Avian Skeletal Morphology

To Know
Skull/Face
• Cranium
• Occipital
• Parietal
• Frontal
• Squamosal
• Jugal (zygomatic arch)
• Quadrate
• Interorbital Septum
• Maxilla
• Premaxilla
• Dentary
• Foramen Magnum
• Orbit
• Sclerotic Ring
• Hyoid Apparatus
• Occipital Condyle
• Vomer
• Pterygoid
• Palatine

Trunk and Limbs
• Vertebral ribs
• Sternal ribs
• Uncinate processes
• Sternum and keel
• Pectoral Girdle
  • Scapula
  • Coracoids
  • Furcula

Wing
• Humerus
• Radius
• Ulna
• Carpometacarpus
• Pollex

Pelvic Girdle
• Pubis
• Femur
• Tibiotarsus
• Fibula
• Tarsometatarsus
• Hallux

Vertebral Column
• Synsacrum
• Pygostyle
• Atlas
• Axis
• Cervical vertebrae
• Thoracic vertebrae

Skeletal System
Study the skeleton by observing skeletons, skulls, and individual disarticulated bones in conjunction with the descriptions and diagrams below. In what ways has the avian skeleton been adapted for flight?

The skeleton is usually considered in two parts: The Axial skeleton (including the skull, vertebral column, ribs and sternum) and the Appendicular skeleton (the wings, legs, pectoral and pelvic girdles).

Skull
The lines of demarcation between individual bones of the skull are nearly impossible to see in adult birds because of fusion that accompanies ageing. Consequently,
you will be looking at regions rather than separate bones in some cases. The skull can be divided into two groups of bones: cranium and face. Refer to Figure 1.

**Cranium** -- These bones enclose the brain and constitute the posterior part of the skull. The **occipital** forms the base or rear portion of the cranium. The large opening in the base of the bone is the **foramen magnum**. The spinal cord connects to the brain through this foramen. The back and posterior region of the brain case are formed by a medially fused pair of squarish bones, the **parietals**. Anterior to the parietals is another pair of bones, the **frontals**, which form the roof of the skull and the **orbit** (eye socket). Lateral to the frontals and parietals on each side of the head are the **squamosals**. They form the sides of the brain case and the posterior margins of the orbits. The ear opening lies under the lower edge of the squamosal.

The floor of the brain case is formed by part of the sphenoid. Viewed ventrally, the sphenoid is roughly triangular in shape with the base attached to the occipital and the apex projecting anteriorly. A thin vertical plate, the **interorbital septum** separates the orbits. In some birds, the septum is incomplete, with one or more openings between the orbits.

**Face** -- These bones compose, or are directly associated with the upper and lower mandibles (the **maxilla** and **dentine**). The quadrate, a quadrangular bone with a central constriction, connects the squamosal and sphenoid with the lower mandible, zygomatic bar, and pterygoid. The quadrate is one of the kinetic bones of the skull; the articulation at each end is free.

A slender **zygomatic arch** comprised mainly of the **jugal** lies below each orbit. The **maxilla** forms the posterior part and side of the upper mandible and part of the palate. It connects with the jugal posteriorly, and the palatine ventrally. Since the right and left halves do not connect medially, the palate is cleft. The two **premaxillae** fuse anteriorly to form the tip of the upper mandible.

In a ventral view of the skull, a pair of long, slender bones lying parallel to each other can be seen extending from the premaxillary portions of the palate posteriorly to the basisphenoidal rostrum. These are the **palatines**, which comprise most of the palate. Their shape varies among birds. In some they are little more than slender rods; on others they are flattened at one or both ends, sometimes in different planes. At their posterior tip the palatines articulate with the **pterygoids** – short, thick, T-shaped bones extending obliquely between the quadrates and the palatines and the basipterygoid process of the sphenoid. The pterygoid is another of the kinetic bones of the skull (Figure 3).

One other bone, the prevomer or vomer, is present in the palate of some groups, e.g., present in paleognathus birds but small or absent in neognathus birds. It is a thin, vertically flattened bone extending forward from the rostrum between the palatines. The **V** - shaped lower mandible completes the face. Each side is a strong fusion of five bones which are derivatives of the reptilian jaw. The two sides are fused anteriorly. Note the cups and processes at the posterior ends where the mandible articulates with the quadrate.
**Trunk & Limbs** (Figure 2)

A. Vertebral column  -- The vertebrae comprise five groups. (1) The cervicals extend from the skull to the first vertebra with a complete rib reaching the sternum. There may be 13 - 25 in birds. The high degree of flexibility is made possible by the heterocoelous condition of the centrum of each vertebra. The anterior articular surface is convex dorsoventrally and concave from side-to-side. The posterior surface is the reverse. Thus, the articulation between vertebrae is similar to two saddles fitted together. Note the first two vertebrae, the specialized atlas and axis. The atlas is ring-shaped and forms a ball-and-socket joint with the occipital condyle on the occipital. It rotates on a process of the axis. (2) The five thoracic vertebrae bear complete ribs. (3) The three lumbar vertebrae, (4) four sacral and (5) six of the twelve caudal vertebrae are fused with the pelvis into the synsacrum. Note that the transverse processes of these vertebrae can be seen within the synsacrum. The last six caudal vertebrae are unfused. The last one is a fusion ancestrally of several vertebrae and is called the pygostyle. It bears the tail feathers.

B. Ribs  -- Some of the first ribs (the first two in pigeons) do not attach to the sternum. Note that the ribs are in two segments, the vertebral ribs and the sternal ribs. On the vertebral portion of all but the first and last ribs is an uncinate process - a tab-like projection. These overlapping processes provide some rigidity to the rib cage as well as serving for muscle attachment.

C. Sternum  -- The large breastbone in most birds has a large keel (carina) to which the massive pectoral muscles used in flight are attached. Flightless birds lack the keel (ratite condition). The posterior margins of the sternum are used as a taxonomic character. There may be one or two notches or holes (fenestrae) or nothing at all.

D. Pectoral Girdle and Wings  -- The pectoral girdle consists of three pairs of bones: The scapulas, the flat bones lying on the dorso-lateral surface of the ribs; the coracoids, the stout bones which brace the shoulder against the sternum; and the clavicles, which fuse anterior to the sternum to form the furcula (wishbone).

The wing has several fused and missing elements from the basic vertebrate limb. The humerus is the stout bone connected to the shoulder. Note the small opening at the proximal end through which the cavity within the bone is connected to an air sac inside the body. At the distal end the humerus widens to create two surfaces which articulate with the ulna and the radius. The ulna is the stouter and more curved; the radius is the more slender. The rows of bumps on the ulna are the points of attachment of the secondary flight feathers. The carpals are reduced by fusion to two in birds: the radiale at the end of the radius, and the ulnare at the end of the ulna. These two bones are fusions of carpals. Some carpals also are fused with some of the metacarpals to form the carpometacarpus.

E. Pelvic Girdle and Legs  -- The pelvis is a fusion of the three pelvic bones shared by all vertebrates: ilium, ischium, and pubis. On the lateral surface is a socket, the acetabulum, for the attachment of the femur. All three bones meet at this point. The ilium is the dorsal part of the pelvis. It is dorsally concave anteriorly and convex posteriorly. It is fused with...
the transverse processes in the **synsacrum**. The ischium is the thin bone extending ventrally from the ilium and forming the side of the pelvis. The opening in the side of the pelvis is along the line of fusion of the ilium and ischium. The pubis is the thin rod-like bone.

The legs also exhibit fusion and reduction or loss of parts. The **femur** has a prominent head which fits into the acetabulum. The groove on the distal end is a space for the patella and the two knobs are points of attachment for the **tibiotarsus** and **fibula**. The fibula is much reduced and exists only as a splinter bone partly fused to and lying parallel to the tibiotarsus. The tibiotarsus is a fusion of the tibia at its distal end with some tarsal elements. The other tarsals are fused with a fusion of the second, third, and fourth metatarsals to form the **tarsometatarsus**. Remnants of the three metatarsals are visible at the distal end where they articulate with the toes.

In this lateral view of the pigeon's skeleton several major structural characteristics of birds are clearly visible. Note the many fused bones along the axial skeleton (the skull, spinal column, and pelvis). The fused bones provide a strong, stable central platform for the flight muscles. Note how light the bird's skeleton is; some birds the skeleton weighs less than the feathers. In the pigeon these paper-thin bones form the structural framework of an aircraft that can easily exceed sixty miles an hour, fast enough to outfly a Peregrine Falcon in level flight.
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 caudal (meaning toward the tail). Where 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 airdal surface of the wing forward, creating forward "lift" force (much the way a propeller airdal 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.