Chapter 8

The Pigeon

Introduction

The pigeon, *Columba livia*, belongs to the Aves or birds. Although birds have long been recognized as the flying, feathered vertebrates, recent fossil discoveries—among the more exciting paleontological developments of the last few decades—have revealed that feathers first evolved in several groups of theropod dinosaurs. Feathers are therefore not unique to birds and can no longer be used to diagnose them as a group. Nonetheless, birds are the only living vertebrates with feathers. The terms Aves and birds have long been used to refer to the same group of amniotes, but they are not precisely synonymous. The Aves are considered the group that includes the ancestor of living birds and all of its descendants. However, the fossil remains of much more primitive birds have long been known to science.

Indeed, birds have a long fossil record, beginning with the earliest bird, the Late Jurassic *Archaeopteryx lithographica*. The group including *Archaeopteryx* and all other birds is termed the Avialae and is recognized by development of the forelimbs into wings. The fossil record documents several substantial radiations during the Jurassic and Cretaceous Periods, of which many became extinct. As examples, the Confuciusornithidae (a group of toothless, flying birds that still had mainly separate digits in the manus and a pair of long ornamental tail feathers in, presumably, males), Hesperornithiformes (a group of flightless, diving birds with the forelimb represented only by a splint-like humerus), and Ichthyornithiformes (a group of ancient flying birds) may be mentioned. These groups had all become extinct by the end of the Cretaceous.

Modern birds, the Aves, began their radiation during the Cretaceous. They are among the most numerous of vertebrate groups, having diversified to include at least 9,700 living species (and molecular studies suggest that there might be twice as many species as currently recognized). The Aves are characterized by complete loss of teeth and a very large sternal keel. They are subdivided into the Palaeognathae and Neognathae, which are differentiated primarily on palatal features. The paleognaths include two lineages, the flightless ratites (e.g., ostriches, emus, rheas, cassowaries) and the tinamous.

Ratites and tinamous comprise some 54 living species, so most of present-day avian diversity is represented by the neognaths. Twelve main lineages are recognized, but their interrelationships are largely unresolved. Among these may be mentioned the sister groups Anseriformes (ducks, geese, swans) and Galliformes (chickens, grouse, pheasants, turkeys), which together apparently form the outgroup to other neognaths. The Procellariformes (albatrosses, petrels, and shearwaters), Pelicaniformes (pelicans, gannets, cormorants), Sphenisciformes (penguins), Gaviformes (loons), and Podicipediformes (grebes) are part of another lineage, as are the Falconiformes (eagles, falcons, ospreys) and Strigiformes (owls). The Passeriformes, the great group of songbirds, together with Piciformes (barbets, toucans, woodpeckers) and Coraciiformes (hoopoes, hornbills, kingfishers) represent yet another lineage. The pigeon is included with doves in the Columbiformes, which is part of the lineage including Charadriiformes (auks, curlews, snipes, terns, gulls, puffins), Ardeidae (bitterns, egrets, herons), and Gruiformes (cranes, coots, rails, bustards).

Section I—Skeleton

The structure of birds, most of which can fly, has been highly modified to meet the demands of flight. The skeleton has a number of such modifications, most obviously perhaps in the forelimbs, which are adapted to form a bony frame for the wings (Figure 8.1). Also, however, the skeleton has undergone changes to reduce weight, clearly an advantage in a flying animal, and mobility, which gives the wings a rigid support. Several bones of many birds are pneumatic—hollow and containing extensions of the respiratory system's air sacs, described in more detail below (Figure 8.2).

Skull, Mandible, and Hyoid Apparatus

The bones of the skull (Figures 8.3 and 8.4) are extensively fused to provide strength while minimizing weight. As the sutures are often obliterated, it is diffi-

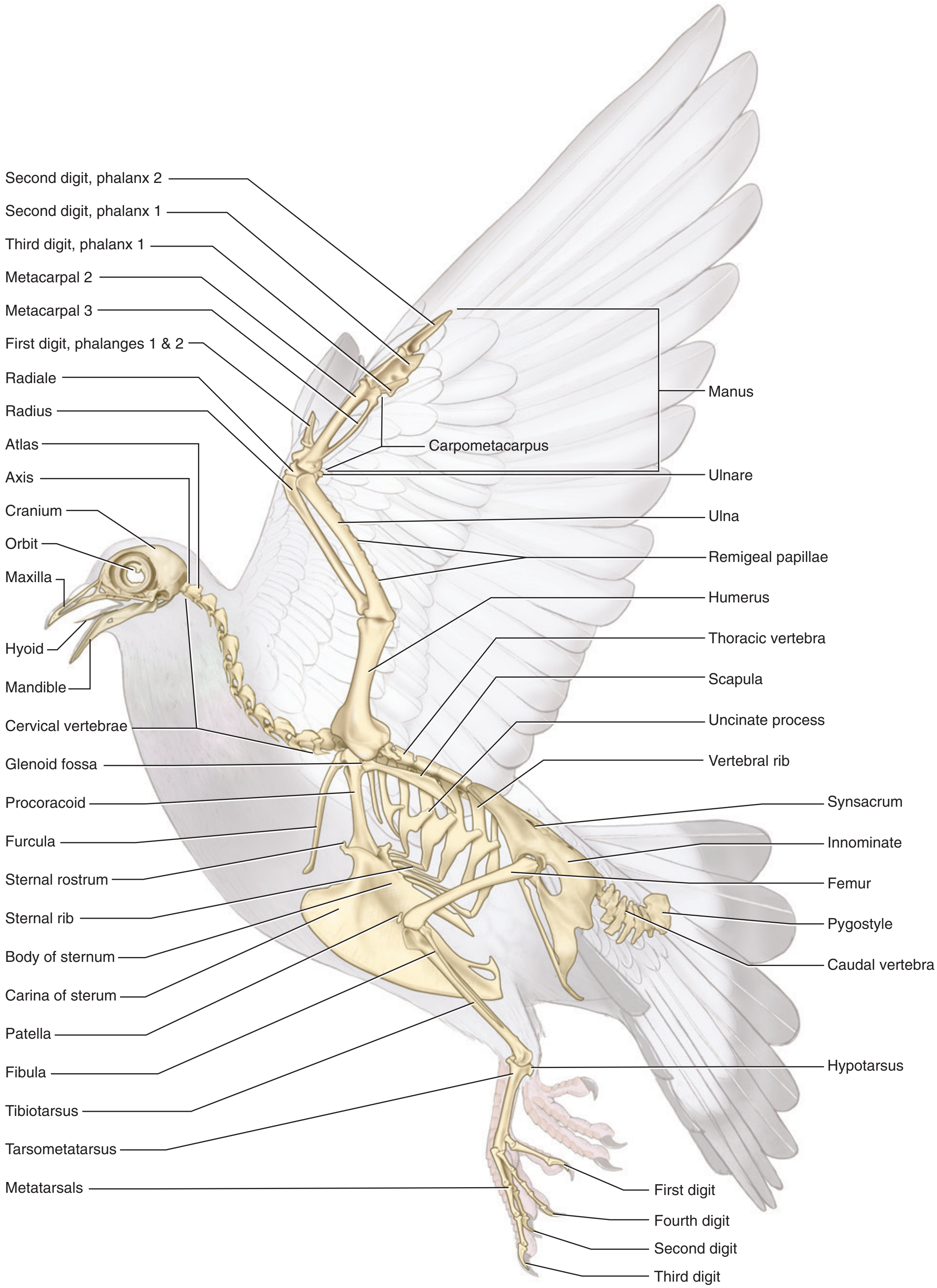


FIGURE 8.1 Skeleton of the pigeon in left lateral view, superimposed on body outline.

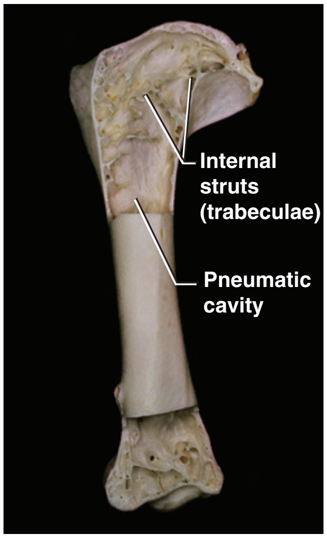


FIGURE 8.2 Humerus of pigeon with proximal and distal ends sectioned to reveal internal structure.

cult to distinguish many of the bones in an adult individual. Attempting to identify each bone is, at this level of study, impractical, and it is more useful to examine various regions of the skull.

Note the large **orbits**. The often incomplete, bony septum between the orbits is formed by the **mesethmoid**. The **sclerotic ring** is a circle of small bones that support the eyeball. The **postorbital process** lies at the posteroventral margin of the orbit. The cranium, posterior to the orbits, is composed of paired **frontals** that cover most of the roof of the skull, **parietals**, smaller rectangular bones, and **squamosals** on the lateral wall of the cranium, and, posteroventrally, the **occipital**, which is formed from several bones fused into a single unit. These cranial bones can usually be distinguished, although the sutures between them are often indistinguishable.

The **quadrate** lies toward the ventral part of the orbit and is mobile in birds. It has a prominent orbital process, as well as an otic process, which contacts the cranium. Just ventral to this contact is a large, oval depression, the **auditory meatus**, which is bounded posteroventrally by the **paroccipital** process and leads into the **middle ear**. The bony region, pierced by various foramina, visible within the meatus contains the inner ear. The quadrate has a ventral process that articulates with the **mandible** to form the jaw joint.

The **foramen magnum** is the large opening in the occipital. At its anterior edge is the single **occipital condyle**. Anterior to the occipital condyle lies the **basioccipital** (Figure 8.4), one of the components of the occipital. The **basisphenoid** lies anterior to the basioccipital and has a tapered anterior end. The **parasphenoid** lies anterior to this tapered end of the basisphenoid. The **basipterygoid processes**, one on either side, extend anterolaterally from the posterior end of the parasphenoid and contact the **pterygoid**, each of which articulates anteriorly with a **palatine**.

Anterior to the orbit, a complex of bones form the upper jaw and support the **bill** (Figures 8.1, 8.3, 8.4). This complex is the **maxilla**, and it includes the **nasals**, **premaxillae**, and **maxillae** (in this sense, as single bony elements). From its dorsal contact with the frontal, each nasal sends out two slender processes, one contacting the maxilla, the other contacting the premaxilla. The latter is a large element forming most of the dorsal and ventral anterior part of the upper jaw. Near its dorsal articulation with the nasal, the premaxillae can, in life, bend or flex slightly dorsally in many birds. The maxilla forms most of the posterior part of the upper jaw ventrally and contacts the palatine posteriorly. Finally, note the **zygomatic arch**, a slender bridge between the maxilla anteriorly and the quadrate posteriorly. It is formed almost entirely by the **jugal**; a small posterior contribution is made by the **quadratojugal**.

The mandible or lower jaw is composed of various bones, but they are difficult to distinguish. The **dentary** forms nearly the anterior half of the mandible. Its posterior end coincides roughly with the **mandibular foramen**. Most of the lateral surface posterior to the foramen is formed by the **supra-angular**. The **angular** is a smaller bone ventral to the supra-angular. The **articular** is a small element that articulates with the quadrate of the skull. Two other bones are present but are on the medial surface of the mandible.

The hyoid apparatus (Figure 8.3) is a slender, elongated, Y-shaped structure that supports the tongue. It is formed by various elements, but they are difficult to distinguish and are not considered separately.

Postcranial Skeleton

Vertebrae

The vertebral column (Figure 8.1) normally includes 14 **cervical**, 5 **thoracic**, 6 **lumbar**, 2 **sacral**, and 15 **caudal vertebrae**. The column of the pigeon, as with most birds, is notable for its degree of fusion, with the exception of the cervical vertebrae. The atlas and axis are followed by 12 other cervical vertebrae, all fully mobile. The forelimbs of most birds are so specialized for flight that they are unavailable for other functions such as grooming or obtaining food. The long, mobile, S-shaped neck allows some of the functions usually performed by the forelimbs in other vertebrates. The last two cervicals bear small **ribs** that do not attach to the **sternum** (see below).

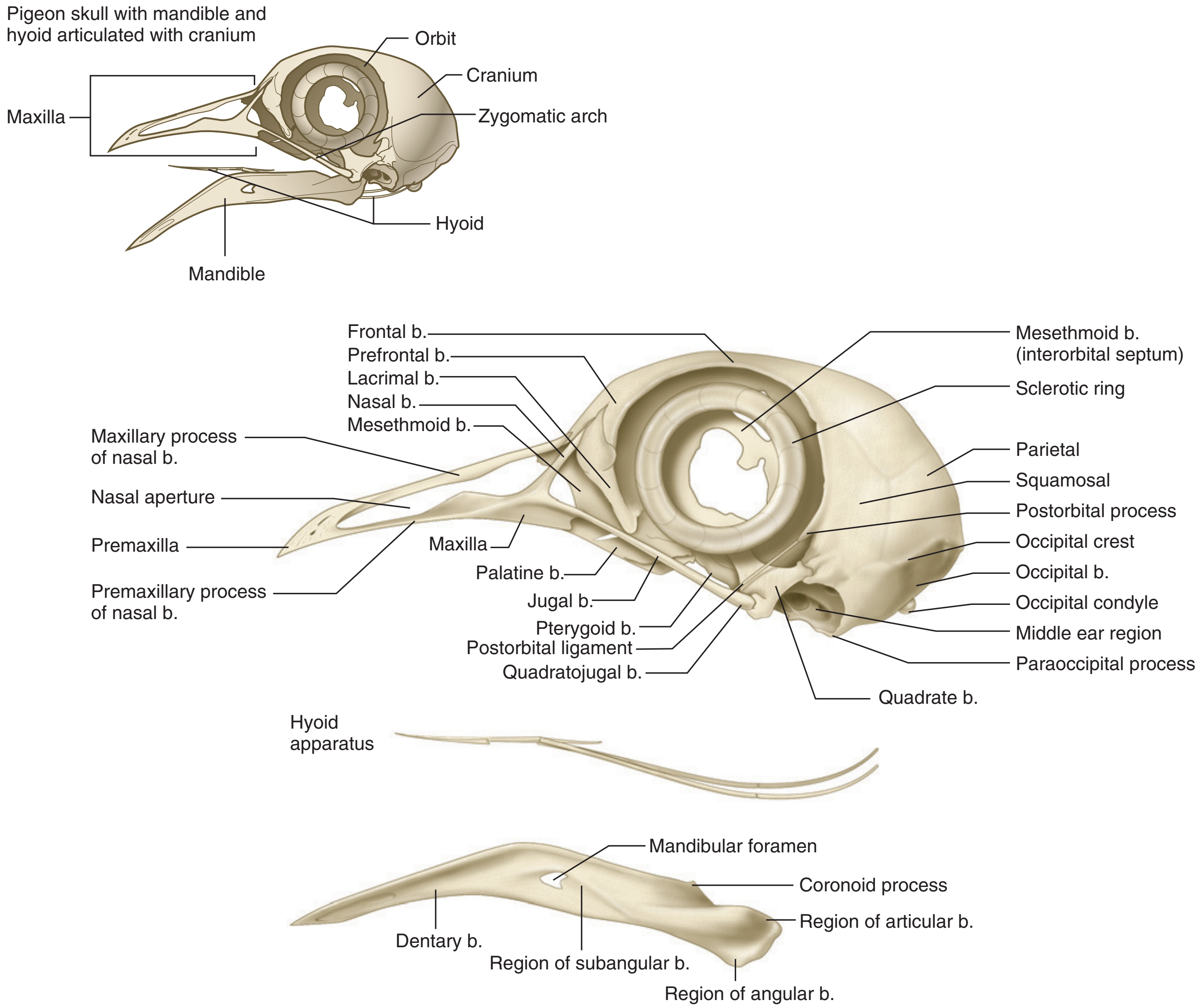


FIGURE 8.3 Skull of the pigeon in left lateral view. Inset figure shows elements in position, and large illustration indicates detail.

There are five thoracic vertebrae, the first four of which are fused together. The thoracics each bear a pair of ribs. The fifth thoracic is fused to the first of the six lumbar vertebrae, which are all fused together and incorporated into the **synsacrum** (see below), as are the two sacral vertebrae. Of the 15 caudal vertebrae, the first five are incorporated into the synsacrum, the following six are free and mobile, and the last four are fused together to form the **pygostyle** (Figures 8.5 and 8.6). The extensive fusion of sections of the vertebral column posterior to the neck renders the trunk rather rigid. This inflexibility may be a feature that helps to reduce weight, as it decreases the need for extensive musculature to maintain a streamlined and rigid posture during flight.

Ribs

There are several types of ribs (Figure 8.1). As noted above, ribs are associated with the last two cervical vertebrae. These ribs do not reach the sternum and are often referred to as *floating* ribs (or bicipital cervical ribs). The five ribs associated with the thoracic vertebrae are each formed from a robust, dorsal element, a **vertebral rib**, and a more slender, ventral element, a **sternal rib**. The vertebral rib, as its name implies, extends from the vertebra and articulates with the sternal rib, which in turn articulates with the sternum. In some specimens the last vertebral rib may articulate with the sternal rib of the preceding rib. Note the prominent, posteriorly projecting **uncinate processes**, which

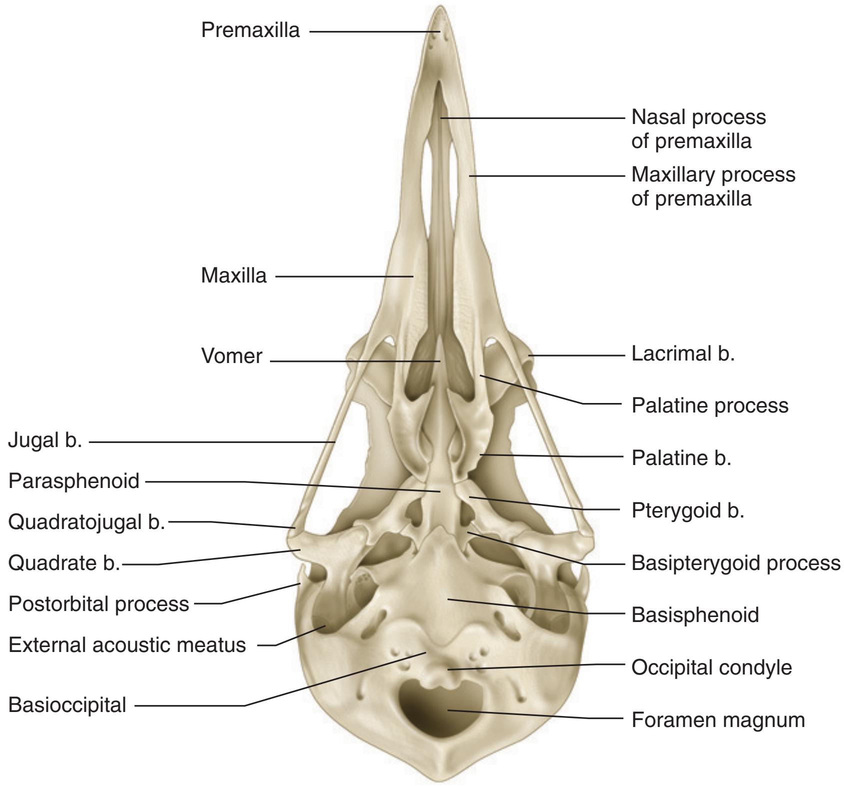


FIGURE 8.4 Skull of the pigeon in ventral view.

overlap the subsequent vertebral rib and help brace the ribs.

Sternum

The **body** of the **sternum** (Figures 8.1 and 8.12) is a large, curved plate of bone. Its most prominent feature is an extremely large vertical plate, the **carina** or keel. The body articulates anteriorly with the **procoracoids** (see below) and more posteriorly with the sternal ribs. The large **caudolateral process** projects posteriorly from behind the articular surfaces for the sternal ribs and helps form the **sternal notch**.

Pectoral Girdle and Forelimb

The pectoral girdle of birds is modified to produce a rigid and stable brace for the requirements of flight. These modifications are so pronounced that they usually are retained even in birds that are secondarily flightless. For example, the **scapula**, **procoracoid**, and **furcula** are tightly bound near the shoulder joint; the procoracoid is a stout, elongated element bracing the forelimbs against the sternum.

The scapula (Figures 8.1 and 8.12) is an elongated, blade-like bone that narrows anteriorly. Its anterior end forms part of the **glenoid fossa**, which articulates with the **humerus**.

The procoracoid (Figures 8.1, 8.10, and 8.12) is a stout bone. Its posterodorsal surface articulates with the scapula and completes the glenoid fossa. Dorsomedially, it articulates with the furcula (see below). The procoracoid widens ventrally and articulates with the body of the sternum, thus acting as a strut between the sternum and shoulder joint. The **triosseal canal** is a bony passage formed in many birds by three bones (hence its name), usually the scapula, procoracoid, and furcula, that serves as the passage for the tendon of the **supracoracoideus muscle** (see below). In the pigeon, however, the canal is formed only by the procoracoid. It is an oval opening located near the dorsal end of the procoracoid, just ventral to its articulation with the furcula.

The furcula (or wishbone) is a structure formed by the ventral fusion of the right and left clavicles and the median interclavicle. It is present in the pigeon, but in some species the clavicles remain unfused. In many mounted skeletons, a ligament extends between the ventral end of the furcula and the anterior end of the carina of the sternum.

The forelimb (Figure 8.1) consists of a stout proximal humerus, followed by the longer **radius** and **ulna**. The radius is the straighter, more slender bone. The ulna is bowed and has a short **olecranon process** distally. Its

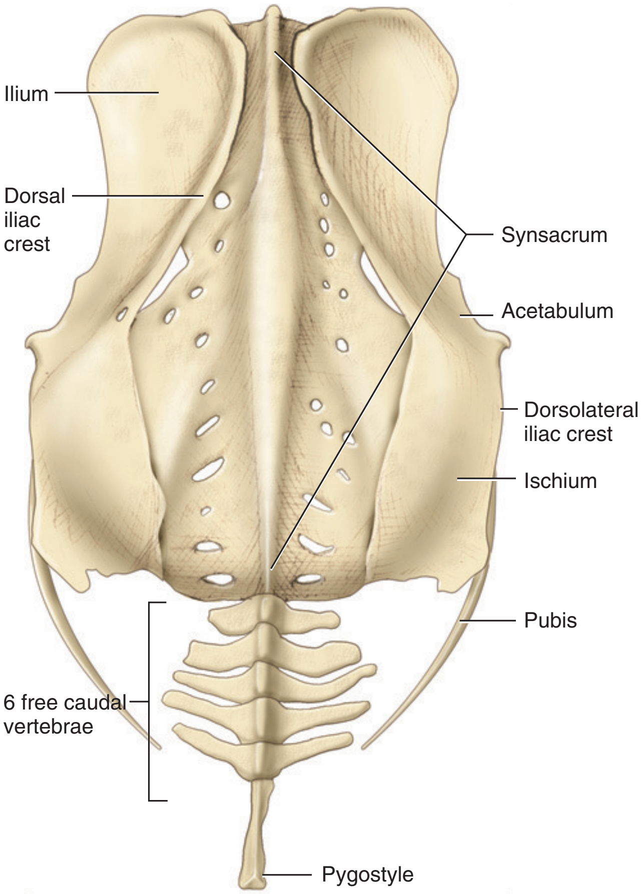


FIGURE 8.5 Posterior part of vertebral column and pelvis of the pigeon in dorsal view.

posterior margin has several **remigeal papillae**, knob-like markings for the attachment of flight feathers. The manus consists, as usual, of carpals, metacarpals, and phalanges, but these have been highly modified in birds. Two **carpals** remain unfused: the **ulnare**, a slender bone that articulates with the ulna, and the **radiale**, which articulates with the radius. These carpals are followed by the **carpometacarpus**, an elongated element composed of several carpals, proximally, and three metacarpals fused together.

There has been considerable debate over the homology of the digits of birds, with some researchers considering them homologous with digits 1, 2, and 3 (as is typical of theropod dinosaurs) and other researchers considering them homologous with digits 2, 3, and 4. Recent morphological and developmental analyses suggest that the digits of birds represent digits 1, 2, and 3. The two elongated structures of the manus are **metacarpal II** (robust and nearly straight) and **metacarpal III** (slender and bowed). Although it is difficult to discern, **metacarpal I** (the alular metacarpal) is fused into the proximal end of the carpometacarpus, along with the carpals. The **phalanges** are also highly modified. Those of the alular digit are represented by the short, triangular fused element, including **phalanges 1** and **2**, at the proximal end of the carpometacarpus. **Phalanges 1** and **2** of digit 2 extend distally from metacarpal II. A small triangular element at the articulation between the carpometacarpus and phalanx 1 of digit 2 is **phalanx 1** of digit 3.

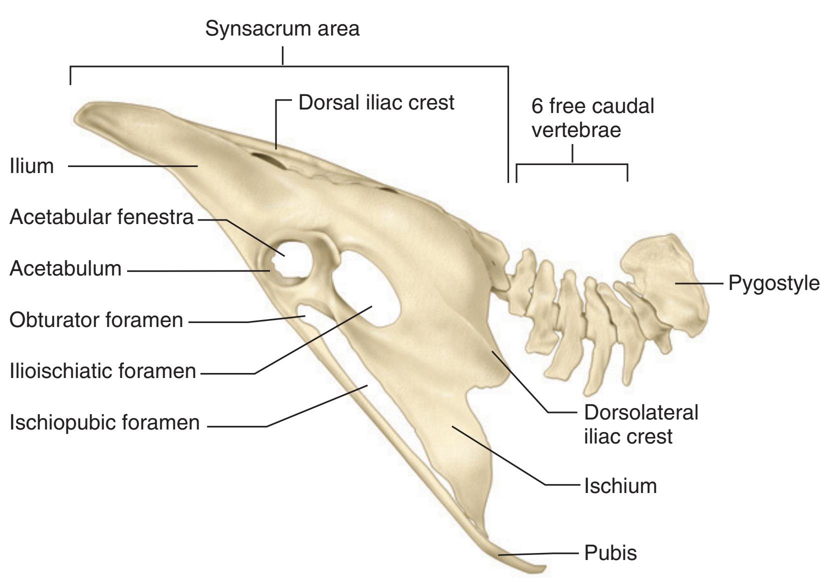


FIGURE 8.6 Posterior part of vertebral column and pelvis of the pigeon in left lateral view.

Pelvic Girdle and Hind Limb

The pelvis (Figures 8.1, 8.5, and 8.6) includes left and right **innominate** bones, each of which is formed by an **ilium**, **ischium**, and **pubis**. The ilium is the largest element, forming the dorsal half of the pelvis. It has two distinct regions: an anterior concave region and a posterior convex region (in dorsal view). The posterior part of the **dorsal iliac crest** separates these regions, just dorsal to the **acetabulum**, the depression that receives the head of the **femur** (see below). The crest continues posteriorly as the **dorsolateral iliac crest**. The ischium lies ventral to the posterior part of the ilium. The separation between these bones is marked roughly by the **ilioischiadic foramen**. The acetabulum is directly anterior to it. Note that the floor of the acetabulum has an opening, the **acetabular fenestra**. The curved pubis is a very slender and elongated bone extending posteroventrally from the acetabulum, along the ventral margin of the ischium. Two other openings may be noted. The **obturator foramen** lies anteriorly between the pubis and ischium; the long and narrow **ischiopubic fenestra** lies more posteriorly.

A notable feature of birds is that the pelvis is solidly and extensively fused to the synsacrum, the posterior series of fused and expanded vertebrae (see above). The whole unit, pelvis and synsacrum together, form a rigid platform for muscles of the hind limb and tail, and is part of the system that helps a bird to maintain a stable, streamlined posture during flight.

The hind limb (Figure 8.1) includes several bones. The **femur** is the proximal bone. It is followed by the longer **tibiotarsus**, which is formed by fusion of the tibia and several **tarsals**. Articulating anteriorly between the femur and tibiotarsus is the small **patella**. A slender, splint-like **fibula** lies along the lateral surface of the tibiotarsus. Several tarsals and the 2nd, 3rd, and 4th **metatarsals** fuse together to form the **tarsometatarsus**, which bears a protuberance, the **hypotarsus**, on its posteroproximal surface. **Metatarsal I** articulates with the posterodistal surface of the tarsometatarsus. There are four digits in the **pes**, each ending in a claw. The first, or **hallux**, has two **phalanges** and is oriented posteriorly, while the three remaining digits point anteriorly. This arrangement, the most common among birds, represents the anisodactyl condition. Other arrangements include the zygodactyl (digits 1 and 4 are reversed) heterodactyl (digits 1 and 2 are reversed), syndactyl (digits 2 and 3 are fused together for much of their length), and pamprodactyl (digits 1 and 4 pivot between facing anteriorly and posteriorly) conditions. Digit 2 has three phalanges, digit 3 has four phalanges, and digit 4 has five phalanges.

Key Terms: Skeleton

acetabular fenestra
acetabulum
angular
articular
auditory meatus
basioccipital
basipterygoid processes
basisphenoid
body of **sternum**
bill (beak)
carina (keel)
carpals
carpometacarpus
caudal vertebrae
caudolateral process
cervical vertebrae
dentary
dorsal iliac crest
dorsolateral iliac crest
femur
fibula
foramen magnum
frontals
furcula
glenoid fossa
hallux
humerus
hypotarsus
ilioischiadic foramen
ilium
innominate
ischiopubic fenestra
ischium
jugal
lumbar vertebrae
mandible
mandibular foramen
maxilla (as a complex forming the upper jaw)
maxillae (as single bony elements)
mesethmoid
metacarpal I (alular metacarpal)
metacarpal II (major metacarpal)
metacarpal III (minor metacarpal)
metatarsal I
metatarsals
middle ear
nasals
obturator foramen
occipital
occipital condyle
olecranon process
orbits
palatine
parasphenoid
parietals
paroccipital
patella
pes
phalanges
postorbital process
premaxilla
procoracoid
pterygoid
pubis
pygostyle
quadrate
quadratojugal
radiale
radius
remigeal papillae
ribs
sacral vertebrae
scapula
sclerotic ring
squamosals
sternal notch
sternal rib
sternum

supra-angular	**triosseal canal**
supracoracoideus muscle	**ulna**
synsacrum	**ulnare**
tarsals	**uncinate processes**
tarsometatarsus	**vertebral rib**
thoracic vertebrae	**zygomatic arch**
tibiotarsus	

Section II—External Anatomy

The **bill** (or beak) is the most prominent feature of the head (Figure 8.7). It includes the maxilla and mandible, which are covered by a horny sheath or **rhamphotheca**. Open the mouth and note the absence of teeth. The **nares** (sing., **naris**) pierce the maxilla. Immediately posterior to them is the **operculum**, a soft swelling of the integument. The **eyes** are large, as would be expected in a vertebrate that depends largely on vision. The **external acoustic meatus**, leading to the tympanic membrane of the ear, lies posterior and just ventral to the level of the eye, but is concealed by **feathers** (Figures 8.8, 8.9).

The most obvious feature of birds is the presence of feathers, which in most birds serve primarily for flight and temperature control and will be examined in more detail below. The **neck** appears shorter than it really is (see Section I), but this is due to the covering of feathers. The **forelimbs** are strongly modified to form wings. Spread the wings and note the prominence of the feathers. In contrast, the distal part of the hind limb, including the pes, is covered by horny **scales**.

The dorsal region is the **dorsum**, whereas the ventral region includes the expanded **breast** anteriorly and the **venter** or belly posterior to it. At the posterior end of the body, the **tail** includes the short posterior, fleshy stump of the body, the **uropygium**, as well as the feathers extending from it. Spread the feathers on the dorsal surface of the uropygium to reveal the **uropygial gland** (Figure 8.11). The gland produces an oily secretion used in preening that protects the feathers. Spread the ventral tail feathers and note the slit-like opening of the **cloaca** (Figure 8.14).

There are several types of feathers in birds, but only the larger **contour feathers** are described here. Contour feathers are those that are typically thought of as feathers, such as the flight feathers on the wings and tail, as well as smaller feathers that cover much of the body. Examine a contour feather (Figure 8.8) from the wing of the pigeon. Note the central **shaft** or quill. The **calamus** is the hollow, basal part of the quill, while the **rhachis** is the part bearing **barbs**, the tiny, parallel structures that branch from the rhachis. Numerous **barbules** branch out from each barb and each barbule bears tiny **hooklets** that interlock with hooklets of adjacent barbules to help maintain the shape and structure of a feather. Magnification is required to observe barbules and hooklets. The barbs are arranged in two **vanes**. The vanes are usually symmetrical around the rhachis in most contour feathers covering the body, but are asymmetrical in most of the flight and, to a lesser degree, tail feathers. In flight feathers, the vane facing the leading edge of the wing is narrower than at the trailing edge.

Feathers are designated by their position on the body, and there are numerous different types. Here, only the more typical ones important in flight on the tail (Figure 8.7) and wing (Figure 8.9) are distinguished. The **remiges** (sing., **remex**) are the large feathers of the wing. On the trailing edge of the wing, the **primary remiges** (or, simply, primaries) are the feathers attaching to the distal end of the wing, the carpometacarpus and phalanges, and are numbered from 1 to 10 in proximal to distal order. Those attaching to the ulna are the **secondary remiges**, of which there are usually 15, numbered in distal to proximal order. The **tertiary remiges**, usually four in number, lie proximal to the most proximal secondaries. The **coverts**, which vary in size, cover nearly all of the remainder of the wing. The exception is a small patch of (usually four) **alular quills**, which arise from the alular phalanx and together form the **alula** or bastard wing. Though relatively small, the alula is an extremely important flight structure that helps avoid stalling during low velocity flight. The feathers of the tail are termed **rectrices** (sing., **rectix**).

Key Terms: External Anatomy

alula (bastard wing)	**neck**
alular quills	**operculum**
barbs	**primary remiges**
barbules	**rectrices** (sing., **rectix**)
bill (beak)	**remiges** (sing., **remex**)
breast	**rhachis**
calamus	**rhamphotheca**
cloaca	**scales**
contour feathers	**secondary remiges**
coverts	**shaft**
dorsum	**tail**
external acoustic meatus	**tertiary remiges**
eyes	**uropygial gland**
feathers	**uropygium**
forelimbs	**vanes**
hooklets	**venter**
nares (sing., **naris**)	

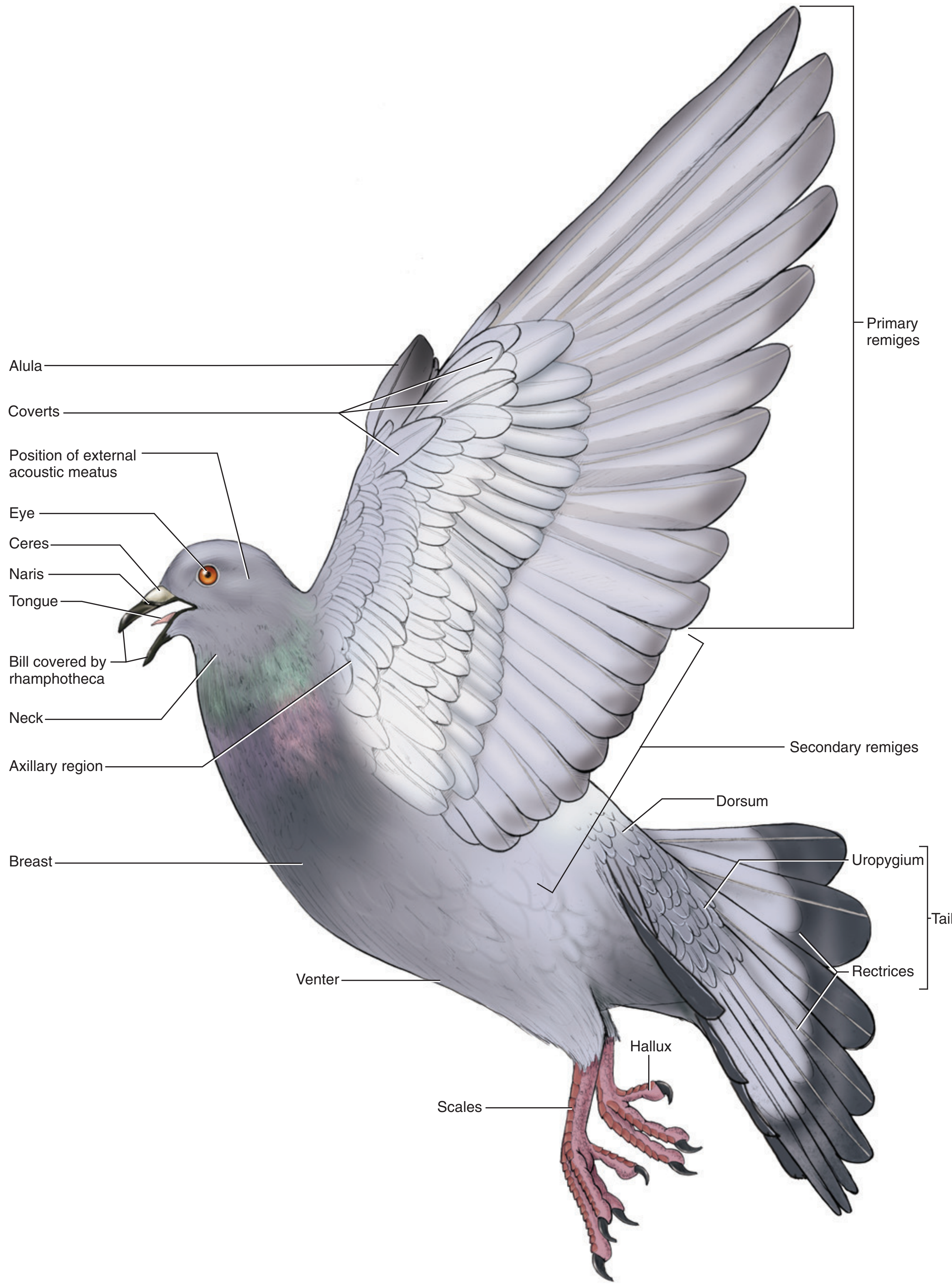


FIGURE 8.7 External features of the pigeon, with forearm (wing) abducted, in left lateral view.

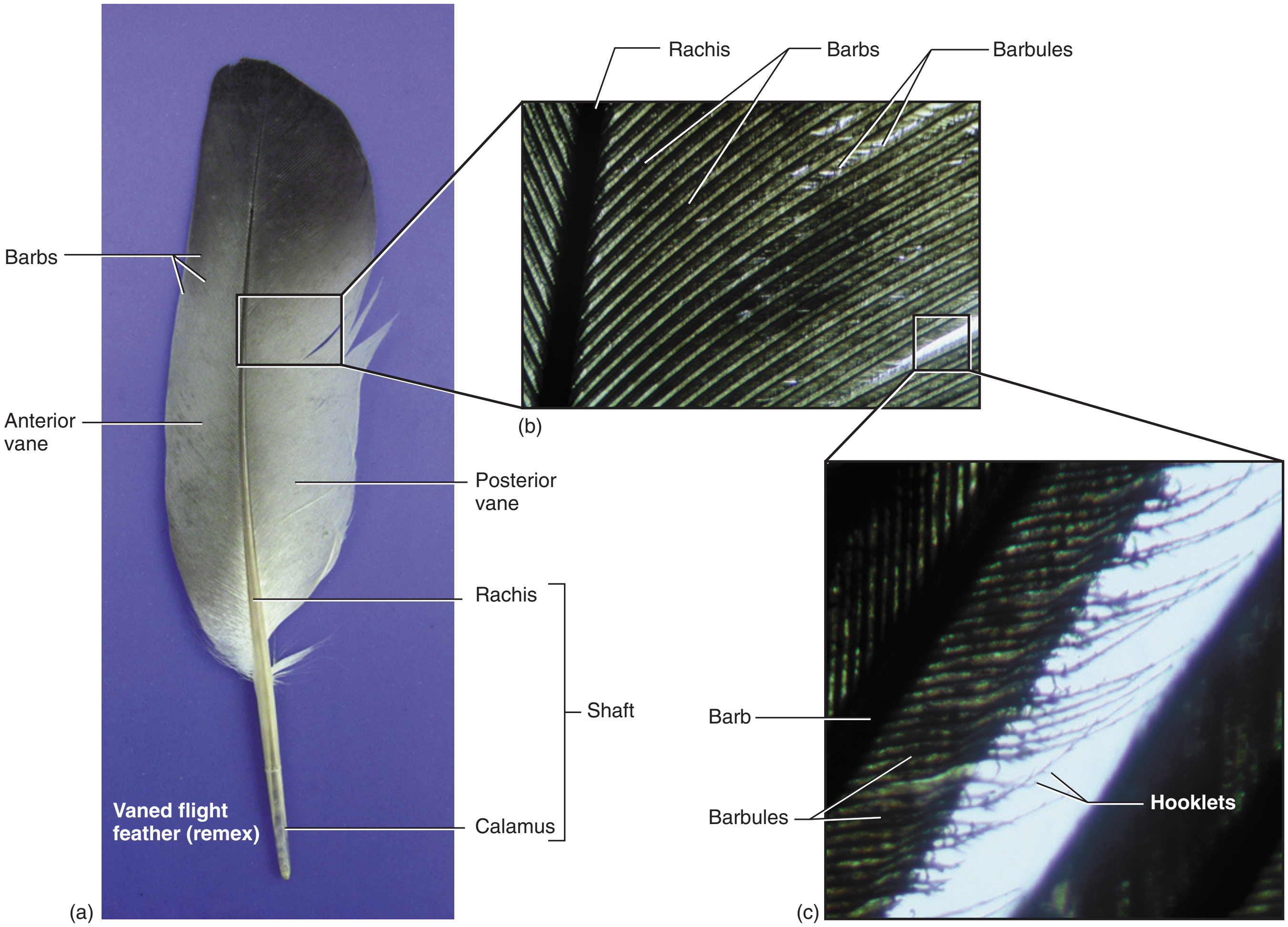


Figure 8.8 Feather of the pigeon, with blowups showing successively finer detail of structures.

Section III—Musculature

As the flight and wing musculature are among the more interesting features of the pigeon, they are the focus of this dissection. To study the musculature, the skin must be removed. Begin by brushing aside the feathers from the midventral surface of the thoracic region. Note that there are no feathers attached at the midline. Make a longitudinal incision through the skin, but work carefully, as it is quite thin. Extend the incision from the cloaca anteriorly to the anterior part of the breast, and then spread the skin, separating it from the underlying tissue using a blunt probe. In most places the skin will come off readily, but in some spots muscular slips attach to the skin, and must be cut through. You will reveal the **pectoralis** (Figure 8.10), the largest and most superficial of the flight muscles. At the anterior part of the pectoralis lies the thin-walled **crop**, a sac-like specialization of the **esophagus** (see below) that is used to store food. Carefully continue the incision anteriorly, being careful not to injure the crop, to just below the bill. Skin the neck, but do not damage vessels.

Several folds of skin form the wing surface. The large fold between the shoulder and carpus, forming the leading edge of the wing, is the **propatagium**. Several delicate muscles and tendons lie within it. A large **postpatagium** projects posteriorly from the ulna. With the wing outstretched, gently push back on the leading edge of the propatagium. The tension you feel is due to the **long tendon** (see below). Begin skinning the wing ventrally, near the central part of the brachium, and work your way anteriorly. As you approach the leading edge, be watchful of the tendon, a thin, whitish strand, and uncover it. Proceed to skin the rest of the wing up to the carpus. Then continue skinning the dorsal surface of the wing and body.

The dominance of the pectoralis can now be appreciated. It arises from the sternum and, being the main depressor of the wing, inserts mainly on the humerus. The shoulder is covered mainly by several parts of the **deltoideus** muscle (Figures 8.10 and 8.11). Anteriorly, the deltoid is represented by the **pars propatagialis,** a single hypertrophied belly consisting of **long** and

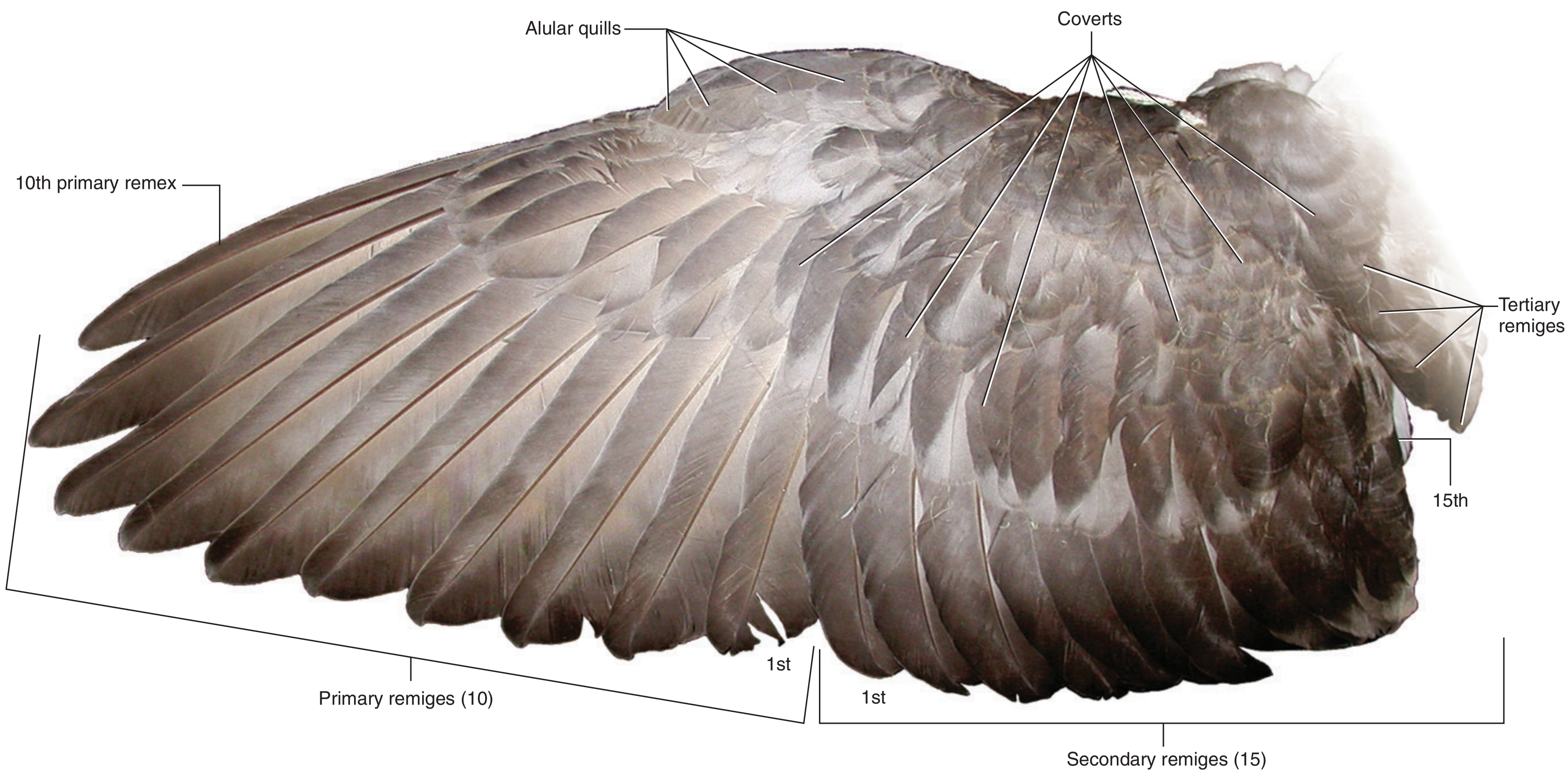


FIGURE 8.9 Extended left wing of the pigeon, in dorsal view, showing arrangement of feathers.

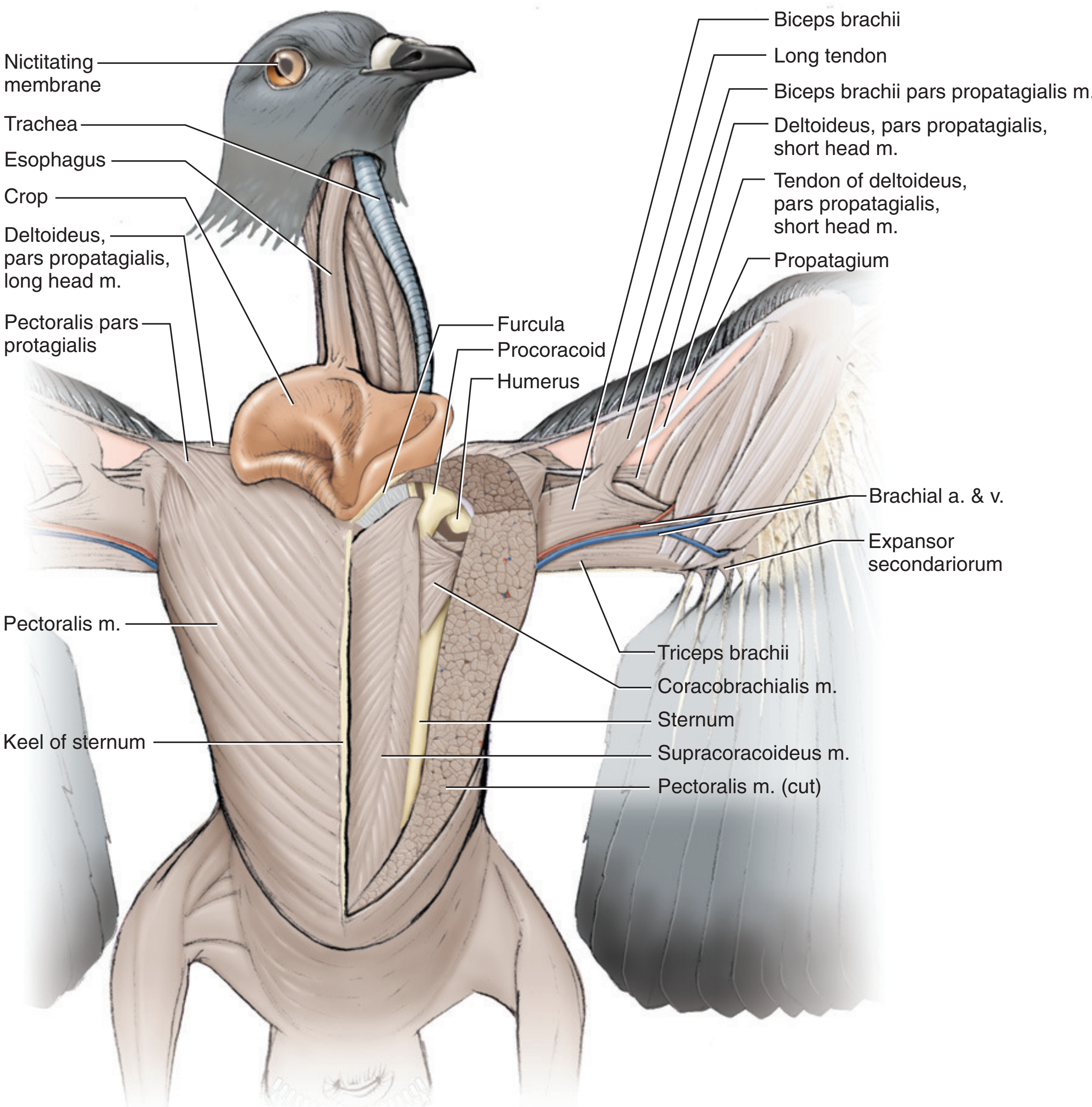


FIGURE 8.10 Pectoral and wing musculature of the pigeon in ventral view. Left-side pectoralis muscle cut away to show underlying structures.

short heads. The long head is the smaller, anterior, sheet-like portion. The more posterior short head is thicker. The long head is just anterior to a small, triangular slip of the pectoralis that inserts on the common belly of the pars propatagialis. The tendon of the long head, the long tendon noted above, extends laterally toward the carpus and divides into two separate tendons, but these may be difficult to discern. Distally, the short head forms a tendinous sheet that mainly spreads to cover the muscles on the antebrachium. The **biceps brachii** muscle covers the anteromedial part of the brachium. The pars propatagialis is a slip of the biceps and arises from its anterior edge. Anteriorly, the pars propatagialis fuses with the tendon of the long tendon. Its distal end gives rise to a tendon that angles distally to fuse with one of the divisions of the long tendon. The wing muscles described in this paragraph, except the biceps brachii, serve mainly to alter tension of the wing surface. They are commonly referred to as tensors and play a significant role in flight aerodynamics.

Several other wing muscles may be noted. Just posterior to the short head of the pars propatagialis of the deltoideus is the **deltoideus major**, which pulls the humerus medially and posteriorly. The triceps brachii has three portions, but only two of them, the **scapulotriceps** and **humerotriceps**, can be readily identified. The third, the coracotriceps, is a small muscle arising from the tendon of the **expansor secundariorum**. This tendon extends

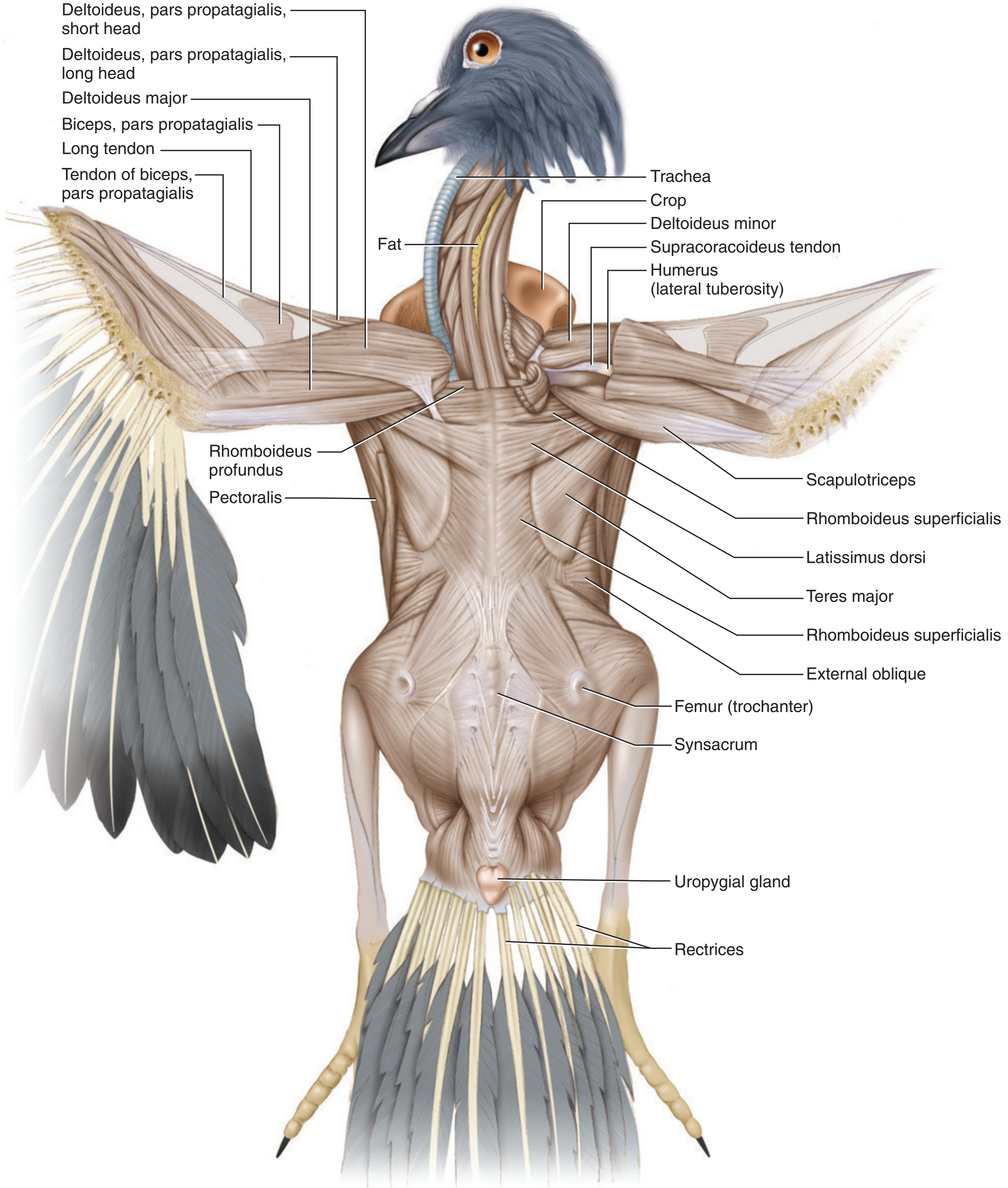


Figure 8.11 Musculature of the pigeon in dorsal view.

from the axilla, or armpit, along the posterior edge of the triceps brachii. Carefully dissect the margin of the postpatagium to find the small and delicate muscular portion, which fans onto the quills of the secondary remiges. The expansor secundariorum acts to spread the secondaries.

The main elevator of the wing is the **supracoracoideus**, which lies deep to and is covered entirely by the pectoralis. To expose it, make a cut through the pectoralis near its center and at right angles to the fiber direction, but do so only a few millimeters at a time. Spread the incision as you cut. This will help avoid damaging the

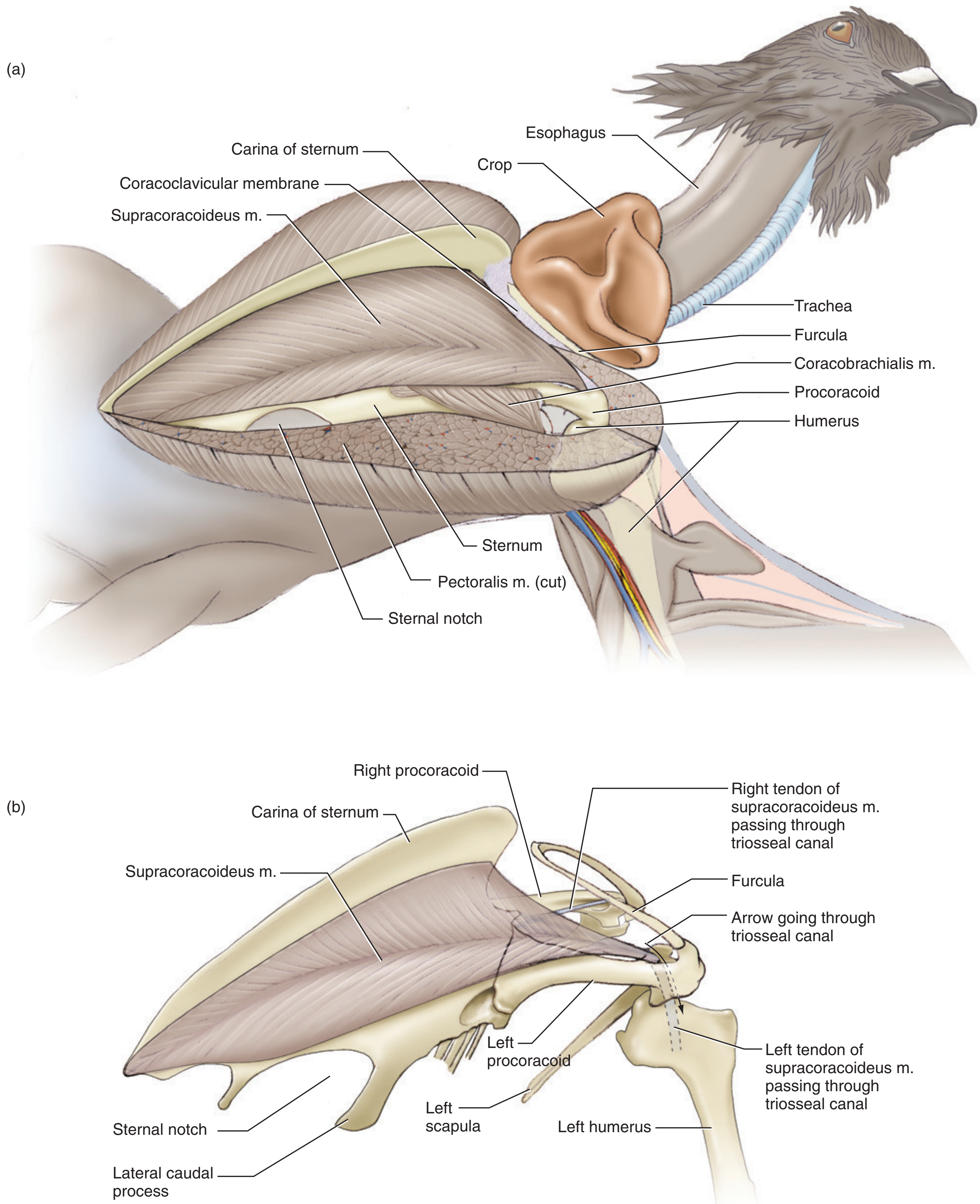


FIGURE 8.12 Pectoral musculature of the pigeon in left ventrolateral view. (a) Left-side pectoralis muscle cut away. (b) Sternum and appendicular skeleton isolated to show supracoracoideus muscle and the course of its tendon through the triosseal canal.

underlying supracoracoideus. Once you have cut through the pectoralis and identified the supracoracoideus, cut out a large portion of the pectoralis to expose the supracoracoideus (Figures 8.10 and 8.12). Its fibers converge toward the middle of the muscle and extend to a stout anterolaterally directed tendon that passes through the triosseal canal onto the dorsal surface of the humerus. This acts as a pulley system, through which the wing is elevated mainly by a muscle, the supracoracoideus, that lies ventral to the wing. This arrangement enhances stability for flight by maintaining the center of gravity below the wings. To see the tendon of the supracoracoideus (Figures 8.10–8.12), cut the deltoideus major and the pars propatagialis of the deltoideus near their center and reflect them. You will uncover the **deltoideus minor**, which contributes to elevation of the wing. The tendon passes just posterior to the posterior margin of the deltoideus minor.

Other musculature that may be noted without much further effort includes the **rhomboideus superficialis** and **rhomboideus profundus**, which extend between vertebral spines and the scapula. The superficialis covers all but the anteriormost portion of the profundus. The **latissimus dorsi** is a relatively small muscle extending laterally from the middorsal line. These muscles form part of the complex of muscles that help support and stabilize the shoulder. Although there are various other back muscles, an interesting condition in birds is the relative lack or smaller size of the back musculature as compared, for example, with that of the cat. Strength and stability of the trunk is not compromised, however, as the skeletal elements are firmly fused together (see above), and this in turn allows the musculature to be reduced to minimize weight.

Key Terms: Musculature

biceps brachii

crop

deltoideus

deltoideus major

deltoideus minor

esophagus

expansor secundariorum

humerotriceps

latissimus dorsi

long tendon of **long head, pars propatagialis** of **deltoideus**

pars propatagialis of **biceps brachii** (biceps slip, biceps propatagialis, patagial accessory)

pars propatagialis, long and **short heads** of **deltoideus**

pectoralis

postpatagium

propatagium

rhomboideus profundus

rhomboideus superficialis

scapulotriceps

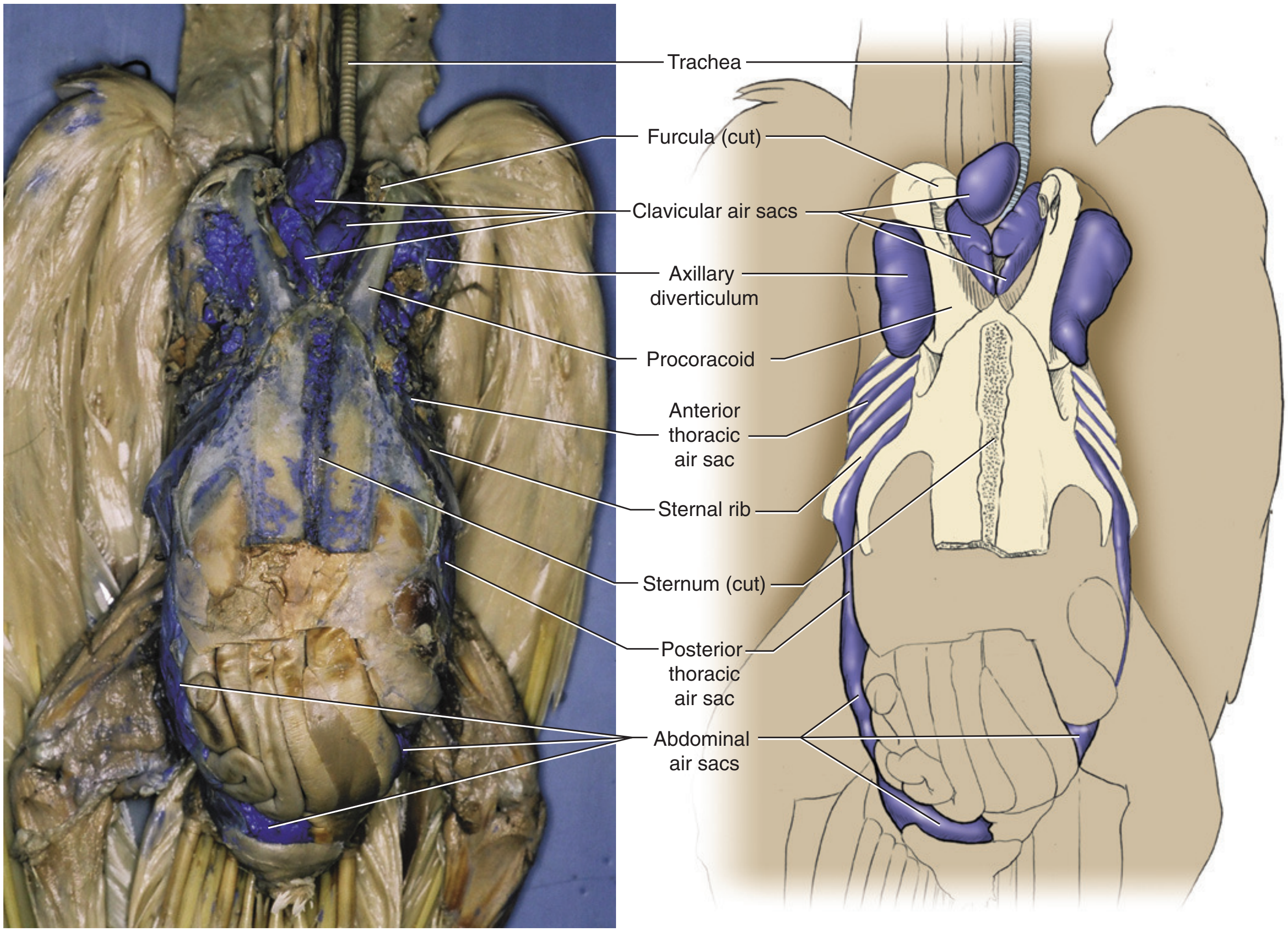
supracoracoideus

Section IV—Body Cavity, Viscera, and Vessels

The sternum and pectoral musculature must be removed to examine the structures within the body cavity, including viscera and blood vessels. Unfortunately, removal of the sternum and muscles as described below often obliterates much of the extensive respiratory system, the **air sacs** that form auxiliary air pathways in the avian respiratory system. This system was noted above in connection with the continuation of this system into several bones of the body. In birds, the respiratory system is arranged to produce a continuous stream of air through the lungs, which is made possible by the presence of the air sacs. In contrast, the system in other air-breathing vertebrates, in which air passes into and out of the lungs through the same pathway, results in a residual volume of air in the lungs. The avian system is considerably more efficient and allows the high metabolic levels required for sustained flight. The system is also involved in cooling. Although some of the air sacs can be seen when the body cavity is exposed, the system is best seen and appreciated in a prepared specimen. If a preparation is available, use Figure 8.13 to identify the major air sacs.

Return to the task of exposing the body cavity. Clear the connective tissue from the lateral part of the pectoral muscles, just posterior to the axillary regions, but do not damage any vessels. Make a longitudinal incision through the abdominal muscles, just to one side of the midventral line, and, using stout scissors, follow anteriorly along the lateral margin of one of the pectoral muscles, cutting through the ribs as you do so. Lift the sternum as much as possible and clear the connecting tissue until you see the vessels that pass to the sternum, so that you will avoid damaging them. Using a sharp scalpel, cut through the anterior part of the pectorals, as shown in Figure 8.14. You will also need to cut (with stout scissors) through the furcula and coracoid. Repeat this procedure for the pectorals on the other side. You will then be able to lift the sternum with the pectoral musculature attached to it. Remove the sternum by clearing the connective tissue between it and the deeper structures. Cut through the vessels, the **pectoral arteries** and **veins** (Figure 8.14), extending to the breast as close to the sternum as possible.

Note the **heart** (Figure 8.14) lying anteriorly on the midline. Its four main chambers include the **left** and **right atria** (sing., **atrium**) and **left** and **right ventricles** (a very small **sinus venosus** is also present but will not be identified). The **lungs**, right and left, are tucked laterally to the heart. Probe to find them, and partially remove the serosa covering them to see their spongy texture. Posterior to the heart are the lobes of the **liver**; note that

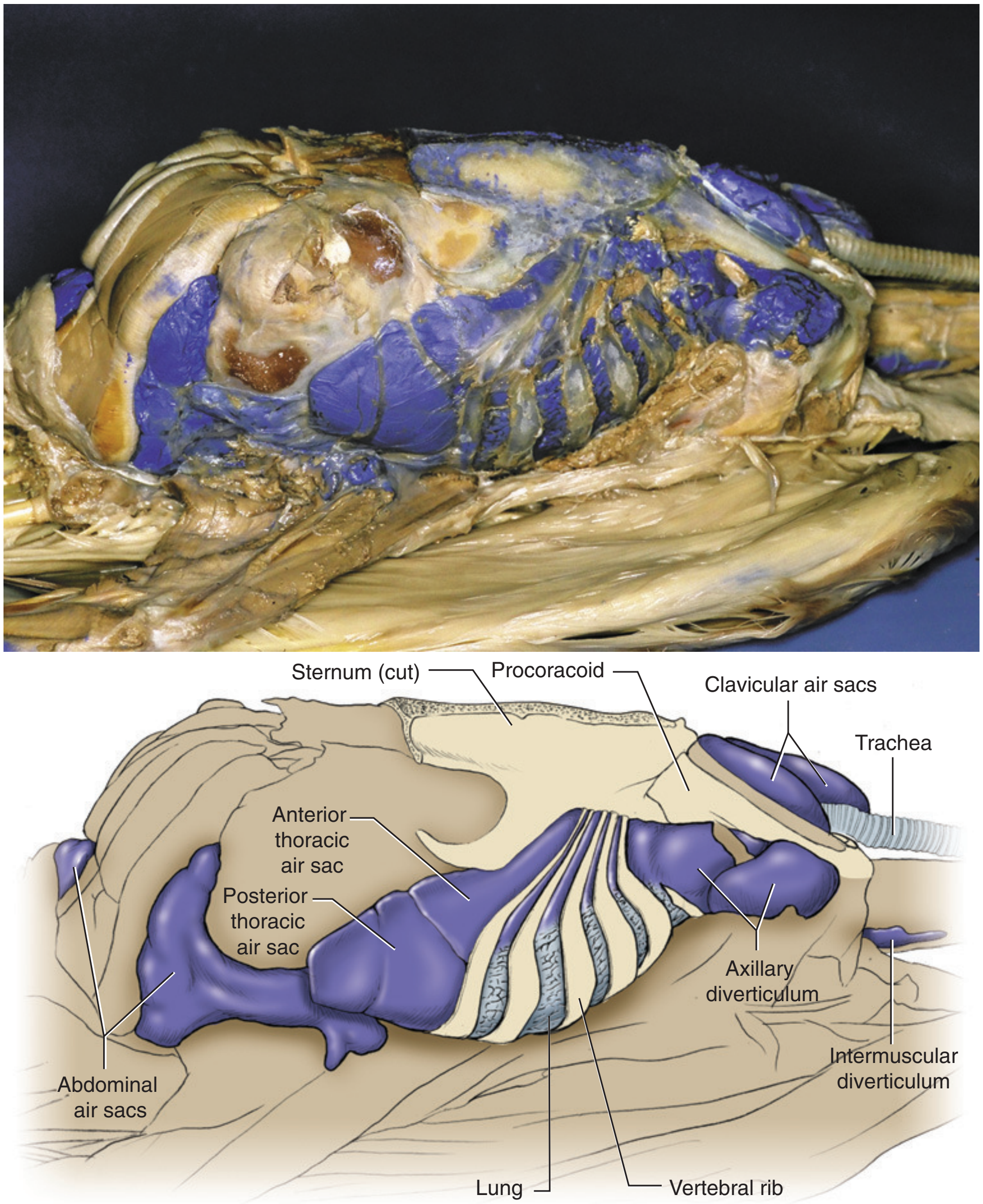


(a)

Figure 8.13 Photographs and interpretive illustrations of trunk of the pigeon to show the arrangement of major airs sacs of the respiratory system. (a) Ventral view. (b) Left lateral view (see page 243).

the right lobe is considerably larger than the left. Tucked deep to these lobes, on the left side, is the **gizzard**, the very muscular, distal portion of the complex, two-part **stomach** of birds. The glandular **proventriculus**, the anterior part of the stomach (though it is actually a modification of the distal part of the esophagus), continues posteriorly from the **esophagus** and lies deep to the heart, as does the posterior part of the trachea. These structures will be seen shortly (Figure 8.15). The highly coiled **small intestine** is relatively long, in contrast to the short and straight **large intestine** (Figures 8.16 and 8.17). The division between these structures is marked by the presence of a pair of small diverticula, the **colic ceca**.

Return to the heart (Figure 8.14). The **ascending aorta** arches anteriorly from the left ventricle and gives off the paired **brachiocephalic arteries** before curving to the right and posteriorly as the **aortic arch**. Each brachiocephalic soon divides into a smaller **common carotid artery** and larger **subclavian artery**. The common carotid is a short artery that extends anteriorly to the base of the neck, where it divides into several arteries. The most apparent branch is the **internal carotid artery**, which extends anteriorly along the midventral surface of the neck, close beside the other side's internal carotid. These vessels converge and continue together, deep to the musculature, toward the base of the neck. Each gives off several branches, including the external carotid artery. The other branch of the common carotid gives rise to several, mainly anastomosing, vessels that ascend the neck dorsal to the internal carotid, but it is not necessary to attempt to trace these. The subclavian artery extends laterally for a short distance (after the origin of the common carotid) before subdividing into the **axillary artery** and pectoral artery, already noted above. The latter is a large vessel that quickly branches into several smaller arteries to supply the extensive pectoral musculature. The axillary artery gives off several branches before continuing into the arm as the **brachial artery**.



(b)

FIGURE 8.13 *Continued*

Most of the regions supplied by these arteries are drained by veins that ultimately enter the **right** or **left anterior vena cava**, each of which is formed by the confluence of three large vessels, the **jugular**, **subclavian**, and **pectoral veins**. The jugular lies along the lateral surface of the neck, draining the head and neck. The right jugular is usually larger than the left. The subclavian vein is a short segment that mainly receives the **axillary vein**, which in turn receives the **basilic vein** from the arm. It is the basilic and not the **brachial vein** that follows the brachial artery. The brachial vein is represented by an anterior branch of the axillary that divides into two narrow vessels along the anterior margin of the brachial muscle. The pectoral vein, which divides further into branches much as those of the pectoral artery, usually enters the anterior vena cava but enters the subclavian in some specimens. The right anterior vena cava proceeds almost directly posteriorly to enter the sinus venosus, but the left anterior vena cava turns right and crosses the heart to enter the sinus venosus. The **posterior vena cava** (Figures 8.16–8.18) is a large vessel that drains the posterior part of the body. It can be found by lifting the lateral margin of the right atrium. Its branches will be followed shortly.

The **pulmonary trunk** leaves the right ventricle and almost immediately splits into **left** and **right pulmonary arteries** (Figures 8.14 and 8.15) to the lungs. The left

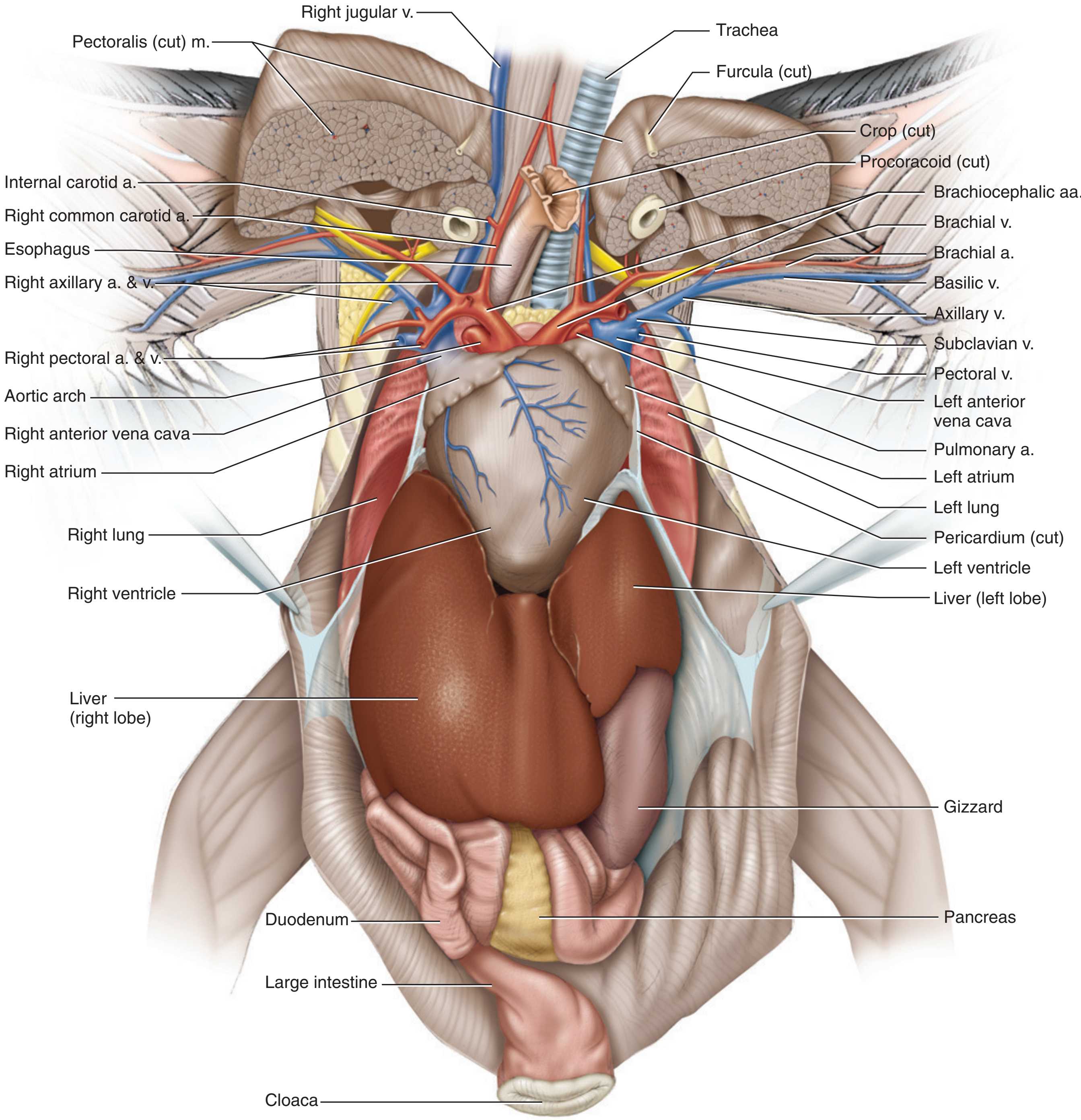


FIGURE 8.14 Trunk of the pigeon in ventral view. Pectoral musculature and sternum removed to reveal heart, viscera, and vessels.

pulmonary artery is easily apparent and can be found passing dorsal to the left brachiocephalic artery. There are two **right** and two **left pulmonary veins** that return blood from the lungs. These vessels enter the left atrium separately. They are not easy to find, but will be seen when the heart is removed (Figure 8.15).

Lift the heart and note the great vessels, just described, associated with it. Cut each vessel, and remove the heart. This will expose the lungs and allow you to follow the trachea and esophagus posteriorly (Figure 8.15). The trachea is held open by cartilaginous rings. More posteriorly it bifurcates into left and right **bronchi**, which extend into the lungs. The **syrinx** is the sound-producing organ located at the base of the trachea. Examine the cut vessels, and identify the pulmonary arteries and pulmonary veins. The latter exit the lungs just posterior to the entrance of the bronchi. There

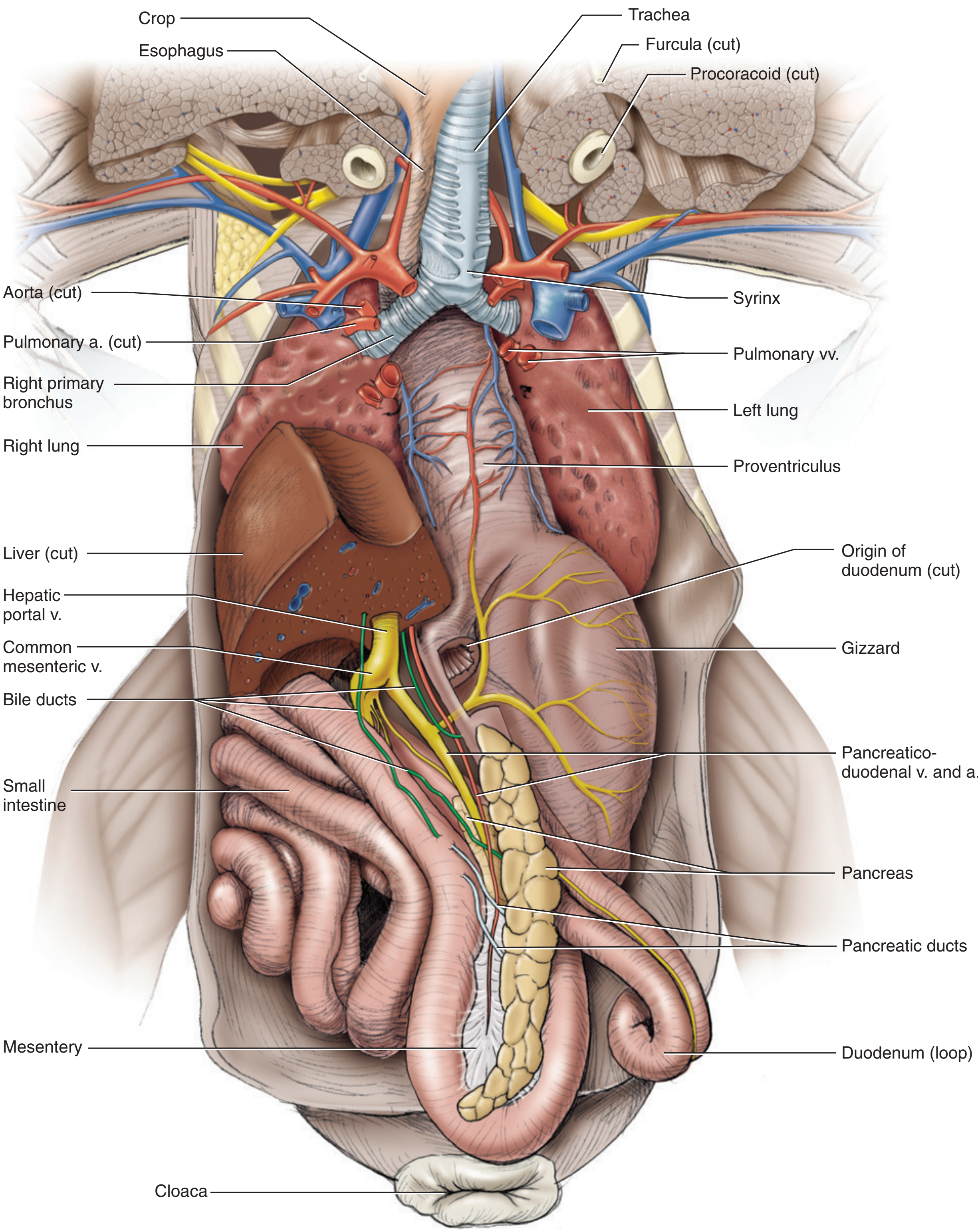


FIGURE 8.15 Trunk of the pigeon in ventral view. Pectoral musculature and heart removed to reveal viscera and vessels.

are two main veins on each side but it may be difficult to discern them. The pulmonary arteries enter the lungs somewhat anterior to the bronchi.

Remove the left lobe of the liver, being careful not to injure vessels external to it. Once it has been removed, you will be able to follow the esophagus to the stomach. In birds, the stomach is a complex, two-part organ. The more proximal proventriculus secretes strong hydrochloric acid and digestive enzymes that begin the chemical digestion of food. The thicker, muscular gizzard performs most of the mechanical breakdown of food.

Next, examine the intestines. Note that they are bound by mesentery. Various vessels will be seen either supplying or draining the viscera. For the time being, identify the large **hepatic portal vein** (Figure 8.15) that extends between the viscera and the right lobe of the liver. Lift the lobe to note the entrance of the vein into the liver. Cut the portion (and only that portion) of the right lobe that is posterior to the entrance of the hepatic portal vein. You will now be able to follow the intestinal tract more easily. The **duodenum**, the first part of the **small intestine**, arises from the junction of the proventriculus and gizzard. It makes a long loop, consisting of ascending and descending portions that lie close together. Between them is the narrow, elongated **pancreas**. Follow the remaining part of the small intestine. It passes into the short and straight large intestine, which continues posteriorly into the cloaca. A pair of small **colic ceca** (sing., **cecum**) mark the division between the small and large intestines.

Return to the duodenum. Carefully dissect the connective tissue between its ascending and descending portions and the pancreas. You will reveal several structures, including the bile ducts and pancreatic ducts (Figure 8.15). There are three of the latter, but only two are readily apparent. Also, you will reveal a large vein, the **pancreaticoduodenal vein**, accompanied by the smaller **pancreaticoduodenal artery**, associated with the pancreas.

Carefully uncoil the intestines to observe that the **posterior mesenteric vein**, a branch of the hepatic portal system, extends posteriorly and eventually joins the venous system of the posterior abdominal cavity (see Figures 8.16–8.18). Once the hepatic portal system has been studied, find the point where the posterior vena cava, which returns blood from most of the body posterior to the heart, passes through the left lobe of the liver. This occurs dorsal to the entrance of the hepatic portal vein. Cut through the vena cava and remove the remainder of the liver. Cut through the distal end of the proventriculus, just dorsal to its union with the gizzard. Find the **celiac** and **anterior mesenteric arteries** (Figure 8.16) as they emerge from the aorta, just to the right of the distal end of the proventriculus. The ovoid, dark-colored **spleen** lies in this region as well and can vary in size. Follow the celiac artery, noting its main branches. Cut through them and the anterior mesenteric artery. Also cut through the posterior end of the small intestine, just anterior to the colic ceca, and the posterior mesenteric vein. Then remove the digestive tract.

Clear away connective tissue to expose the urogenital structures and the vessels lying on the dorsal wall of the abdominal cavity. Each **kidney** is superficially subdivided into three lobes by the vessels that pass through it. Males (Figure 8.16) possess a pair of approximately bean-shaped **testes**. Each lies on the anterior lobe of a kidney. In nonbreeding males, the testes are much smaller than in breeding males and may be difficult to identify. The **vas deferens** carries semen from the testis to the cloaca. It leaves, slightly expanded, the dorsomedial side of the testis and extends posteriorly to the cloaca as a relatively straight, narrow tube. It is slightly wider and may be convoluted in breeding males. It passes for most of its length along the medial side of the **ureter**, the wider tube that carries urine from the kidneys to the cloaca. The ureter emerges from between the anterior and middle lobes of the kidneys. Near the cloaca, the vas deferens crosses the surface of the ureter and extends to the cloaca, lateral to the ureter.

In females (Figure 8.17) only the left-side reproductive organs are present, those of the right side having degenerated soon after their initial formation. The **ovary** lies on the anterior end of the left kidney. Its morphology and size varies in accordance with the breeding season. The ovary contains numerous spherical **follicles** in various stages of development. Mature ova pass from the ovary and enter the oviduct through its anterior opening, the **ostium**. The **oviduct** is a relatively straight tubular structure (Figure 8.17) that becomes large and convoluted. It conducts the ovum to the cloaca and is subdivided into glandular portions that perform specific roles (such as secreting the shell membrane or the shell itself), but these portions are not identifiable grossly. The left and right ureters of the female are in the same position as in the male. A vestigial posterior portion of the right oviduct may be present along the posteromedial end of the right ureter.

Return to the posterior vena cava and follow it posteriorly (Figures 8.16–8.18). It is formed at the level of the anterior part of the kidneys by the confluence of the **right** and **left common iliac veins**. An **anterior renal vein**, draining the anterior lobe of the kidney, enters each common iliac. The common iliac turns laterally between the anterior and medial lobes of the kidney. As it does

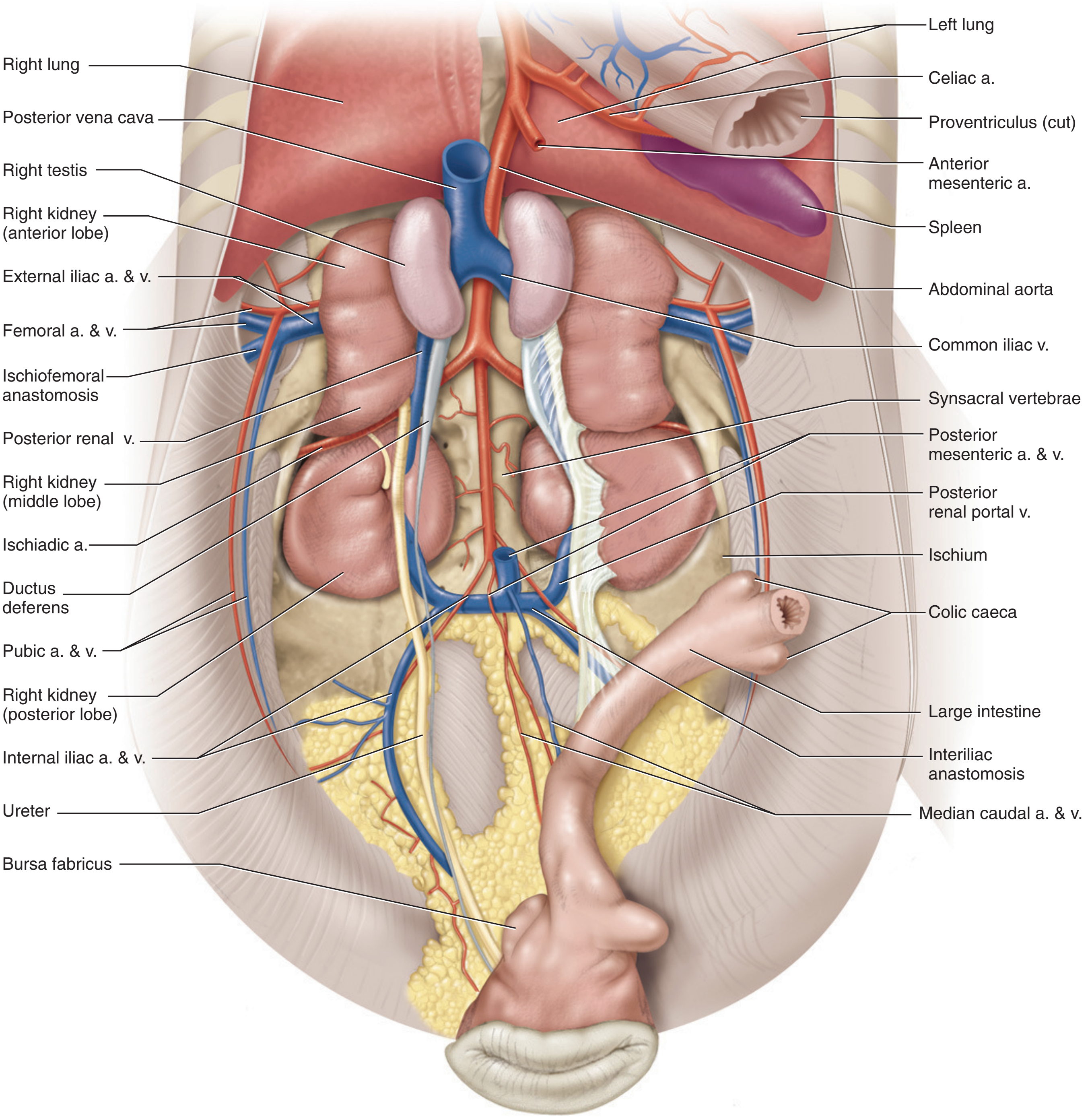


FIGURE 8.16 Posterior end of the pleuroperitoneal cavity of the male pigeon in ventral view. Gizzard and small intestine removed to show urogenital structures, viscera, and vessels.

so, it receives the **posterior renal vein,** a large vessel that extends posteriorly on the kidney with the ureter and vas deferens in the male and the oviduct (left side only) in the female. The posterior renal vein arises from several branches in the posterior lobe of the kidney and receives a branch from the middle lobe of the kidney.

The **posterior renal portal vein** enters the posterior lobe of the kidney. To follow its path, as well as that of many other veins in this region, kidney tissue must be removed (Figure 8.18). Begin by exposing the posterior portions of the posterior renal vein. Then follow the posterior renal portal vein as it passes anteriorly through the kidney, deep to the posterior renal vein. Between the posterior and middle lobes of the kidney, the renal portal receives the **ischiadic vein,** which is the main vein of the hind limb. The paired **ischiadic arteries** lie ventral to the ischiadic veins and are easily seen. Trace the

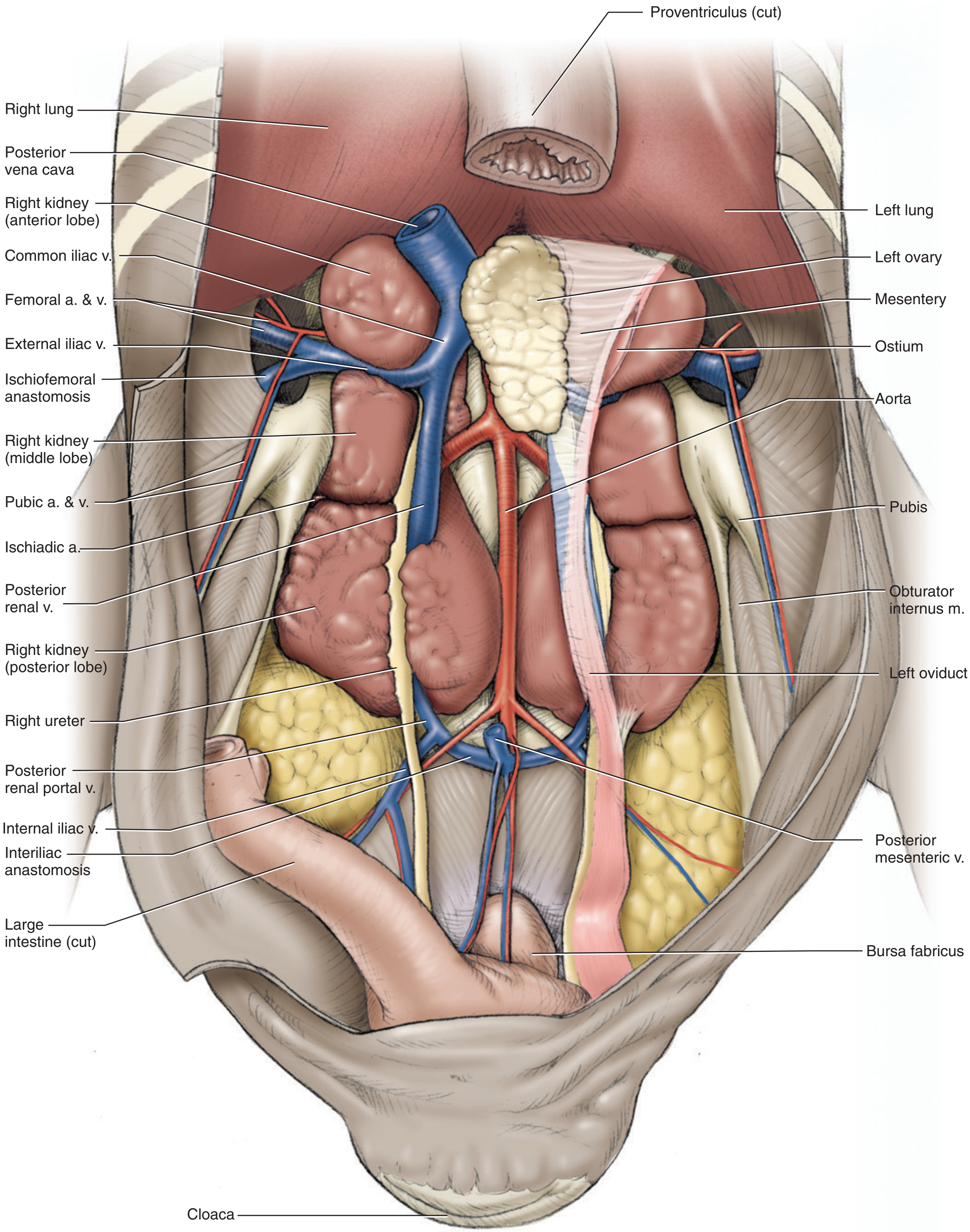


FIGURE 8.17 Posterior end of the pleuroperitoneal cavity of the female pigeon in ventral view. Gizzard and small intestine removed to show urogenital structures, viscera, and vessels.

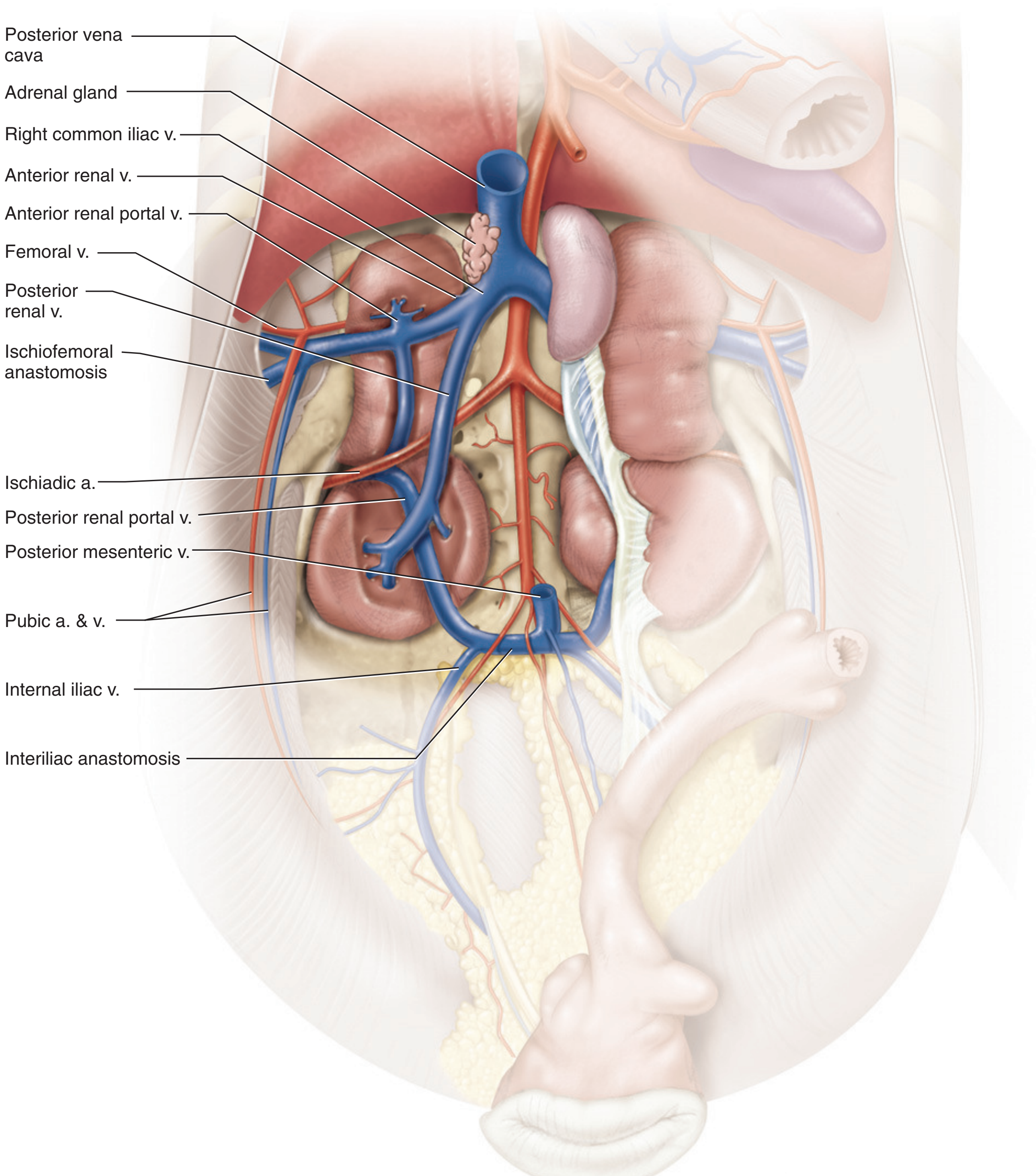


FIGURE 8.18 Posterior end of the pleuroperitoneal cavity of the (male) pigeon in ventral view. The right-side kidney has been dissected to reveal the pattern of renal and renal portal veins.

origin of one from the descending aorta. The artery supplies the middle and posterior lobes of the kidney. Follow the ischiadic vein laterally, but do not damage the superficial and narrow **pubic vein** and **artery** lying on the musculature along the pubic bone. The ischiadic vein, accompanied by the ischiadic artery, passes through the ilioischiadic foramen (Figure 8.6) as it enters the abdominal cavity from the hind limb.

Continue to follow the posterior renal portal vein. Between the anterior and middle lobes of the kidney, the renal portal vein unites with the external iliac vein to form the common iliac vein. The **anterior renal portal vein** enters almost directly opposite that of the posterior renal portal vein. Follow the external iliac vein laterally to its tributary, the **femoral vein,** which drains most of the anterior part of the thigh. The main vein of the hind limb is the ischiadic vein, but most of the blood is diverted to the femoral vein by the **ischiofemoral anastomosis**, a large vessel between the ischiadic and femoral veins. It appears as a large branch, larger indeed than the femoral, passing posteriorly deep to musculature. You may follow it by cutting through the musculature. Lastly, note the anterior of the pubic vein, draining the lateral abdominal wall, near the origin of the external iliac. The **external iliac artery** lies deep to the external iliac vein. Carefully probe to find it. It gives rise to the **femoral artery**, supplying the hind limb, and the pubic artery, supplying the lateral abdominal wall. Trace the external iliac artery to its origin from the descending aorta. Further anteriorly, note the **anterior renal artery**, which supplies the anterior and middle lobes of the kidney.

Examine the posterior end of the abdominal cavity. The posterior renal portal vein is formed by the confluence of the narrower **interior iliac vein** and the wider, transversely oriented **interiliac anastomosis**. The posterior mesenteric vein, which was cut during removal of the intestines, arises from the middle of the interiliac anastomosis and passes anteriorly as part of the hepatic portal system. A small branch accompanies the **posterior mesenteric artery** to the posterior end of the large intestine. The narrow **median caudal vein** enters the interiliac anastomosis opposite the origin of the posterior mesenteric vein. The internal iliac vein drains the posterolateral region of the abdominal cavity. The **internal iliac artery** accompanies the internal iliac vein. Beyond the origin of the internal iliac arteries, the descending aorta continues posteriorly as the **median caudal artery**.

Key Terms: Body Cavity, Viscera, and Vessels

air sacs
anterior mesenteric artery
anterior renal artery
anterior renal portal vein
anterior renal vein
anterior vena cava, right and **left**
aortic arch
ascending aorta
atrium (plur., **atria**), **right** and **left**
axillary artery
axillary vein
basilic vein
brachial artery
brachial vein
brachiocephalic artery, right and **left**
bronchi
celiac artery
colic ceca
common carotid artery
common iliac vein, right and **left**
duodenum
esophagus
external iliac artery
femoral artery
femoral vein
follicles
gizzard
heart
hepatic portal vein
interiliac anastomosis
interior iliac vein
internal carotid artery
internal iliac artery
ischiadic arteries
ischiadic vein
ischiofemoral anastomosis
jugular vein
kidney
large intestine
liver
lungs
median caudal artery
median caudal vein
ostium
ovary
oviduct
pancreas
pancreaticoduodenal artery
pancreaticoduodenal vein
pectoral arteries
pectoral vein
posterior mesenteric artery
posterior mesenteric vein
posterior renal portal vein
posterior renal vein
posterior vena cava
proventriculus
pubic artery
pubic vein
pulmonary artery, right and **left**
pulmonary trunk
pulmonary vein, right and **left**
sinus venosus
small intestine
spleen
stomach
subclavian artery
subclavian vein
syrinx
testes
ureter
vas deferens
ventricle, right and **left**