdominal side                        |
| 37. Ventral   | ___ Back (posterior) edge of the wing as the bird flies      |
| 38. Carpal    | ___ Dorsal or top  |

39. Avian structure has several adaptations that support flight. Name three.

- 1.
- 2.
- 3.

40. Name four bones found in the thoracic limb.

- 1.
- 2.
- 3.
- 4.

41. Name a pneumatized bone.

- 1.

42. List the three largest bones of the pelvic limb.

- 1.
- 2.
- 3.

43. What is the synsacrum?

44. Name the four bones of the pectoral girdle.

- 1.
- 2.
- 3.
- 4.

45. What is the importance of the trioseal canal?

46. What are the three principal bones in the pelvic girdle?

- 1.
- 2.
- 3.

47. Name four parts of a feather.

- 1.
- 2.
- 3.
- 4.

48. What is a molt?



49. Name five types of feathers and their location.

- 1.
- 2.
- 3.
- 4.
- 5.

50. You have completed Section Three, Avian Skeletal System and Feathers. What was the most interesting part of this section to you?