Lab Overview

Concepts and definitions

We will examine vertebrate morphology comparing the structure and function of systems and structural units among the major groups. This comparative method allows us to analyze the evolutionary history of structures. Evolution is the long term effect of the adaptation of a species to its environment (i.e. the change of function and structure) and is the product of natural selection. In this lab we will be able to trace the history of such adaptations and gain a better understanding of how an organism evolves.

The study of morphology is useful for understanding the phylogenetic relationships among organisms.

Systematics is an ordered system for the study of relationships among organisms. There are three major components to systematics.

Taxonomy is the naming of organisms.

Classification makes statements about the relationships among organisms. There are different classifications.

Phylogenetic reconstruction tries to reflect the evolutionary history of the group.

Homology refers to an intrinsic similarity indicating a common evolutionary origin (shared ancestry). Homologous characters may seem unalike superficially, but can be proved to be equivalent by the following criteria: similarity of anatomical construction, similar topographic relations to the animal body, similar physiological function, and similar courses of embryonic development.

Analogy means there's a similarity of function or appearance in structures of two species not related. It is due to convergent evolution.

Primitive character in an organism means that the character is similar to that of the ancestors of the organism or that it is shared by all living groups related to one another (e. g. five digit limbs).

Derived character in an organism means that the character has changed from the one present in the ancestors of the organism (e.g. human brain).

Paedomorphosis – The adult stage possesses features typical of the juvenile stage of the organism's ancestor. It is the end result of one of several processes of **heterochrony** (evolution in the development of individuals). Two such processes of heterochrony that result in paedomorphosis are:

Neoteny – Development of some or all somatic features is retarded relative to sexual maturation, resulting in sexually mature individuals with juvenile features. (e.g., salamanders, humans).

Progenesis/ paedogenesis – A decrease of the duration of ontogenetic development, resulting in retention of juvenile features in the sexually mature adult. That is, organism becomes sexually mature rapidly (e.g. some parasitic crustaceans).

When referring to certain morphological features of an organism there are particular terms that are used to describe the direction in which these features occur on the organisms body. They are used for the location of a single feature and also to refer to the placement of one feature to another.

Cranial/ rostral – Towards the head end of a quadruped.

- **Superior** – Towards the head end of bipedal organism (e.g. humans).

Caudal – Towards the tail end of a quadruped.

- **Inferior** – Towards the feet of a bipedal organism (e.g. humans).

Dorsal – Towards the back of a quadruped.

- **Posterior** – Towards the back of a bipedal organism (e.g. humans).

Ventral – Towards the belly of a quadruped.

- **Anterior** – Towards the belly of a bipedal organism (e.g. humans).

Lateral – Refers to the side of the body.

Medial – Refers to a position towards the midline.

Median – Used for a structure in the midline.

Distal – Refers to a part of some organ, appendage, blood vessel, etc. that is farthest from the point of reference (e.g. human hands are distal to the center of the body).

Proximal - Refers to a part of some organ, appendage, blood vessel, etc. that is nearest from the point of reference (e.g. human shoulders are proximal to the center of the body).

Left and right – They always pertain to the specimen's left and right.

-ly or **–ad –** Form adverbs from the above adjectives and the new term implies motion in a given direction (e.g. caudally, or caudad, means that it moves towards the tail).

Planes and sections of the body

Sagittal – A longitudinal, vertical section from dorsal to ventral that passes through the median longitudinal axis of the body. It lies in the sagittal plane.

Parasagittal – Parallel, but lateral to, the sagittal plane.

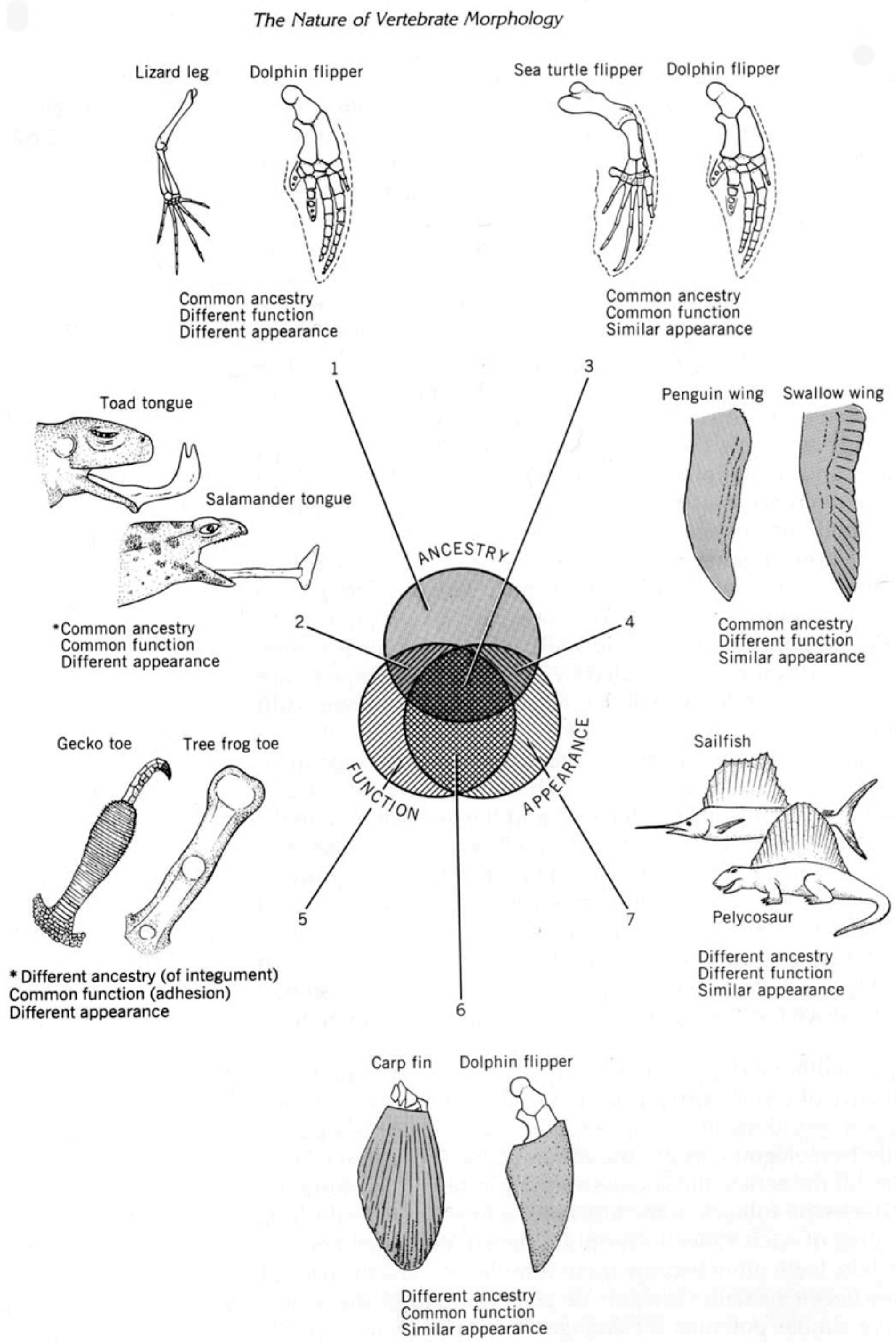
Transverse – A section cut across the body from dorsal to ventral, and at right angels to the longitudinal axis. It lies in the transverse plane.

Frontal (coronal) – Lying in the longitudinal axis, and passing horizontally from side to side.

Chordates

There are four characteristics that define an organism as a chordate.

1. Notochord – All chordate embryos have a notochord, which is a longitudinal, flexible rod located between the gut and the nerve cord. In some invertebrate chordates and primitive vertebrates, the notochord persists to support the adult, but in most vertebrates a more complex, jointed skeleton develops and the adult retains only remnants of the embryonic notochord.
2. Dorsal, hollow nerve cord – The nerve cord of a chordate embryo develops from a plate of dorsal ectoderm that rolls into a tube located dorsally to the notochord. The chordate nerve cord forms the central nervous system – the brain and spinal cord.
3. Pharyngeal slits – The lumen of the digestive tube of nearly all chordate embryos opens to the outside through several pairs of slits located on the flanks of the pharynx, the region of the digestive tube just posterior to the mouth. Probably functioned in early chordates as devices for filter feeding but became modified for gas exchange and other functions during vertebrate evolution.
4. Postanal tail – Most chordates have a tail extending beyond the anus. The chordate tail contains skeletal elements and muscles and provides much of the propulsive force in many aquatic species.



The distinctions and relations among common ancestry (homology), common function (analogy), and common appearance. For example: in #2 the tongues are homologous, but the projection mechanisms are not; in #5 the critical parts of the integument are not homologous, but the toes are.

Invertebrate Chordates

- **Subphylum Cephalochordata**
  - Known as lancelets because of their bladelike shape, they closely resemble the idealized chordate. A tiny marine animal only a few centimeters long, the lancelet wiggles backward into the sand, leaving only its anterior end exposed. The animal feeds by using a mucous net secreted across the pharyngeal slits to filter tiny food particles from seawater drawn into the mouth by ciliary pumping. The water exits through the slits, and the trapped food passes down the digestive tract.

    - The lancelet frequently leaves its burrows and swims to a new location. Though a feeble swimmer, the lancelet displays, in rudimentary form, the method of swimming that fish use. Coordinated contractions of muscle segments, serially arranged like rows of chevrons (<<<) along the sides of the notochord, flex the notochord from side to side in a sinusoidal (~) pattern.
- **Subphylum Urochordata**
    - Commonly called tunicates. Most tunicates are sessile marine animals that adhere to rocks, docks, and boats. Seawater enters the animal through an incurrent siphon, passes through the slits of the dilated pharynx into a chamber called the atrium, and exits through an excurrent siphon. The food filtered from this water current by a mucous net is passed by cilia into the intestine. The anus empties into the excurrent siphon. The entire animal is cloaked in a tunic made of a cellulose-like carbohydrate called tunicin. Because they shoot a jet of water through the excurrent siphon when molested, tunicates are also called sea squirts.
    - The adult tunicate scarcely resembles a chordate. But all four chordate trademarks are manifested in the larval form of some groups of tunicates. The larva swims until it attaches by its head to a surface and undergoes metamorphosis. The larva is mostly a habitat-seeking form.

Lamprey dissection

Characteristics of lampreys and hagfishes

Lampreys:

- 1 or 2 dorsal fins, separate from caudal fin
- eyes well developed in adults
- barbels absent
- teeth on oral disk and tongue
- sexes separate
- larval stage termed ammocoete
- distribution is anadromous and freshwater, mainly found in cool zones of the world
- parasitic (anadromous and freshwater) and nonparasitic (freshwater) life styles

Hagfishes:

- dorsal fin absent (caudal fin extends onto part of the dorsal surface)
- eyes degenerate, lens absent, eye musculature absent
- barbels present around mouth
- teeth only on tongue
- numerous mucous pores along body
- ovaries and testes in same individual but only one gonad functional
- no larval stage
- scavenger life style

Natural history of lampreys and hagfishes

Lampreys – Length 10-60 cm; 100 cm max. They are eel-like, with lateral eyes and a ventral mouth consisting of a circular disc set with horny teeth. They are characterized by the lack of paired fins and scales. The skeleton is cartilaginous and not well developed except for the skull and branchial region. No vertebral centra are developed. Dorsal and caudal fins are present. The gallbladder and bile ducts disappear in adults.

All lampreys share a long larval life. Very small eggs, 1mm in diameter and deprived of any specialized shell, are deposited in nests made in gravel bottoms of streams.

When the tiny larvae hatch they drift to soft bottoms in pools and eddies and begin a life of straining out organic matter at the mud-water interface. This period may be up to five years or so in length, after which metamorphosis takes place and a new type of existence is begun. The larvae are radically different from their parents; they were originally described as a distinct genus, Ammocoetes. This name has been retained as a vernacular name for the larval form.

There are two types of lampreys, parasitic and nonparasitic. The parasitic type make their living by attacking fishes with their sucking mouths, rasping holes in the skin with their piston-like tongues, and pumping out blood and body fluids. Lampreys do not generally kill their host but detach, leaving a weakened animal with an open wound. The digestive tract is reduced, as is appropriate for such a rich and easily digested diet such as blood and other fluids. Some lampreys of this type are anadromous, spending their adult growth period in salt water before returning to streams to spawn and die. Others remain freshwater, or some are strictly freshwater.

Nonparasitic lampreys are usually called "brook" lampreys. These confine feeding to the larval stage, and after metamorphosis they spend a few months in hiding while the gonads mature. They then spawn and die.

Except for the tropics, lampreys are worldwide in distribution.

Hagfishes – Length 40-60 cm; 80 cm max. Like lampreys, they are eel-like without pectoral of pelvic fins. However, hagfishes have no larval stage and develop directly from eggs. The eggs are oval, over 10mm in length, and encased in a tough clear "shell". The eyes are degenerate and completely covered by skin. Large tentacles surround the terminal nasal opening and the mouth, which is not developed as a sucking disc. The feeding action consists of rapid eversion and retraction of teeth situated on each side of the mouth, so that the effect is that of jaws opening laterally as opposed to the up-and-down motion of true jaws. The skeleton is not well developed, with no rudiments of vertebrae, and only a membranous roof in the skull. In contrast to all other vertebrates, they posses also a caudal heart, a cardinal vein heart, and a portal vein heart, in addition to the usual heart.

Hagfishes live in soft bottoms of mud, silt, or clay at depths of 25 to 600m, with records of 5 to 1000m. They are known to burrow in the bottom feeding on polycheate worms and other soft-bodied animals. They act both as scavengers and predators, being quickly attracted to bait and moribund fishes caught in gill nets. Apparently, individual hagfishes are not wide ranging and tend to live and breed locally.

All known species are entirely marine and with near worldwide distribution, primarily on continental shelves.

Circulatory system of lampreys

The heart of the lamprey is relatively large in comparison to the hearts of most fish. The sinus venosus is a small, vertical, tubular structure, and the atrium overlies the ventricle. A bulbous arteriosus is present at the base of the ventral aorta. The conus arteriosus is underdeveloped, therefore the heart of the lamprey is considered to be a three-chambered one.

Only the right common cardinal vein (right duct of Cuvier) is present in the circulatory system of the lamprey. The dorsal aorta of lampreys is single and medial except for a peculiar section called the cephalic circle. From the circle major arteries supply the head region with blood.

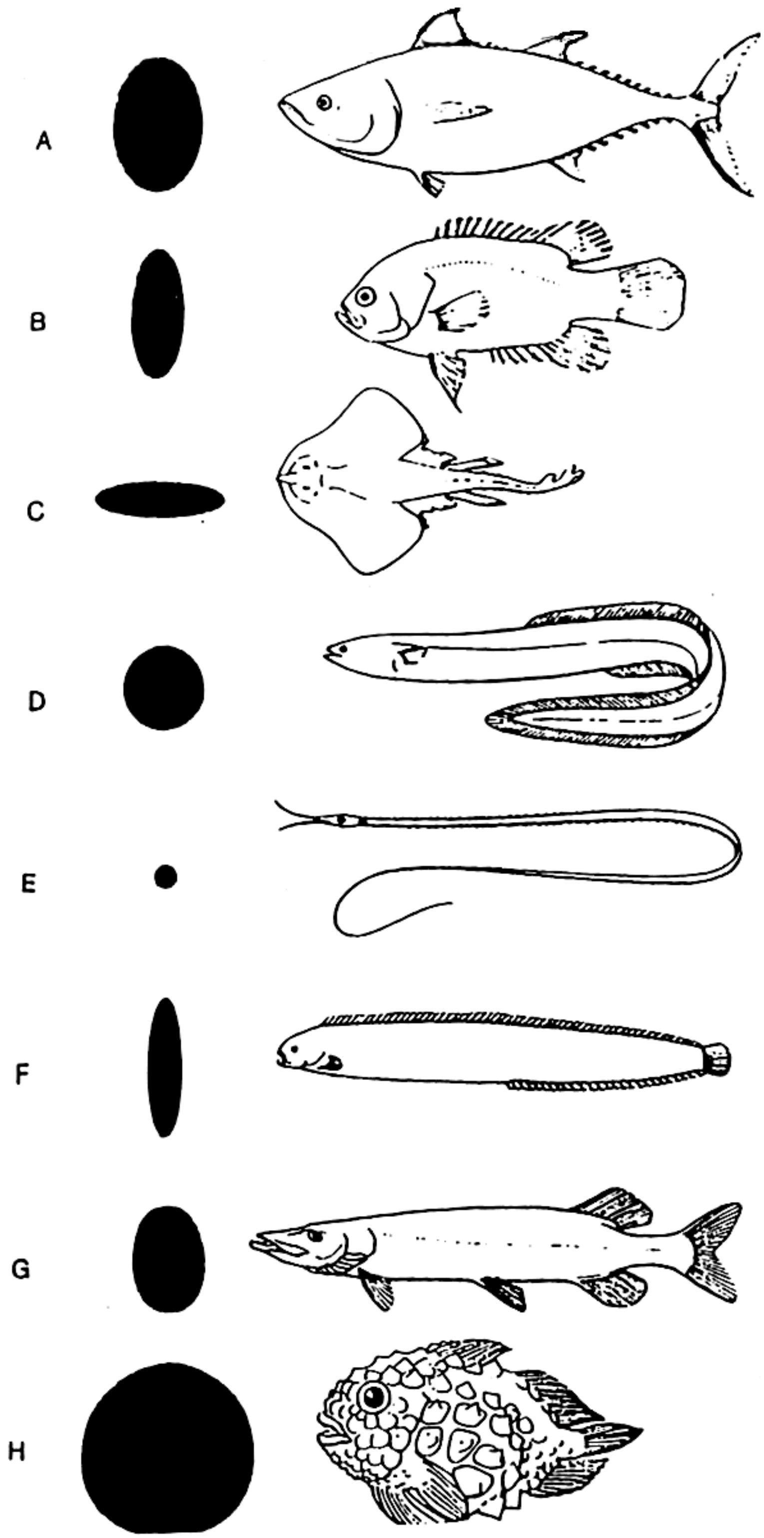
Lab #2 – Fish Morphology and Ecotype Lab

Fishes

- The Ostracoderms and Placoderms are extinct groups of fishes.
- The Ostracoderms' living relatives are represented by the lamprey and the hagfish .
- Characteristics of the Ostracoderms were armored skin, eel-like body and lacking a well defined head, scales, jaws or paired fins.
- The placoderms on the other hand, or fin, had a distinct head, paired fins, scales and were generally armored.
- The lamprey and hagfish are classified in the Agnatha, and are characterized by the lack of scales, paired fins and jaws.
- Characters separating Chondrichthyes (sharks and rays) from Osteichthyes (bony fishes), both members of the Gnathostomata, include:
    - lack of true bone in skeleton
    - outer margins of fins supported by horny rays or filaments
    - no true operculum
    - single nostrils
    - teeth imbedded in gums
    - scales tooth-like in structure (placoid or dermal denticles)
    - absence of swim bladder and lung
- Major characters of the Osteichthyes (bony fishes) include:
    - internal skeleton of true bone in greater or lesser amounts
    - skull marked by sutures
    - outer margins of fins supported by bony rays or spines
    - one external gill opening on each side of the head (true operculum)
    - external opening of each nostril is double and more or less dorsal
    - teeth usually fused to the bones
    - exoskeleton consisting of cycloid scales, ctenoid scales, ganoid scales or naked skin
    - swim bladder or functional lung usually present

Body Shapes

- Fish are generally characterized by their body shape looking from the front and from the side.
- The particular shapes of fish are basically adapted to feeding strategies, habitat, and predatory defenses. Can you think of any other advantages for the shape of fish?
- Determine and draw in your notebook the body shapes of specimens in the dissecting tray. What type of habitat would you find each of these examples?
- Think of a tuna, what type of body shape do they have and what advantage would it have over other fish?



A-fusiform, B-compressiform, C-depressiform, D-anguilliform, E-filiform, F-taeniform, G-sagittiform, H-globiform

Mouths and fins

- As with body shapes, mouths have adapted to the environment, feeding strategy, and their particular prey.
- Looking in which direction the mouth opens will help you determine the type of mouth.
- A fusiform shape fish, such as a tuna, would more likely have a terminal mouth than a superior. Looking at the position of the mouth hints to what that particular fish may prey upon.

- Using specimens in the dissecting tray, determine the mouth type each possesses. Draw each fish and note what type of prey it may consume.
- Fins aid fish in locomotion, maneuvering, stabilizing, and sometimes in protection. The shape of the fin is related to the speed of the fish, i.e. **fast** swimming fish such as tuna have **pointed fins** that aids in speed and quick maneuvering. Fish that are **slower** moving have **rounded fins** that serve them better for stability while swimming. Some fins act as "limbs or feelers". Sculpins and sea robins have adapted their pelvic fins to "walk" along the bottom in search of invertebrates. Some pectoral fins have acted like "wings" such as flying fish.
- Fins are supported by rays. Dorsal, pectoral, and anal fins can also have spines associated with the, although some "spines" are actually stiffened rays. True spines are used as an anti predatory defense from piscivorous fish and are usually located at the fish's center of mass. Spines can also make a small fish appear bigger when they are extended. Most fins are considered soft ray fins.
- These specimens give examples of three types of homocercal caudal fins. In your drawings, label the caudal fins. Note that the heterocercal tail found in Chondrychthian (e.g. sharks) fish has the nerve cord within the fin structure. In Osteichthyian fish, the caudal fin is homocercal, meaning that both the top and bottom are symmetrical and do not have a nerve cord through them.

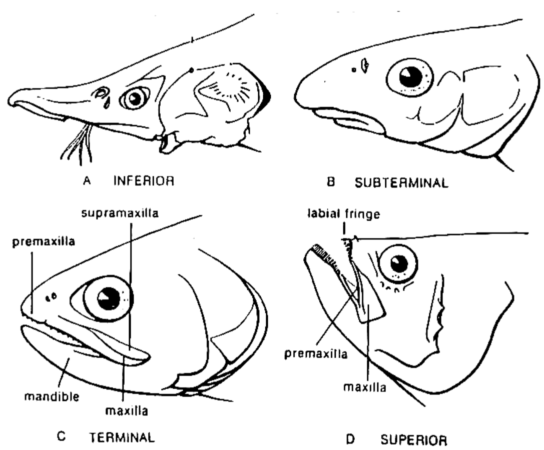
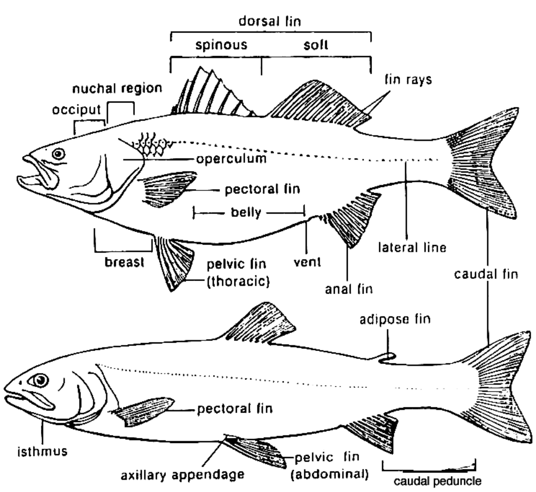


FIGURE 2-2. Examples of mouth positions in fishes. *A*, Inferior (sturgeon); *B*, subterminal (dace); *C*, terminal (trout). *D*, superior (sandfish). (*D*, based on Jordan and Evermann, 1900.)



Locomotion

- Fish use both their bodies and fins top propel them through the water. The undulating motion requires one side of the body to contract while simultaneously; the other side relaxes creating the side-to-side motion. This motion is readily seen in amphibians and reptiles.

- In order for the fish to overcome gravity and to move through the water, lift and thrust must be produced.
    - Lift is partially provided by the swim bladder in most fish giving neutral buoyancy. Those fish without a swim bladder (Chondrichthyes) are negatively buoyant; therefore they must continually swim to produce lift.
    - Thrust occurs when water is pushed away from the fish resulting in a reactive vector or thrust. Lift is also achieved.
- Predatory type open water fish use their caudal fins exclusively to propel themselves through the water. Their pectoral fins act as stabilizers and “wings” to give them lift as they move forward.
- Reef type fish (trigger, butterfly) need more maneuverability and swim using their dorsal and pectoral fins.
- In your notebook, draw a characteristic fish of the anguilliform, subcarangiform, and modified carangiform.

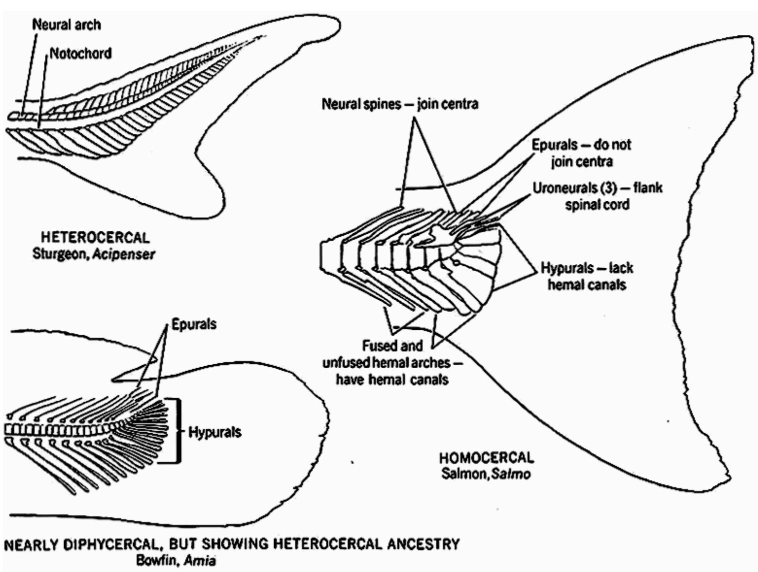
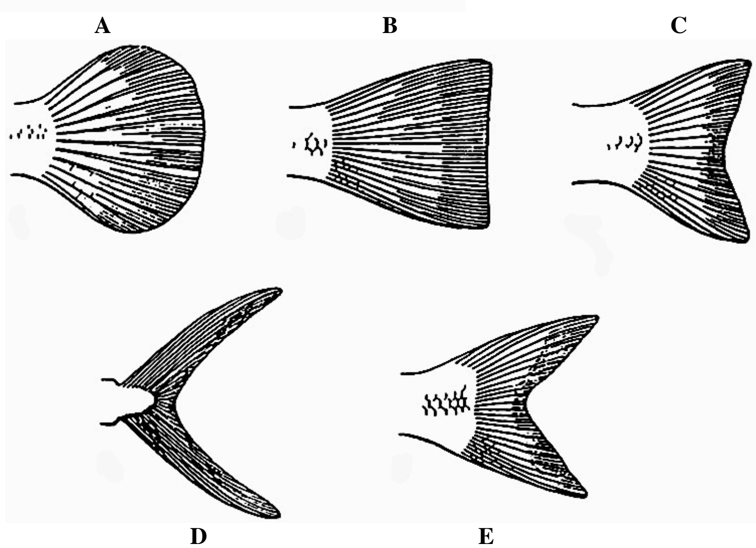
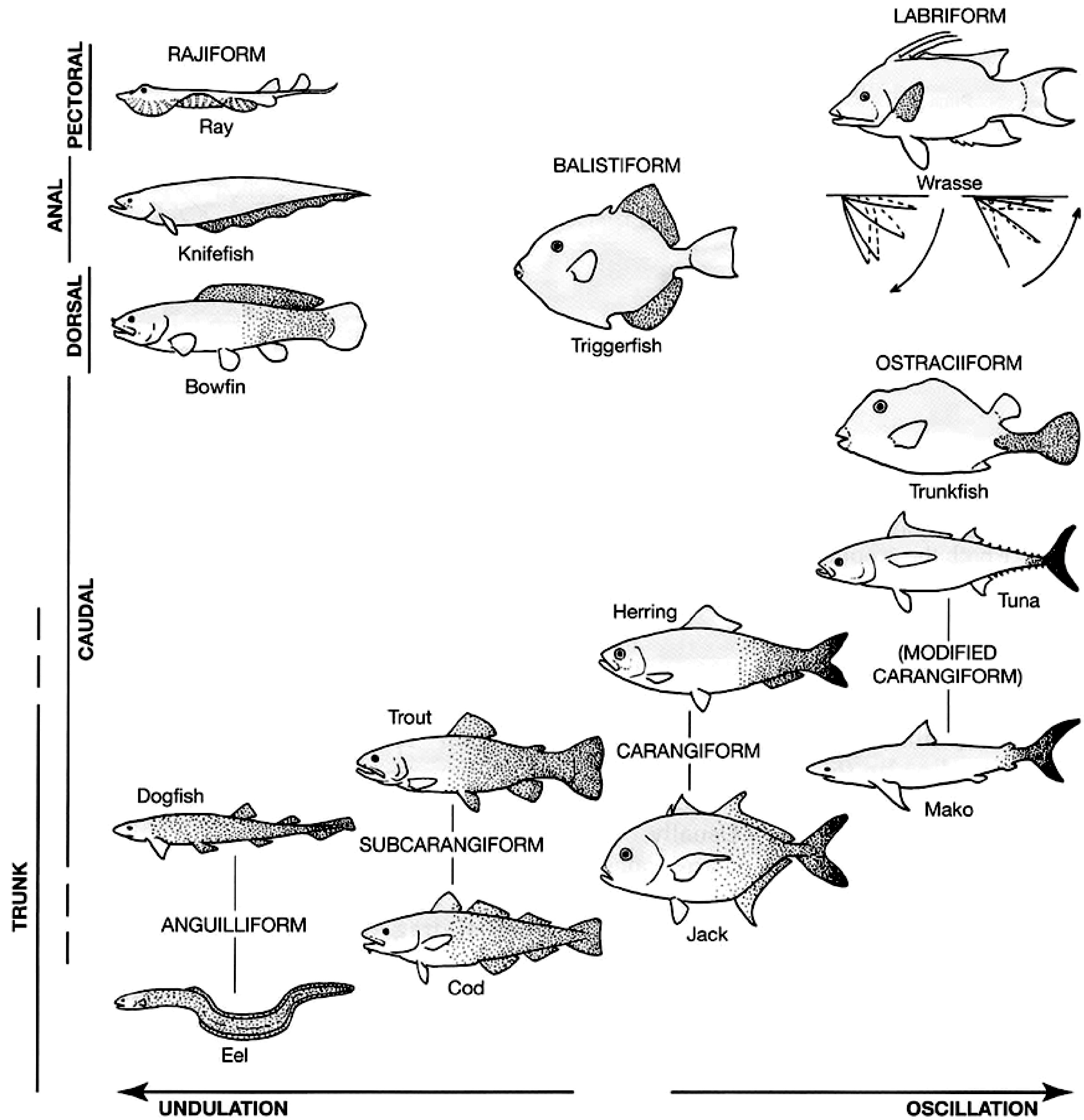


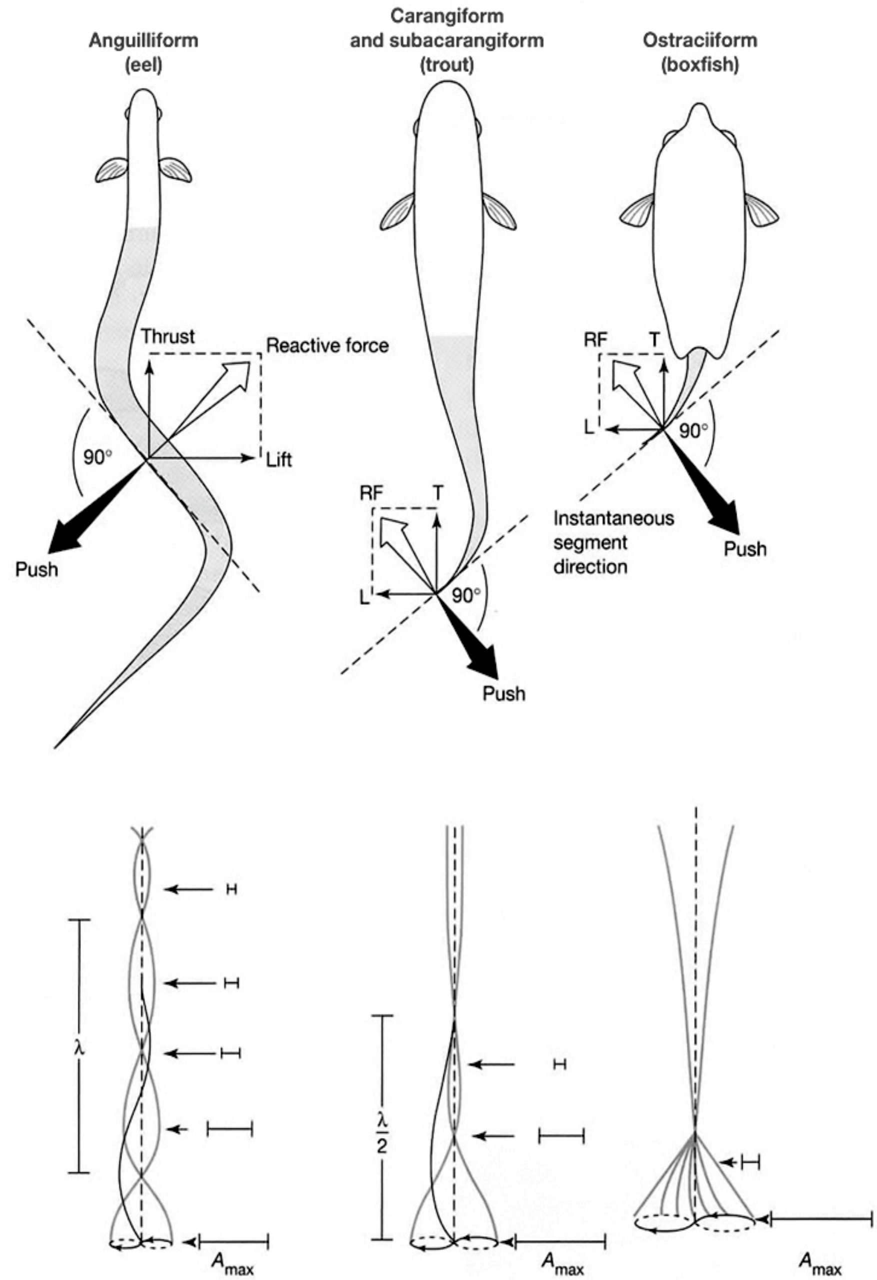
FIGURE 9-13 SHAPE AND STRUCTURE OF THE TAILS OF SOME BONY FISHES.



A, rounded; B, truncate; C, emarginate; D, lunate; E, forked



▲ Figure 6–13 Location of swimming movements in various fishes. Stippled areas of body undulate or move in swimming. Names such as carangiform describe the major types of locomotion found in fishes; they are not a phylogenetic based identification of all fishes using a given mode.



▲ Figure 6–11 Basic movements of swimming fishes. (upper) Outlines of some major swimming types; body regions that undulate are shaded blue. The lift component of the reactive force produced by one undulation's push on the water is canceled by that of the next, oppositely directed undulation. The thrust from each undulation is in the same direction and thus is additive. (lower) Waveforms created by undulations of points along the body and tail. A_{max} represents the maximum lateral displacement of any point. Note that A_{max} increases posteriorly; λ is the wavelength of the undulatory wave.

Basic feeding strategies

- Fish adapted to feed in many different ways. But basically they can be broken down into substrate and open-water feeders. One typical example of an open-water feeder is the dogfish shark.
- The body form of these fish is supremely adapted to the task of feeding in open water. Note the tail, how it is used to propel this fish through the water, and how the pectoral fins are used for rapid maneuvering.

- The mouth is lined with teeth that are replaced as they are worn down, broken, or when they just generally fall out.
- The shark has an excellent sense of smell, and uses this sense to find dead and/or injured prey from long distances. It can smell very minute amounts of blood in the water.
- The lateral line system is able to detect low frequency sound and pressure changes in the water. The thrashing about of many injured fish, invertebrates, birds and a variety of water sports can be detected by sharks from great distances (if you can't find the lateral line, it goes down the midline on the side of the fish, please ask your friendly lab instructor, and they will, in all likelihood, point it out to you).
- The ampullae of Lorenzini, which we will look at in more detail in the following weeks, are used to detect the weak electrical fields generated by all living things. This is a short-range prey detector, most likely. Some skates (which are closely related to sharks) cannot only detect weak electrical fields, but can generate electrical fields that act as perimeter sensors for these fish. Thus the skate lies on the bottom, and anything that disrupts the electric field is subject to attack.
- The very large eyes are used to see its prey. There is a well-developed tapetum lucidum, which serves to reflect light to the front of the eye, and back to the retina. Thus the shark uses light twice, and gains information about its surroundings. This is the same as the glare you see in photographs of your dog, or that look in the eyes of that deer that just jumped in front of you, and suddenly realizes that a Volkswagen rabbit, not a bunny rabbit bearing down on it. All of these characteristics combine to make this fish an excellent open-water predator.
- The pineal gland is attached to the roof of the posterior part (diencephalons) of the forebrain, is the remnant of the "third eye", and continues to have a light sensory function in lampreys and some Chondrichthyes and Osteichthyes. In most bony fishes the pineal gland has a glandular function, secreting melatonin, which aggregates melanin in amphibians and in some fishes. Removal of the pineal from fishes can bring about changes in growth.
- Bottom feeders are exemplified by the skate, flounder and the catfish. The skate and flounder have adopted a sit and wait strategy for finding prey. As the name implies, they sit, either on the top of the sandy or muddy bottom, or partially bury themselves in it. When prey comes by, they attack it. The catfish is a more active feeder, searching out prey on the bottom. It uses its "whiskers" as a sensory apparatus in the muddy, or darker waters.
- Another sit and wait predator is the cutlass. Except rather than burying itself in the substrate, it hides in amongst rocks on a reef, and attacks passerby's. Howdy neighbor!

Predator avoidance adaptations

- One of the really important things to do in life is to not get eaten by a predator. Fish have adapted several strategies, which minimize the risk of being eaten. Draw and describe each of these examples of these adaptations.
- The first thing to do is not to be seen in the first place. This can be accomplished by looking like your surrounding environment.
  - The red drum has vertical bars along the side of the body that can act as camouflage when it is amongst a patch of vegetation of similar width as the bars on its body.
  - The pipefish actually mimics the size and shape of the vegetation it tries to hide in. And if that doesn't work, the pipefish retreats into its burrow as it is approached.
  - The flounder is a master at cryptic coloration. This flatfish is able to alter the coloration pattern on its back to resemble the substrate on which it is lying. It can

even bury itself either partially or completely in the sand, leaving only its eyes bugging out of the sand, as it waits for its prey to stumble by. In most of these cases, not only does the camaflouge work to hide a fish from its predators, it may also serve to hide it from its prey, pretty sneaky huh? Notice there are different types of flatfish. Some are termed left-sided and some right-sided fishes. This determination is based upon the migration of one eye from one side to the other. Left-sided fish are those whose right eye has migrated to the left side and right-sided fish are those whose left eye has migrated to the right side of the head. The fish then settles on the bottom, laying on the side with no eyes on it. To answer your question, it takes a long time, the migration of the eye does not occur over the span of a few seconds or minutes. The fish goes through several developmental stages, each one of which has the eye moved slightly.

- The sea horse combines cryptic coloration (like the flounder), mimicry of vegetation (like the pipefish and red drum) and its prehensile tail to float amongst sea weeds to remain inconspicuous.
- The anchovy, and many open-water fishes utilize the concept of counter-shading. That is, they are dark on the dorsal side (top) and lighter on the ventral (bottom) side. A predator looking down from above the fish will not see the dark back of the fish as it blends in with the dark background of the bottom. A predator looking up from below the fish will not see the light underside of the fish as it blends in with the light background of the surface.
- A mode of predator avoidance, which doesn't require a physical adaptation, is to school with your fellow fish mates. If you and your buddies are seen, it does not necessarily mean that you will be eaten. The bigger the school, the less likely you are to be eaten, but all the more likely that your school will be seen. Also, in a big school, it is difficult for a predator to single out one fish to attack. Another advantage of living in a large school is that you and your fish friends can combine your sensory abilities (vision and lateral line system) to "keep and eye peeled for trouble".

- Another way to avoid being eaten is to make yourself unattractive to a potential predator.
  - The pufferfish will inflate itself with water, causing spines that cover its body to become erect. This tends to keep predators from eating this fish.
  - The gar has solved the problem of potential predation by becoming one of the baddest on the block. Its body is covered in an armor of bones on the head and ganoid scales that cover the body. It has big teeth, strong jaws, lightning fast speed, and did I mention the big teeth? All these characteristics combine to minimize the risk of predation on these fish.

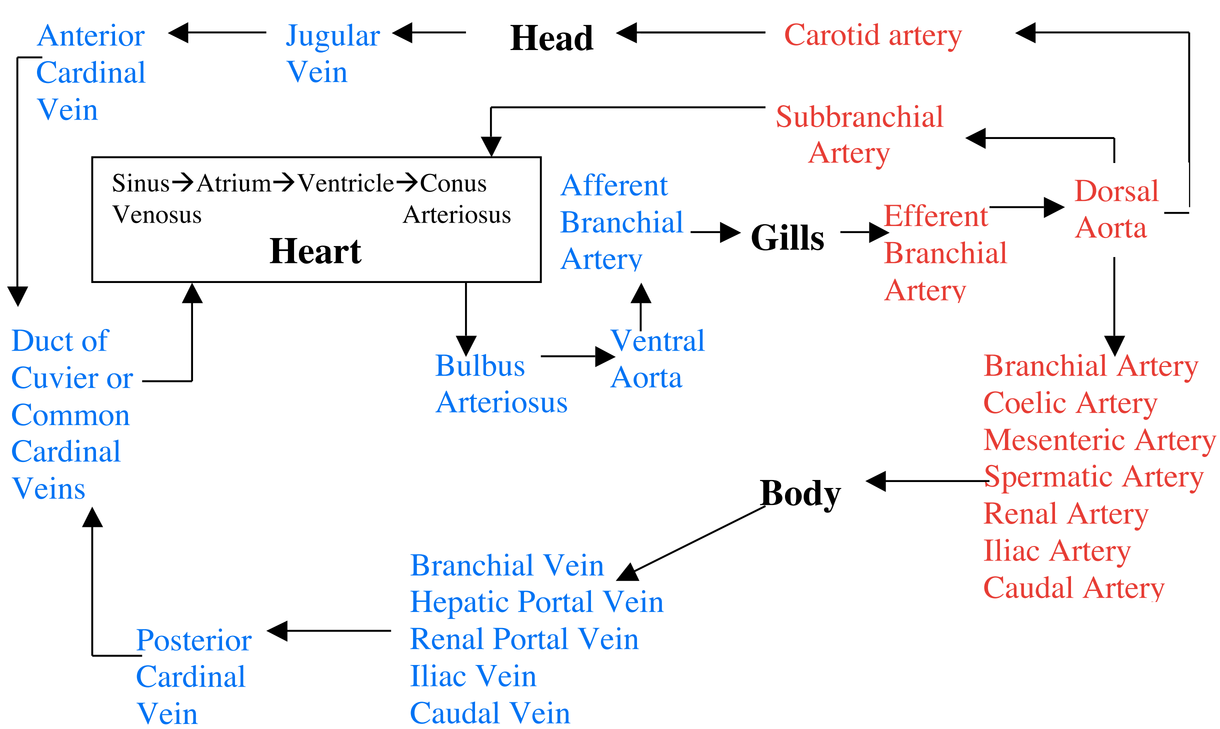
Skeletal system

- Make note:
  - The head is attached to the pectoral girdle.
  - Ligaments attach the vertebrae to each other. There are no zygapophysis to prevent flexure, as you will later see in amphibians and mammals.
  - The teeth in this specimen are all uniform in shape, except for size. While you look at other specimens look at the teeth. You should see that some fish have different shaped teeth within the mouth. This is another feeding and environmental adaptation.
  - The jaws of shark are loosely articulated to the skull by ligaments. When the upper jaw is slightly raised, the lower jaw is lowered. This adaptation allows sharks to protrude their jaws forward increasing the size of their gape, increasing

the amount of each bite and how much fish, marine mammal, or surfer it is going to eat at the first sitting.
  - The internal organs are compacted anterior-ventrally within the body. This adaptation allows an increase in the amount of muscle mass that is available to the fish.
- Draw a skeleton of the bony fish in your lab notebook.

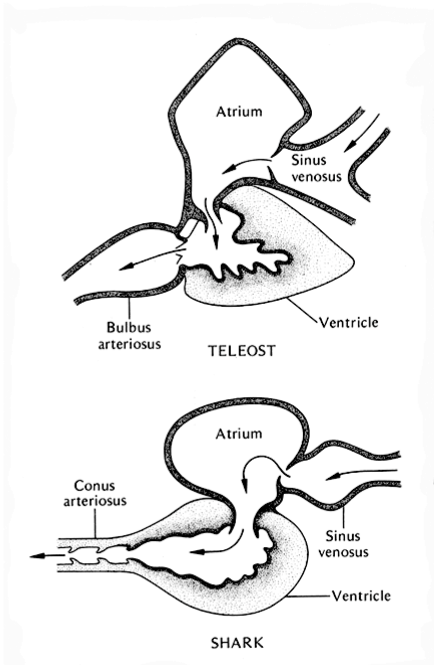
Circulatory system of fishes

- The typical fish heart is said to have four chambers: the sinus venosus, the atrium, the ventricle, and the conus arteriosus. In most teleosts the conus arteriosus is reduced.
- The bulbus arteriosus is a non-contractile, but elastic, basal part of the ventral aorta and not a heart chamber. In sharks the bulbus arteriosus is absent.
- Bony fishes are very variable in heart structure because of the great evolutionary range seen in living forms.
- In lungfishes, both the atrium and the ventricle are partially divided by an incomplete partition. The right division of the atrium receives unoxygenated blood via the sinus venosus, but the left side receives oxygenated blood via the pulmonary vein. The oxygenated blood is guided to the dorsal aorta.
- In anurans (frogs and toads) the atrium is fully divided.
- The following is a simplified diagram of the circulatory system of a typical Osteichthyte:



Oxygenated Blood Vessels
Unoxygenated Blood Vessels

FIGURE 4.6 The two-chambered heart of fish is preceded by an enlarged venous sinus that supplies blood for filling the atrium. The heart ejects blood into a thickened part of the artery, the bulbus arteriosus (in teleosts) or conus arteriosus (in elasmobranchs). [Randall 1970]



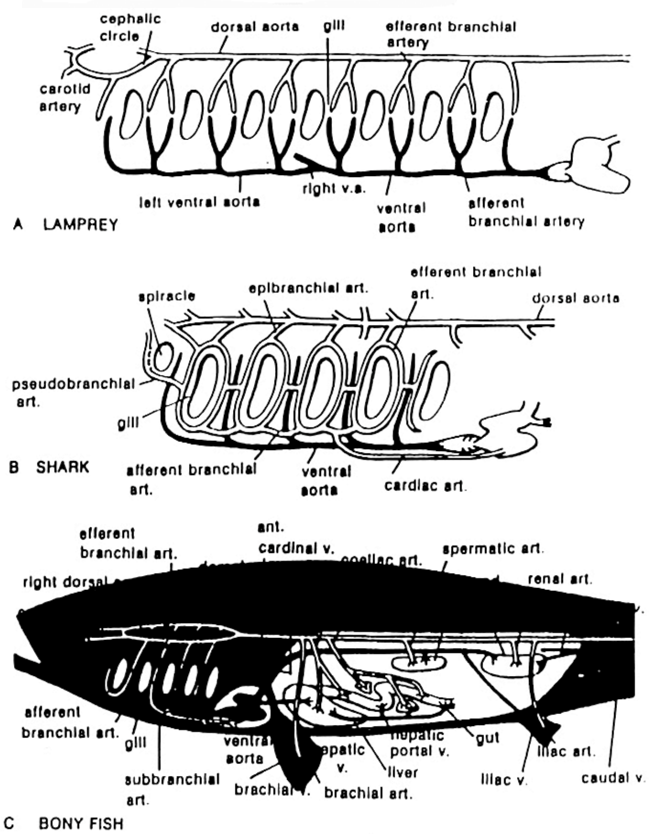


FIGURE 2–33. Diagrams of blood circulation. *A*, Lamprey, branchial arteries; *B*, shark, branchial arteries; *C*, bony fish, showing major blood vessels.

FIGURE 1.5 The gills of a fish consist of several gill arches on each side. Each arch carries two rows of gill filaments. Each filament carries thin parallel, platelike lamellae. In these lamellae the blood flows in a direction opposite to that of the water which flows between the lamellae. [Randall 1968]

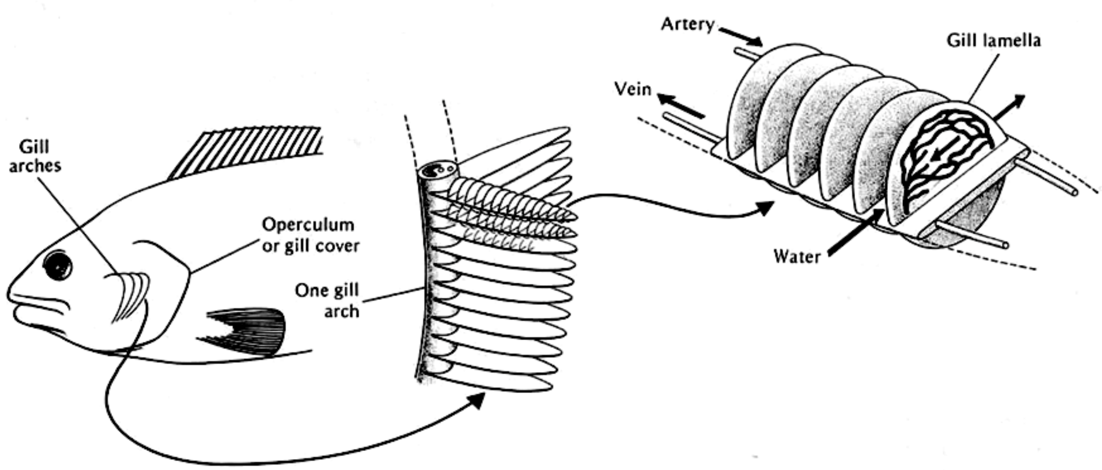
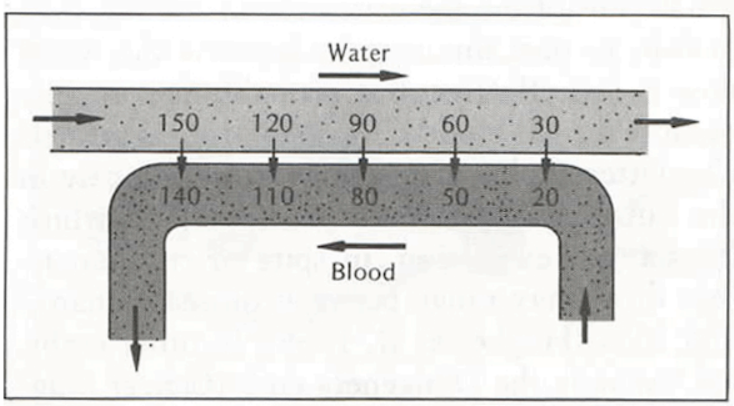


FIGURE 1.6 Diagram of the countercurrent flow in fish gills. The numbers indicate partial pressures of oxygen (P_{O_2}) in water and blood. The blood enters the gill at a low P_{O_2} (in this example 20 mm Hg), and oxygen diffuses from the water into the blood. As the blood runs along the lamella, it takes up more and more oxygen from the water, and as it leaves the lamella, it has nearly reached the P_{O_2} of the incoming oxygen-rich water. The water, flowing in the opposite direction, gradually loses more and more of its oxygen and leaves the gill after having lost most of its oxygen content.



Lab #3 – Shark Dissection #1

Characteristics of subclass Elasmobranchii (rays and sharks)

Subclass Elasmobranchii:

- 5 to 7 separate gill openings on each side
- dorsal fin(s) and spines, if present, are rigid
- males without clasper organ on head
- upper jaw not fused to cranium
- teeth numerous

Superorder Selachimorpha (sharks):

- gill openings mainly lateral
- anterior edge of pectoral fin not attached to side of head
- anal fin present or absent
- pectoral girdle halves not joined dorsally (fused ventrally)
- includes bullhead, cow, frill, whale, nurse, sand tiger, thresher, basking, mackerel (such as the great white), requiem (such as the bull and tiger), hammerhead, dogfish, saw, angel sharks.

Superorder Batoidimorpha (rays):

- gill openings ventral
- anterior edge of the greatly enlarged pectoral fin attached to side of head anterior to the five gill openings
- anal fin absent
- pectoral girdle halves joined dorsally

- includes sawfishes, guitarfishes, electric rays, skates, stingrays, butterfly rays, round stingrays, river stingrays, eagle rays, mantas

Natural history of rays and sharks

Elasmobranchs are typically predaceous fishes that rely more on smell (the olfactory capsules are relatively large) than sight (the eyes are relatively small) for obtaining food. Their circulatory system is very similar to that of the bony fishes, except that the bulbus arteriosus is absent in elasmobranches. All male elasmobranches have claspers just behind the pelvic fins. These are long, intermittent organs used to transfer sperm to the female's oviduct. Ovoviviparous females give birth to live young that develop from eggs incubated in the oviduct until hatching time, oviparous females lay egg cases that hatch later on the reef or ocean bottom. Viviparous females nourish the young in the oviduct by means of a yolk-sac placenta until live birth some months later.

Rays – These notes will refer to the order Myliobatiformes. Rays of this order have large pectoral fins that combine with the head to form a broad disc, with a slender tail usually having strong stinging spines. The caudal and dorsal fins are reduced or absent. Included are the stingrays, river stingrays, round stingrays, butterfly rays, eagle and bat rays, cownose rays, and mantas.

These are all warm-water fishes, seldom entering cold temperate waters, and are usually found close to shore. The river stingrays are found in rivers of South America. The various stingrays, and the butterfly rays live on the bottom, often concealing themselves in sand or other fine materials. Their food is shellfishes and bottom-living fishes. The tail spines are typically barbed and grooved along the edges. The venom produced in the groove can make a wound caused by the spines to be both painful and dangerous. The largest stingrays may reach a width of 2 meters.

The eagle rays, bat rays, and cownose rays feed on the bottom, often dislodging bottom materials through the hydraulic action of powerful movements of their large pectorals. Clams, oysters, and other invertebrates make up most of their food. The teeth of these rays are in the form of broad grinding plates. Locomotion is by flying movements of the wing-like pectorals. The long whip-like tail is usually held straight behind. Some species reach 1.2m in width.

Mantas have turned from bottom feeding to seeking plankton and small schooling fishes. They swim through the water by means of the wide, slender-tipped pectoral "wings", holding the mouth open. These fins, when curled into the spiral testing position, give the impression of horns, hence the name "devil" rays. Although some species reach less than 1m in width, others may reach up to 6m.

Sharks – These notes will refer to two species of the requiem shark family: Carcharhinidae. Included are the silky, bull, tiger, blue, blacktip, and whitetip sharks.

This family contains several well-known medium to large species from tropical and temperate waters. Found from the surface to about 600-800m deep. The silvertip shark is an inshore and offshore animal, for a strong preference for offshore islands; however is not truly oceanic, like the blue (temperate waters) or oceanic whitetip (tropical waters) sharks. The young of the silvertip are restricted to shallower water closer to the shore than adults. The species is viviparous with a mean litter of 5-6 (range1-11) after gestation of one year. They eat mid-water and bottom fishes and dominate over the Galápagos and blacktip sharks at bait. Maximum size is about 300cm.

Like the silvertip shark, the blacktip is an inshore and offshore animal that is not truly oceanic. However, apparently is rarely found at depths over 30m. It also occurs commonly over mouths and in estuaries since it can tolerate reduced salinities; however it does not penetrate far into freshwater, such as the bull shark does. The blacktip shark is very active, fast-swimming predator. Often occurs in large schools at the surface. It leaps out of the water and spins up to 3 times, a behavior thought to be used while feeding on small schooling fish, launching themselves up through the school biting in all directions. The species is viviparous with a mean litter of 4-7 (range 1-10) after a gestation of 10 to 12 months. They eat primarily fishes with some cephalopods and crustaceans taken. Dominated by the silvertip and Galápagos sharks in contests for food. Maximum size is about 255cm.

Hunting techniques in sharks

Pursuit predators – Rely on speed and agility. They will pick an individual from a group and attempt to catch it. For example: blacktip reef sharks select a surgeonfish from a feeding school, hammerheads chase rays. Representative sharks are mako (a member of the mackerel sharks), requiems, and hammerheads.

Ambush predators – They tend to sit and wait, relying on strike, cryptic color, form and behavior to catch unaware prey. Representative sharks are wobbegongs, angels and swell.

Luring predators – Use anatomical features or specialized behaviors to "bait" prey into the strike zone. Representative sharks are cigars, megamouth, deepwater dogfishes, and nurses.

Stalking predators – Use stealth to approach their prey before an attack, relying on going unnoticed by their quarry. Representative sharks are great white (predator of seals and sea lions), broadnose sevengill, wobbegongs, nurses, sandtigers, and some cats.

Predators of large invertebrates – Representative sharks are bullheads, smoothhounds, guitarfishes, leopards, and, in some areas, tigers.

Crevice hunters and grubbers – Able to locate and capture concealed (hiding in the reef or sand) prey. Epaulette sharks and whitetip reef sharks tend to use certain finesse, while some nurse sharks tend to use brute force to retrieve prey. In captivity, hammerhead sharks have been observed to scoop concealed fish from sand with their lower jaw.

Small schooling prey predators – Feed on schools (grouped) prey. Thresher sharks use their tail to herd, whip, and stun schooling fish; saw sharks use their rostrum to impale or incapacitate prey. In general, sharks swim through the school of prey with their mouths open, throw their heads from one side to the other as they swim through the school, take bites from tightly massed prey, or propel themselves vertically through the bottom of the school capturing the prey as they ascend. Representative sharks are blue, oceanic whitetip, blacktips, spinners, and leopards.

Sense organs in elasmobranchs

Elasmobranchs are able to detect weak electrical fields with the ampullae of Lorenzini (external-pit like organs). As well as detecting bioelectric field, thus facilitating prey capture, these receptors can also detect the electric fields induced by the fish's own displacement (swimming or drifting) across the lines of force of the earth's magnetic field. Such induced electric fields can reveal the compass direction along which the shark is traveling. Recently, there is circumstantial evidence that the hammerhead sharks use local features of the geomagnetic field (rather than merely a magnetic compass based on the overall field direction) to orient highly directional movements in deep, current-swept water at night.

In elasmobranches, the relatively small size of the eyes suggests that they do not rely heavily in the sense of vision. Generally, elasmobranches have been thought to be hypermetropic (far-sighted). However, many of them can reduce the pupil to a very small aperture when adapting to bright light. This probably gives reasonably good focus retinas with only a few cones, most probably they only see in black and white.

The pineal gland in some sharks can allow the transmission of up to seven times as much light as adjacent parts of the head. In some species the threshold for detection of light at this sight is below the energy level of moonlight.

The lateral line system responds to deformation by mechanical stimuli, particularly water movement in relation to the shark. Thus, currents from whatever source, the swimming of the shark, water displacements caused by sources of sound can be detected.

Olfaction is one of the most important sense organs for elasmobranchs. Obvious attraction of sharks to baits or to wounded fish upstream from the sharks even in gentle currents has been observed. Extracts of fish flesh, especially those with considerable oil content, have caused search and feeding activity even when presented in very dilute concentrations. Starved sharks appear to be more responsive than well-fed specimens, some detecting the odor of food at a concentration of .0001ppm (parts per million).

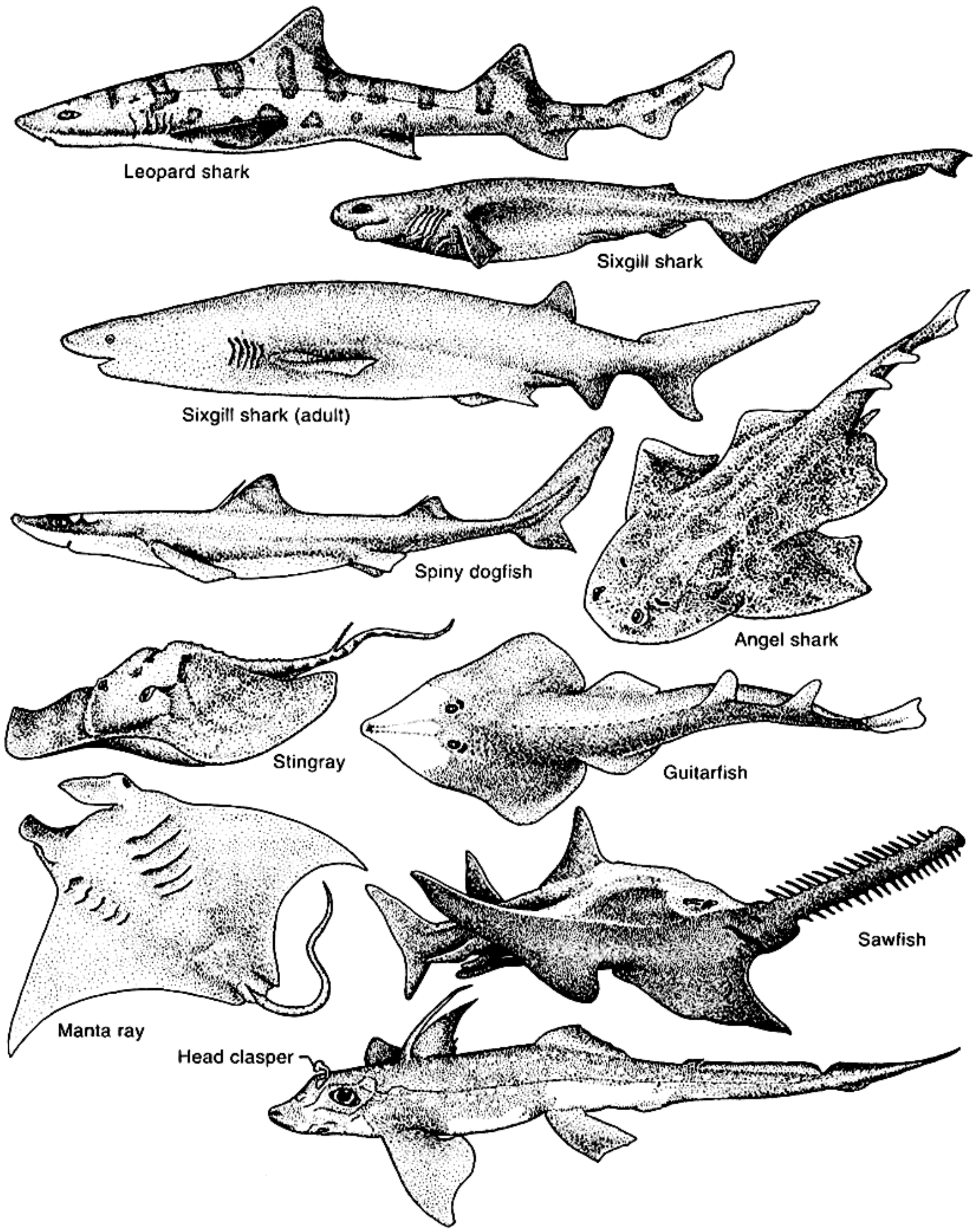


Figure 15.2 Representative Chondrichthyes. Top to bottom: Carchariniformes: leopard shark (*Triakis semifasciata*); Hexanchiformes: juvenile sixgill shark (*Hexanchus griseus*); adult sixgill shark; Squatiniformes: angel shark (*Squatina californica*); Squaliformes: spiny dogfish (*Squalus acanthias*); Myliobatiformes: stingray (*Dasyatis* sp.) Rajiformes: guitarfish (*Rhinobatos* sp); Myliobatiformes: manta (*Manta birostris*); Pristiformes: sawfish (*Pristis perottei*); Chimaeriformes: chimaera (*Hydrolagus collei*). (From Moyle 1993, ©1993 by Chris Mari can Dyck.)

Lab #4 – Shark Dissection #2

Lab #5 – Reptile and Amphibian Morphology and Ecotype Lab

Amphibians

Generalities

- First vertebrates with limbs for terrestrial locomotion.
- Gills variously developed in larvae but retained in a few salamanders.
- Skin and lungs, the latter sometimes lost, as adult respiratory organs.
- Heart with two atria, one ventricle.

Zygapophyses

True processes of the vertebrae, called zygapophyses, appear in amphibians and reptiles (they are only found in very few fishes). Zygapophyses produce a firm and strong vertebral column by interlocking with each other.

Anuran skeleton and locomotion

The skeleton of anurans (frogs and toads) shows general adaptations for salutatory locomotion:

- Elongated hind limb with powerful muscles form a lever system to catapult an anuran into the air.
- Powerful pelvis, with an elongated ileum, that is strongly fastened to vertebral column.
- Stiff vertebral column due to reduction, broadening, and loss of flexibility of individual vertebrae.
- Posterior vertebrae fused into one structure, called urostyle.
- Strong forelimbs and flexible pectoral girdle reduce impact of landing.
- Large eyes with forward placement provide a binocular vision.
- Broad skull, lightly built.

Salamanders use instead the lateral bending characteristic of fish locomotion in concert with leg movement, evidenced by the arrangement of their muscles.

Life styles

Salamanders- With two trends during their evolution: paedomorphosis through neoteny and lung reduction.

Aquatic- They are paedomorphic as a rule since they possess several larval traits: bone pattern, larval tooth, absence of eyelids, retention of functional lateral line system, and some retain external gills. They do not undergo metamorphosis.

Cave dwellers- Some are paedomorphic and some are not. They tend to be white with absence of eyes. They have a long shovel-shaped snout that fits into small places beneath rocks.

Terrestrial- Some are paedomorphic and some are not. Some go through an aquatic larval stage that loses its gills during metamorphosis. In most of them, the young hatch from eggs as miniatures of the adult.

Anurans

Aquatic frogs- Dorsoventrally flattened, thick waists, heavy legs with large webbed feet and well-developed lateral line systems.

Semi-aquatic frogs- Moderately streamlined with webbed feet.

Surface terrestrial anurans- Have blunt heads, heavy bodies, relatively short legs and little webbing between toes. Some, called spadefoot toads, have a keratinized structure on the hind foot that is used for burrowing. Anurans that feed on small reptiles and mammals, such as the horned frog, have a large head and mouth.

Burrowing terrestrial anurans- pointed heads, stout bodies, short legs.

Arboreal frogs- Large eyes and head, slim waists, long legs, adhesive digits.

Representative Amphibians

Salamanders – resemble a typical lizard in form but have a glandular skin, smooth or roughened with tubercles, lack true claws, and have a tail that is somewhat flattened laterally, especially when aquatic.

Frog and Toads – are tailless (except larvae), usually have long hind legs, webbed and unclawed toes, large eyes, and a smooth or warty moist, glandular skin.

Caecilians – are limbless and worm or snakelike, and lack or have a very short tail.

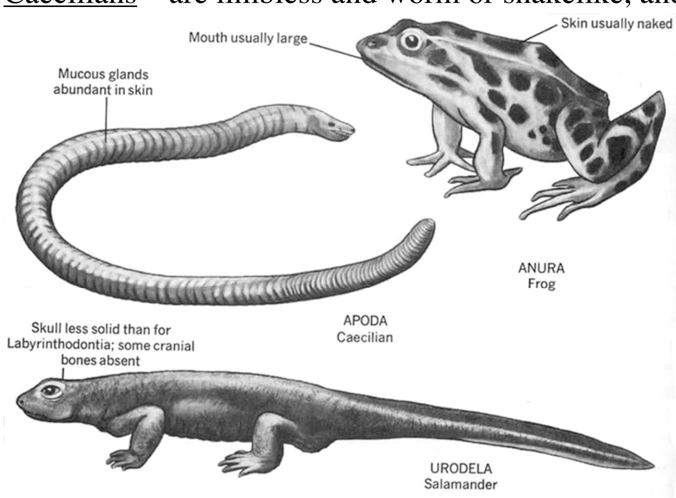


FIGURE 4-2 REPRESENTATIVES OF THE THREE ORDERS OF LISSAMPHIBIA showing some characteristics of the subclass.

Anurans – Body Styles

Anurans are amphibians made up of the frogs and toads. Like many other groups they employ several different body forms to facilitate different environments. These include the following:

Semiaquatic – moderately streamlined bodies with webbed feet; make long jumps. e.g.- leopard and bullfrogs (A)

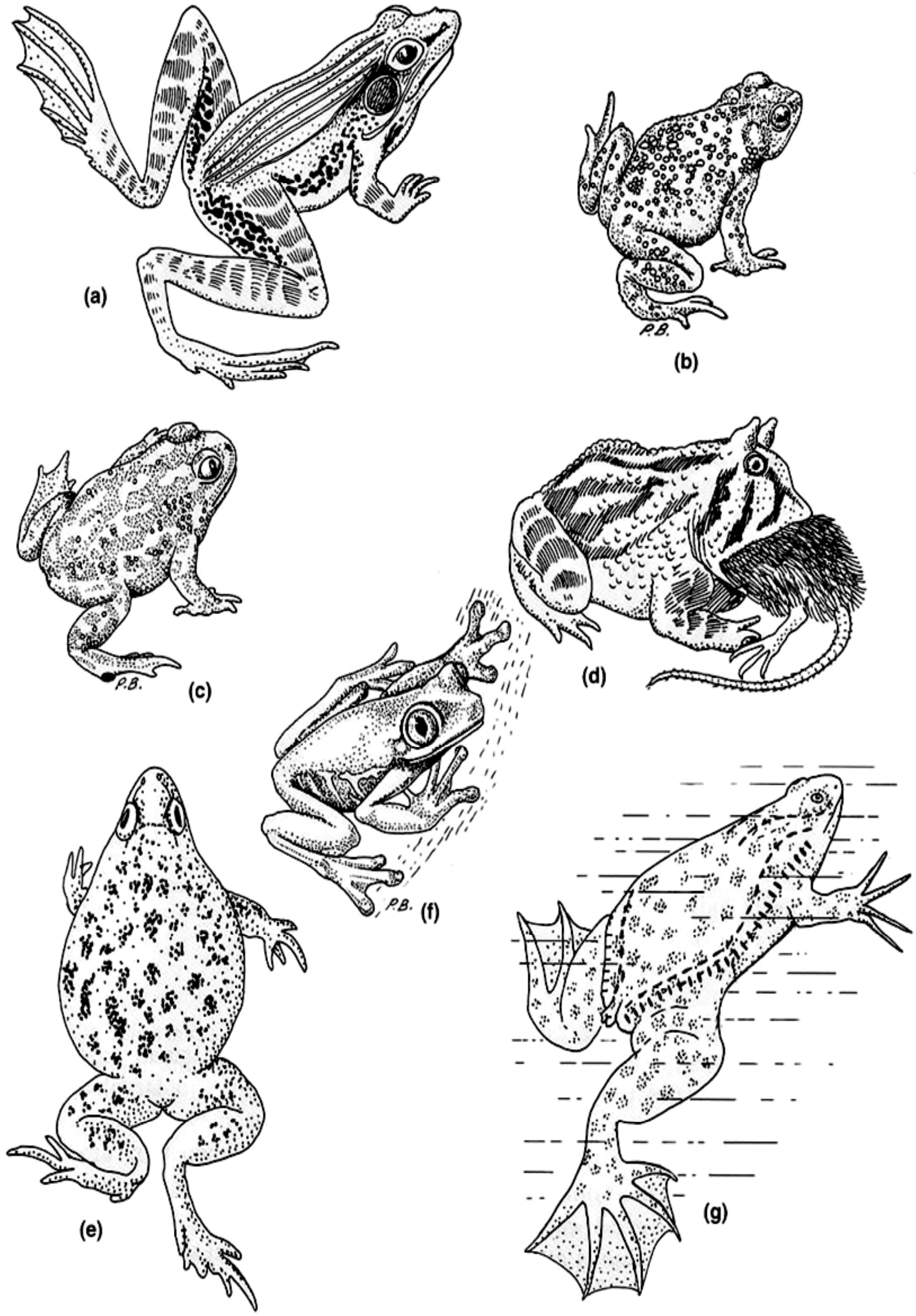
Terrestrial – blunt heads, heavy bodies, short legs, and little to no webbing between the toes; make short hops. e.g. – true toad and spadefoot toad (B&C)

Burrowing – pointed heads, stout, flat bodies, and short legs. e.g. – African ranids (E)

Arboreal – large heads and eyes, slim waists, and long legs and adhesive digits. e.g. – tree frogs (F)

Aquatic – dorsoventrally flattened, thick waists, powerful limbs, well-developed lateral line system, and large hind feet with thick webbing. e.g. – African clawed frog (G)

Identify, draw, and describe each of the following specimens. Try to determine what type of environment the anuran comes from.



▲ Figure 9–7 Anuran body forms reflect specializations for different habitats and different methods of locomotion. Semiaquatic form: (a) African ridged frog (*Ptychadena*, Ranidae). Terrestrial anurans: (b) toad (*Bufo*, Bufonidae); (c) spadefoot toad (*Scaphiopus*, Pelobatidae); (d) horned frog (*Ceratophrys*, Leptodactylidae). Burrowing species: (e), African shovel-nosed frog (*Hemisus*, Hemisotidae). Arboreal frog: (f) Central American leaf frog (*Agalychnis*, Hylidae). Specialized aquatic frog: (g) African clawed frog (*Xenopus*, Pipidae).

Salamander – Body Styles

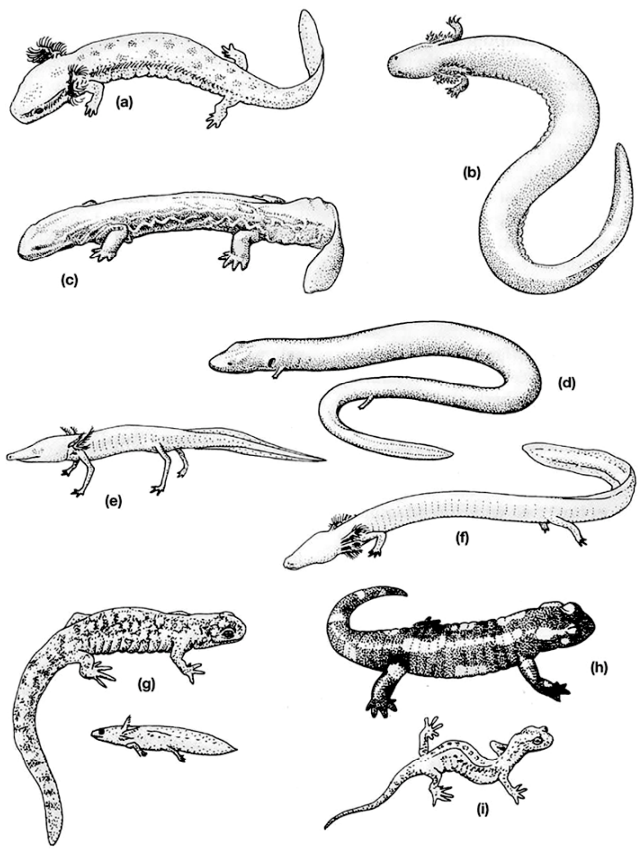
Salamanders exhibit several different body styles which allow them to exploit many environments. These body forms include:

Aquatic – are totally aquatic animals; most have external gills, a retained juvenile trait. e.g. – mudpuppy, siren (A, B, &C)

Cave dwellers – reduced eyes, long thin legs and have external gills. e.g. – Texas blind salamander (D, E, &F)

Terrestrial – have aquatic larvae that lose their gills at metamorphosis. e.g. – tiger salamander (G, H, &I)

Identify, draw, and describe the specimens before you. Try to determine the body style of each and what type of environment it would exploit.



▲ Figure 9–1 Diversity of salamanders. The body forms of salamanders reflect differences in their life histories and habitats. Aquatic salamanders may retain gills as adults: (a) North American mudpuppy and (b) North American siren. They may have folds of skin that are used for gas exchange, or they may rely on lungs and the body surface. (c) North American hellbender. (d) North American congo eel. Specialized cave-dwelling salamanders are white and lack eyes: (e) Texas blind salamander and (f) European olm. Terrestrial salamanders usually have sturdy legs: (g) North American tiger salamander and its aquatic larva, (h) European fire salamander and (i) North American slimy salamander—*Plethodon*, Plethodontidae.

Amphibian breeding tidbits

In the spring, the songs of frogs and toads can be heard for miles (well maybe not in Galveston, but picture it anyway), The male of each species begins to sing at different times with a "symphony" occurring towards the end of the season. Generally, the spring peepers are usually the first to sing with the toads the last. The differentiation of the species singing is important in allowing females to find potential mates and breeding sites. Those singing later are probably singing for nothing.

The spring also brings the march of the salamanders. Terrestrial living salamanders, unlike the mudpuppy, need to find vernal pools to breed and lay their eggs. These pools, appearing in the spring, only last a short time making it very critical that they appear in time for the salamanders to breed. In northern climes, the first of the season, warm rainstorms lasting all day signal the salamanders to march to these pools. These marches are often suicidal, as the salamanders must cross over roadways, making the trip risky business. Salamander tunnels have been built in order for the salamanders to cross under the road, as well as certain grad students acting as crossing guards have been seen on these rainy nights ensuring the salamanders reaching the pools.

Foot Structures in Amphibians

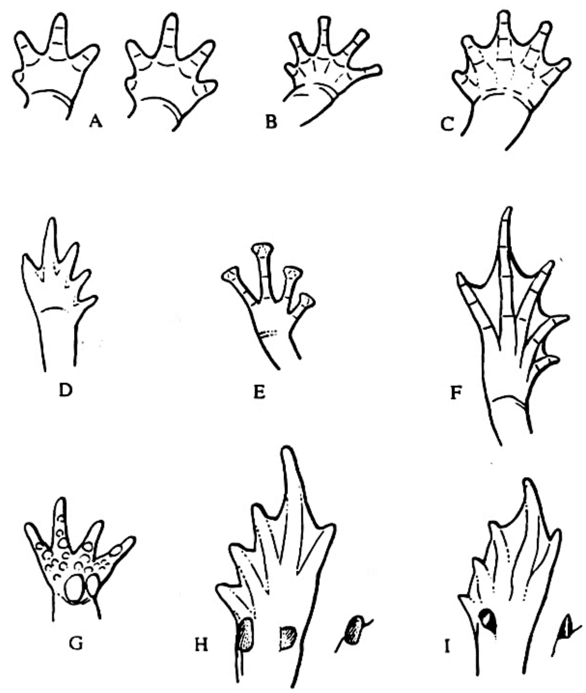


Fig. 4.2 Variations in the foot structure of amphibians. (A) to (F) are upper surfaces of feet, and (G) to (I) are under surfaces. (A) The typical amphibian toe arrangement, four toes on the front feet and five on the hind feet (*Plethodon*). (B) The elongate toes with squarish tips of a climbing salamander (*Aneides ferreus*). (C) The spatulate foot of a rock-dwelling salamander (*Hydromantes*). (D) The hind foot of the Tailed Frog (*Ascaphus truei*), with an enlarged outer toe. (E) Toe pads of a hylid frog, an adaptation for clinging and climbing. (F) Hind foot of a ranid frog showing extensive webbing. (G) Underside of the front foot of a toad showing horny tubercles that reduce abrasion. (H) Underside of the hind foot of a toad (*Bufo*) showing metatarsal tubercles. (I) The sharp-edged black horny spade of spadefoot toads (*Scaphiopus*) used in burrowing.

Reptiles

<u>Generalities</u>

- First vertebrates well adapted for land, with amniotic egg.

- Lungs for respiration.
- Skin with epidermal scales or bony plates.
- Heart with two atria and one partially divided ventricle (completely divided in crocodilians).

Snake skull

Snakes, and some lizards, are an example of flexing of the skull, a process known as kinesis. The skull of a snake contains 8 movable links, with left and right operating independently of each other. Also, the tips of the mandible are joined by elastic tissue instead of being fused to each other, thus lacking a true symphysis.

Life styles

Crocodilians – They have nostrils at the tip of the snout and a secondary palate that separates nasal passages from the mouth. In water, the heavily laterally flattened tail propels the body and the legs are held against the sides.

Turtles

Tortoises – Terrestrial, most have rigid dome shells.

African pancake tortoise – Flat, flexible shell allows it to wedge itself in cracks between rocks to escape predators.

Aquatic turtles – If they swim actively through the water, they are moderately streamlined and have large webbed feet. If they crawl on the bottom of a body of water, they are less streamlined than the swimming forms.

Sea turtles – Limbs have evolved into flippers. In the leatherback sea turtle the shell has been reduced to a series of bony platelets embedded in tough skin.

Lizard vs. Salamander

Some of the major differences between lizards and salamanders (reptiles and amphibians) are outlined below. For each example that applies, look at the specimens provided. Draw and describe the differences seen.

Lizard	Salamander
Skull and Skeletal	
1 occipital condyle	2 occipital condyle
2 vertebrae in sacrum	1 vertebrae in sacrum
5 digits	4 digits
Heart	
Ventricle partially divided	1 ventricle
Epidermis	
Scales – dry and rough	Skin – soft and moist
Barrier to gaseous and aqueous exchange	Gas and water exchange
Gonadic ducts/ Excretion	
Separate ducts	Single duct – gonad and kidney
Nitrogenous waste – urea and uric acid	Waste contains large amounts of ammonia
Waste conc. – don't need large amounts of water	Dilute urine – large amounts of water
Eggs	
Protective, hard shell	Gel coated eggs
Embryo separate from shell -	No separation

Protects against temp. fluctuations	
Allantois – blood vessels –	No allantois
Acts as resp. surface	

<u>Lizards – Body Styles</u>

Lizards exhibit several body styles allowing them to exhibit varying environments. These are not only based upon body shape, but also diet. These include:

Insectivores – small bodies, small mouths, with no other specific adaptations; several lizards eat insects, but these are generalized. **(A&B)**

Herbivores – large bodies, large mouths. Require size to be able to process plant material. **(C&D)**

Ant specialists – flattened body shapes, desert dwellers where prey is difficult to come by. Small bodies and small mouths. **(E&F)**

Nocturnal specialists – large eyes and large head for identifying prey; primarily feed upon flying insects drawn toward lights – also have wall climbing ability in most cases. **(G)**

Arboreal specialists – modified feet for arboreal existence. **(H)**

Legless lizards – have eyelids and are not as flexible as snakes. **(I)**

Large predators – large mouths and body size to enable them to take down larger prey. **(J)**

<u>Lizard Body Forms</u>

About 80% of lizards weigh less than 20 grams and are insectivores.

Spiny swifts and japalures – are small, generalized insectivores. Others have specialized diets. **(A&B)**

Horned lizards – feed only on ants **(E&F)**

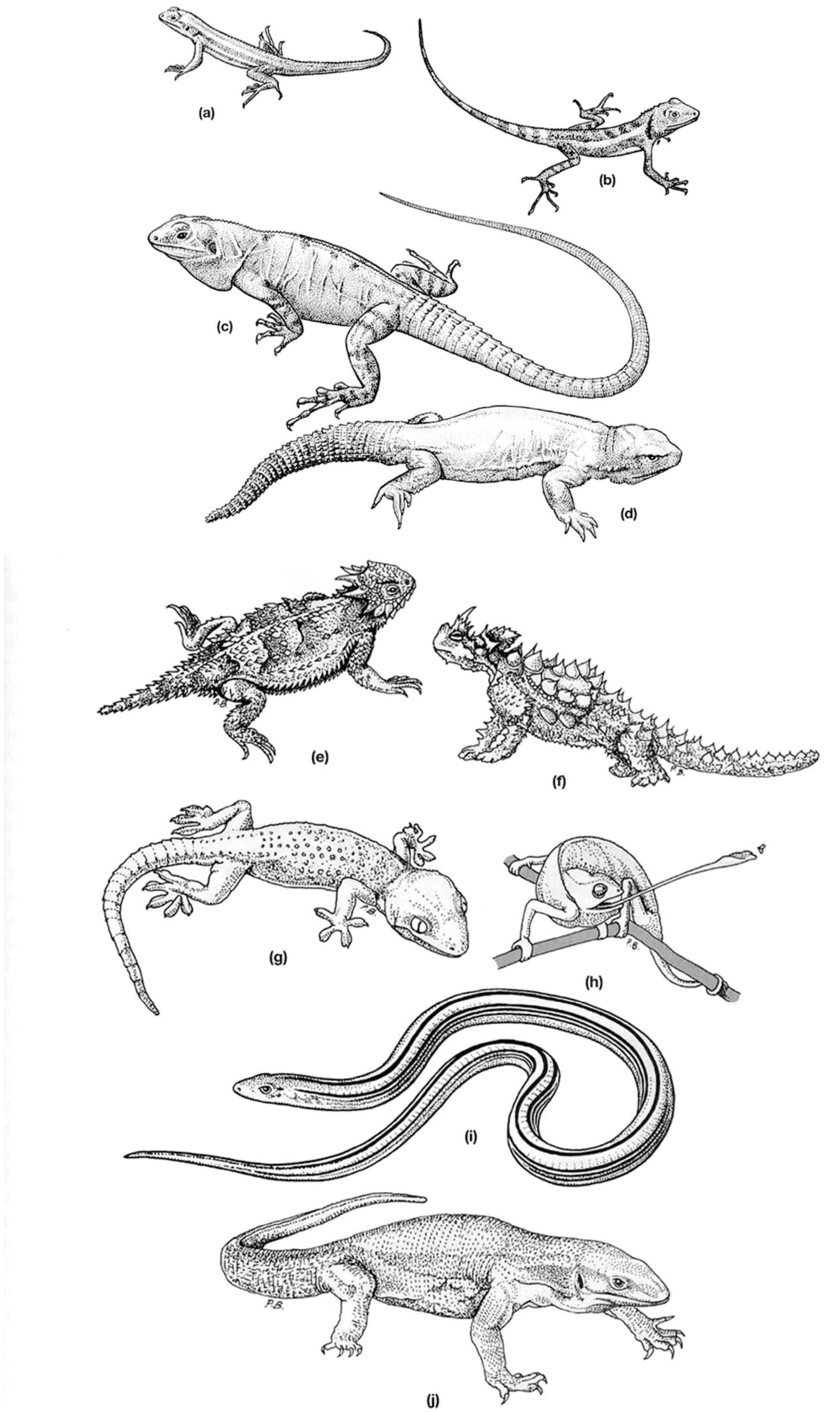
Geckos – are nocturnal, which can be determined by the large eyes compared to body size. **(G)**

The old world **Chameleons** are the most specialized arboreal lizards, with modified <u>zygodactylous</u> (joined digit) feet and prehensile tails. These lizards also utilize a sticky tongue and rotating eyes to locate prey while remaining stationary. **(H)**

Most lizards are herbivorous. **Iguanas** are primarily arboreal, though some can become entirely terrestrial in the absence of large predators. **(C&D)**

Komodo monitor lizard – is an exception to the rule of large lizards being herbivorous. These animals are carnivorous and have been known to reach lengths of seven feet and have the ability to kill large birds and mammals. **(J)**

Legless lizards – associated with dense grass or shrubbery and can often move through such structure more efficiently than their limbed relatives. **(I)**



Snakes – Body Styles

Snakes exhibit several different body styles enabling them to exploit varying environments. These include:

- **Constrictors (A)**
- **Active (B)**
- **Arboreal (C)**
- **Burrowing (D)**
- **Vipers (E)**
- **Sea snakes (F)**

Identify, draw and describe a representative from each group (if available). Include information on what type of environment the snake might come from.

Snake Body Forms

The body form of even a generalized snake, such as a kingsnake **(A)**, is so specialized that little further morphological specialization is associated with different habits or habitats. Kingsnakes are **constrictors**, and crawl slowly, poking their heads into holes that might shelter prey. Olfaction is an important means of detecting prey in these snakes.

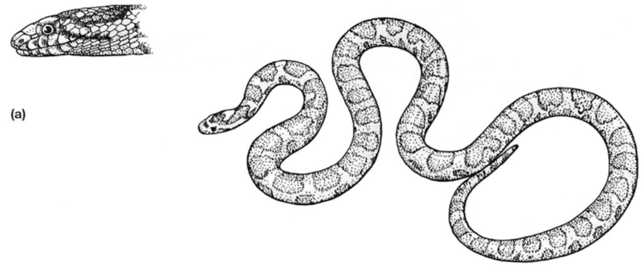
Nonconstrictors such as the whipsnake **(B)** move faster and are more visually oriented. They forage by crawling rapidly, frequently raising the head to look around.

Many **arboreal** snakes **(C)** are elongate and frequently have large eyes. Their length distributes weight and allows them to crawl over even small twigs without breaking them.

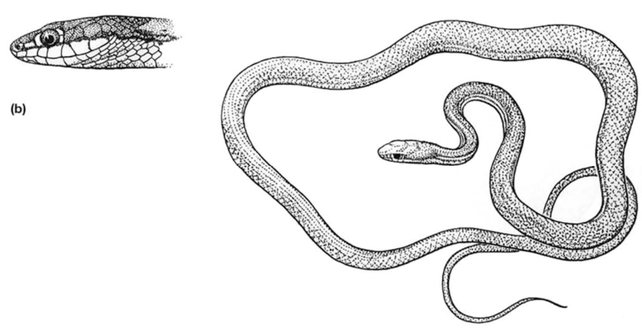
Burrowing snakes (D) are short and have blunt heads and small eyes. The head assists in penetrating the soil while the body and tail resist friction within the burrow.

Vipers (E) are heavily bodied with broad heads. This enables a strong strike and while the head creates a large surface area for the bite.

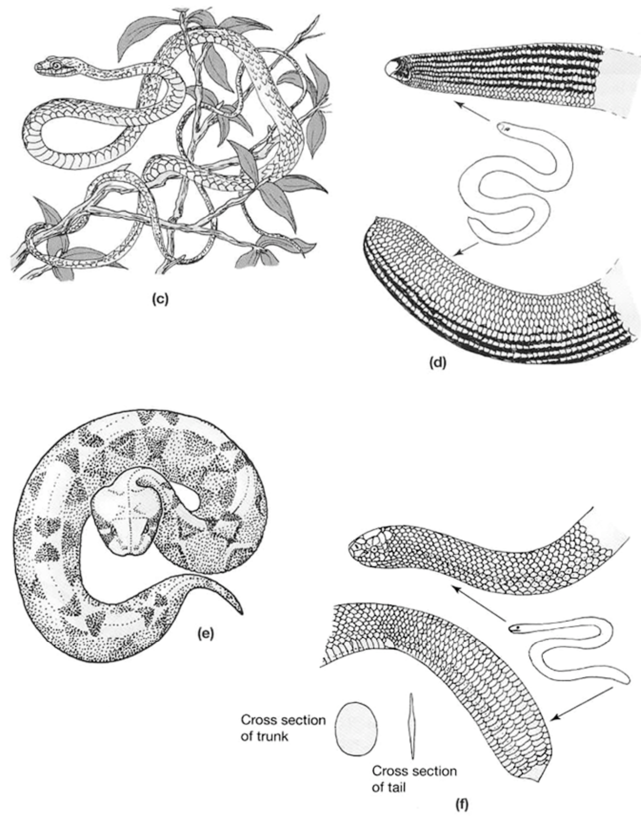
The **sea snakes (F)** are derived from cobras and have extreme morphological specialization for the marine environment. The tail is laterally flattened like an oar, the scales are reduced and the nostrils are located dorsally on the snout.



(a)



(b)



▲ Figure 11–3 Body forms of snakes. Slow-moving constrictors, such as the milk snake (a) *Lampropeltis,* are relatively short and stout. Active, visually oriented snakes such as racers, (b) *Masticophis,* are longer and faster moving. Arboreal snakes such as the parrot snake, (c) *Leptophis,* are still more elongate and can follow their prey out among the twigs at the ends of branches. Burrowing snakes such as the blind snakes, (d) *Typhlops,* have small rounded or pointed heads with little distinction between head and neck, short tails, and smooth, often shiny scales. Their eyes are greatly reduced in size. Vipers, especially the African vipers like the puff adder, (e) *Bitis arietans,* have large heads and stout bodies that accommodate large prey. Sea snakes, such as (f) *Laticauda,* have a tail that is flattened from side to side and valves that close the nostrils when they dive.

<u>Turtle – Body Styles</u>

Turtles come in many shapes and forms and can be distinguished in several different ways including:

- family
- shell type
- neck type
- the environment in which it lives

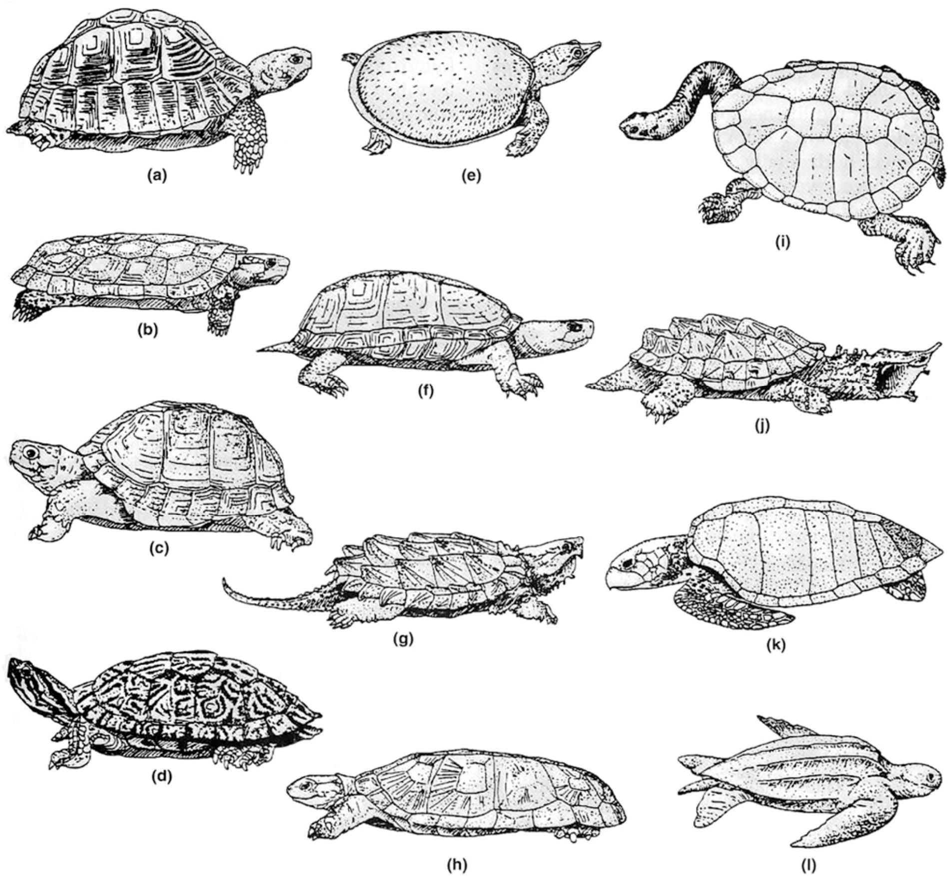
The later will be used in this case.

Terrestrial – most have high domed shells with elephant-like feet. Smaller species may show adaptations for burrowing. e.g. – tortoises, box turtles **(A,B,C)**

Aquatic – have low carapaces which offer little resistance to movement through the water, have webbing between the toes. e.g. – sliders, snapping turtles, softshelled turtles **(D-J)**

Marine – more extensive specialization for aquatic life than other aquatic turtles; have forelimbs modified as flippers. e.g. Kemp's ridley, loggerhead **(K,L)**

Identify, draw, and describe the specimens provided. Try to determine the type of environment the turtle came from and how it is able to exploit the environment.



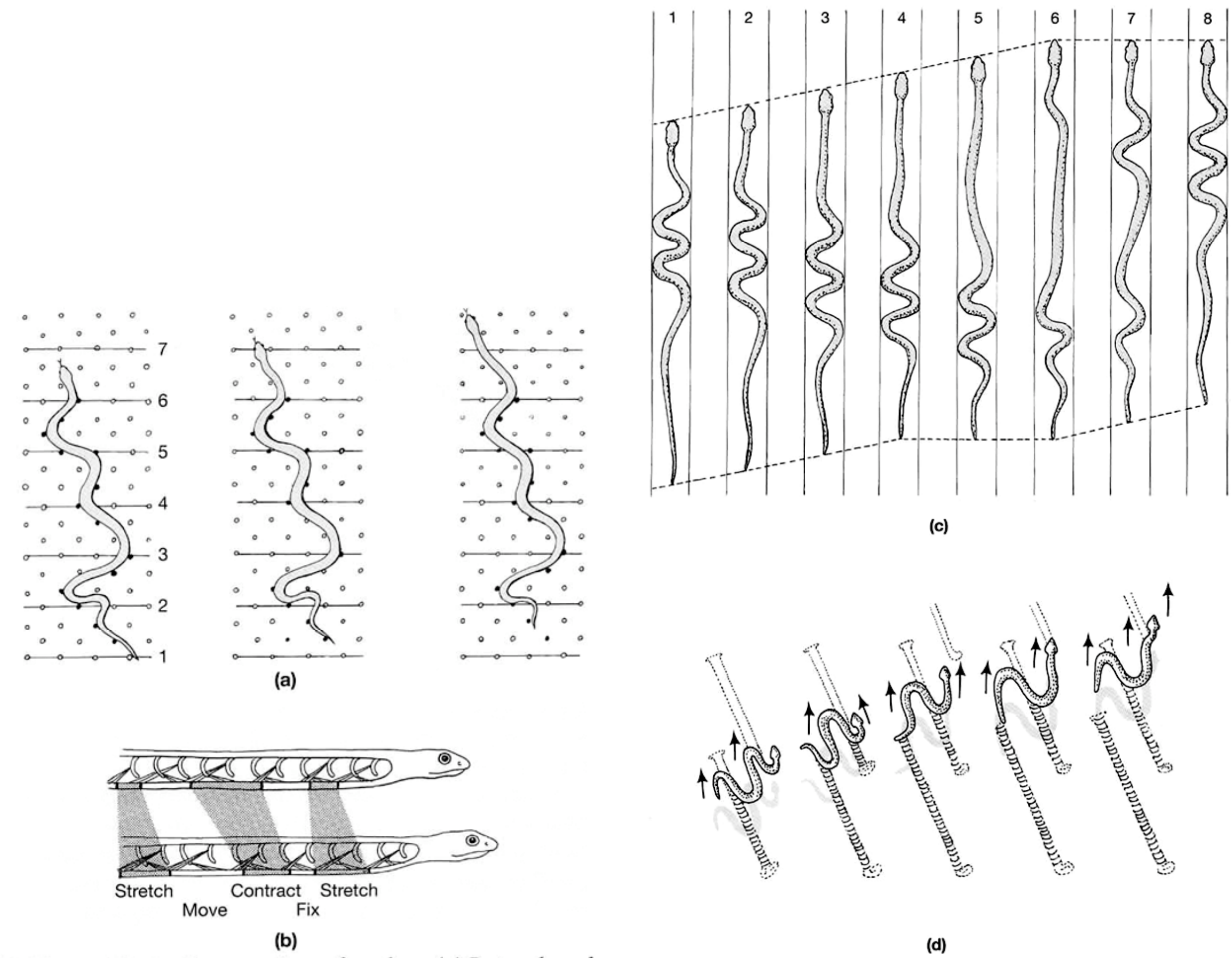
▲ Figure 10–1 Body forms of turtles: (a) Tortoise, *Testudo,* Testudinidae. (b) Pancake tortoise, *Malacochersus,* Testudinidae. (c) Terrestrial box turtle, *Terrapene,* Emydidae. (d) Pond turtle, *Trachemys,* Emydidae. (e) Soft-shelled turtle, *Aplone,* Trionychidae. (f) Mud turtle, *Kinosternon,* Kinosternidae. (g) Alligator snapping turtle, *Macroclemys,* Chelydridae. (h) African pond turtle, *Pelusios,* Pelomedusidae. (i) Australian snake-necked turtle, *Chelodina,* Chelidae. (j) South American matamata, *Chelys,* Chelidae. (k) Loggerhead sea turtle, *Caretta,* Cheloniidae. (l) Leatherback sea turtle, *Dermochelys,* Dermochelyidae.

<u>Snake – Locomotion Types</u>

Snakes utilize four types of locomotion. These include:

- **Curvilinear or Serpentine (A)**
- **Rectilinear (B)**
- **Concertina (C)**
- **Sidewinding (D)**

For the specimens available, identify, draw, and describe the method of locomotion employed. Try to determine how this type is useful/ necessary in the environment in which it lives.



▶ Figure 11–4 Locomotion of snakes. (a) Lateral undulation. (b) Rectilinear. (c) Concertina. (d) Sidewinding.

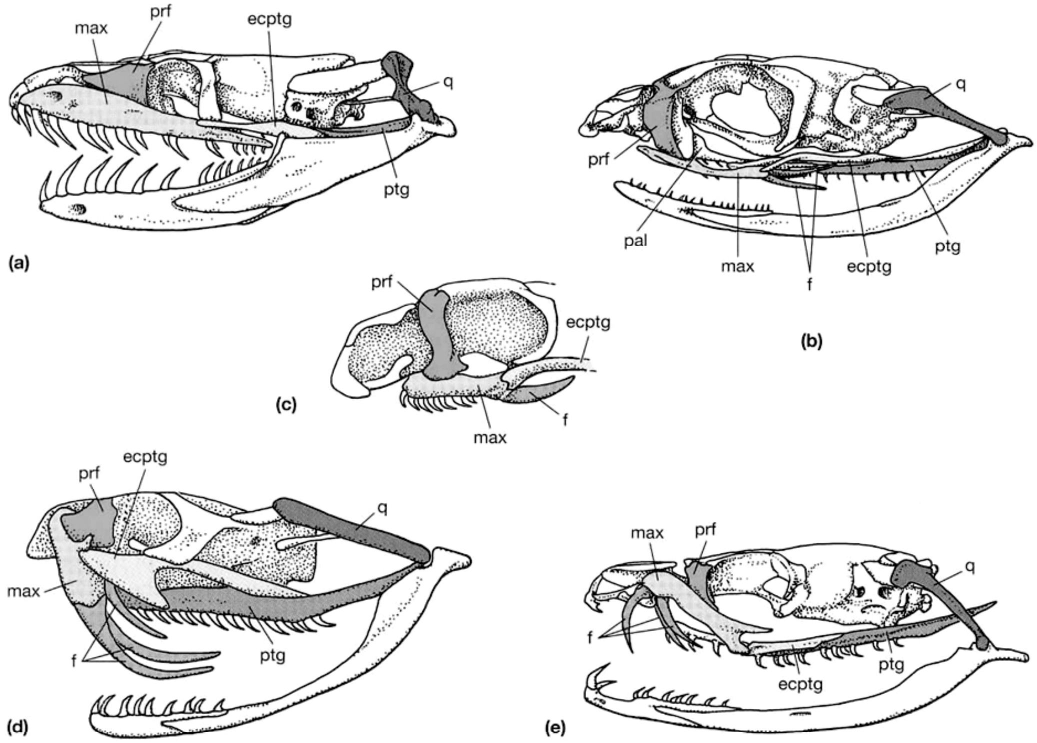
Snake Skulls - Form vs. Function

Opisthoglyph – snakes have one or more enlarged teeth near the rear of the maxilla with smaller teeth in front. Prey includes small lizards and birds, which are held in the mouth until they stop struggling; then are swallowed. Venom is passed along a groove on the surface of the fang. An example of this group is the Madagascar hognose snake.

Proteroglyph – snakes have hollow fangs at the front of the maxilla, with several teeth behind. Fangs are permanently erect and relatively short. Representative species include the cobras, mambas, coral, and sea snakes.

Solenoglyph – in these snakes the hollow fang is the only tooth on the maxilla, which rotates so that the fang is folded against the roof of the mouth when the jaws are closed. Representative species include the rattlesnakes, copperhead, and cottonmouth.

Identify, draw, and describe a representative species from each group (if available). Take note of the placement of the fangs in the mouth as related to its style of feeding.



▲ Figure 11–8 Dentition of snakes. (a) Aglyphous (without fangs), African python, *Python sebae.* (b, c) Opisthoglyphous (fangs in the rear of the maxilla), African boomslang, *Dispholidus typus,* and Central American false viper, *Xenodon rhabdocephalus.* (d) Solenoglyphous (fangs on a rotating maxilla), African puff adder, *Bitis arietans.* (e) Proteroglyphous (permanently erect fangs at the front of the maxilla), African green mamba, *Dendroaspis jamesoni.* The fangs of solenoglyphs (d) are erected by an anterior movement of the pterygoid that is transmitted through the ectopterygoid and palatine to the maxilla, causing it to rotate about its articulation with the prefrontal, thereby erecting the fang. Some opisthoglyphs, especially *Xenodon* (c), have the same mechanism of fang erection. Legend: ecptg, ectopterygoid; f, fang; fro, frontal; max, maxilla; pal, palatine; par, parietal; pmax, premaxilla; prf, prefrontal; ptg, pterygoid; q, quadrate; sut, supratemporal.

Kinesis

Kinesis is an adaptation that allows snakes and some lizards to swallow prey larger than their mouth might normally open. This is due to eight movable links within the skull.

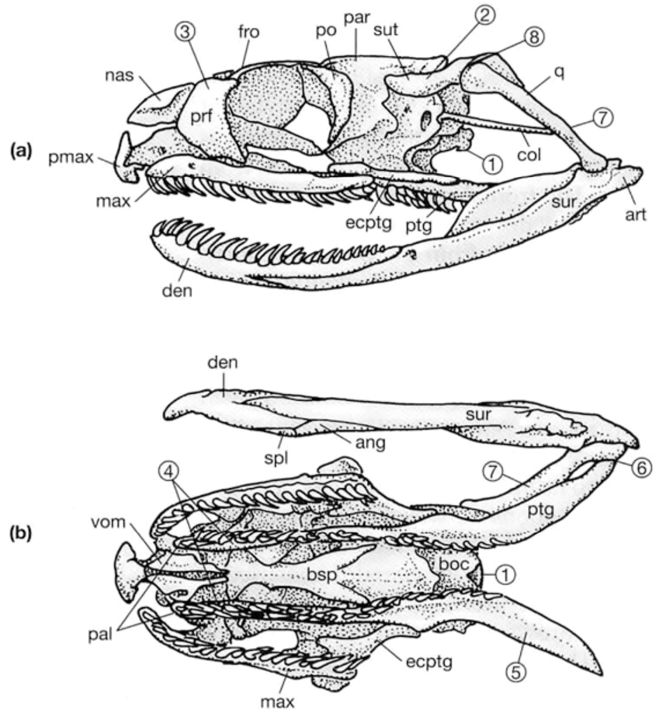


Figure 11–6 Skull of a snake. (a) Lateral and (b) ventral views. A snake skull contains eight movable links: (1) braincase; (2) supratemporal; (3) prefrontal; (4) palatine; (5) pterygoid; (6) pterygoquadrate ligament; (7) quadrate; (8) quadrato-supratemporal tie. Legend: ang, angular; art, articular; boc, basioccipital; bsp, basisphenoid; col, columella; den, dentary; ecptg, ectopterygoid; fro, frontal; max, maxilla; nas, nasal; pal, palatine; par, parietal; pmax, premaxilla; po, postorbital; prf, prefrontal; ptg, pterygoid; q, quadrate; spl, spenial; sur, surangular; sut, supratemporal; vom, vomer.

Amphibian/ Reptile Skeletal System

Look at the skeleton of the frog, snake, and fish. As we have mentioned previously in lab and lecture, true **zygapophyses** appear in the amphibian and reptilian skeleton. The fish, except a few species, do not have these processes off their vertebrae. Throughout the entire vertebral column, the vertebrae are articulated by processes of these zygapophyses. Each vertebrae bears an anterior and posterior pair. These interlock between vertebrae, with the articular surface of the anterior zygapophysis facing upward and that of the posterior zygapophyses facing downward. These articulating processes produce a firmer, stronger vertebral column than is possible when adjacent centra are held together by connective tissue alone, as in fish.

Notice the large size of the hindlimb bones and their attachment to the pelvic girdle. The attachment to the vertebral column via the pelvic girdle increases the support of the muscles and for the mechanics of swimming, in which the hindlimb is principally involved.

Draw or describe the pelvic girdle and hindlimbs of the frog.

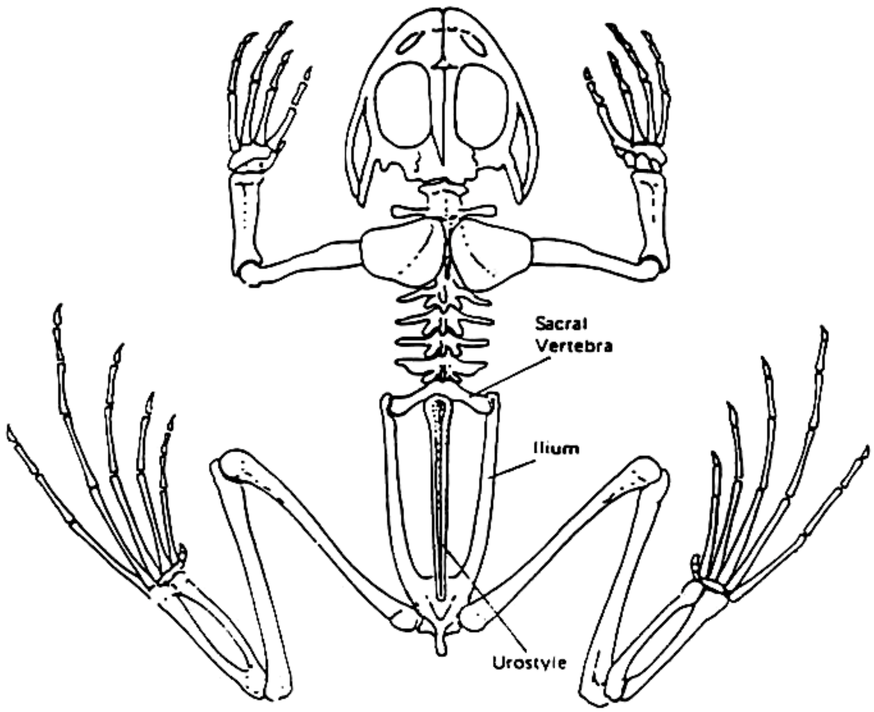


Figure 10-2 An anuran skeleton shows numerous adaptations for saltatory locomotion. The skull is broad and lightly built with large orbits. The number of vertebrae is greatly reduced and the vertebrae themselves are broad and allow little flexion. Behind the sacral vertebra, the remaining vertebrae are fused into a rigid urostyle. The ilia are elongated and form part of the lever system that also includes the long hind legs, feet, and toes. (Modified from Marshall in J. Z. Young [1962] *The Life of Vertebrates*. 2nd ed. Oxford University Press, New York.)

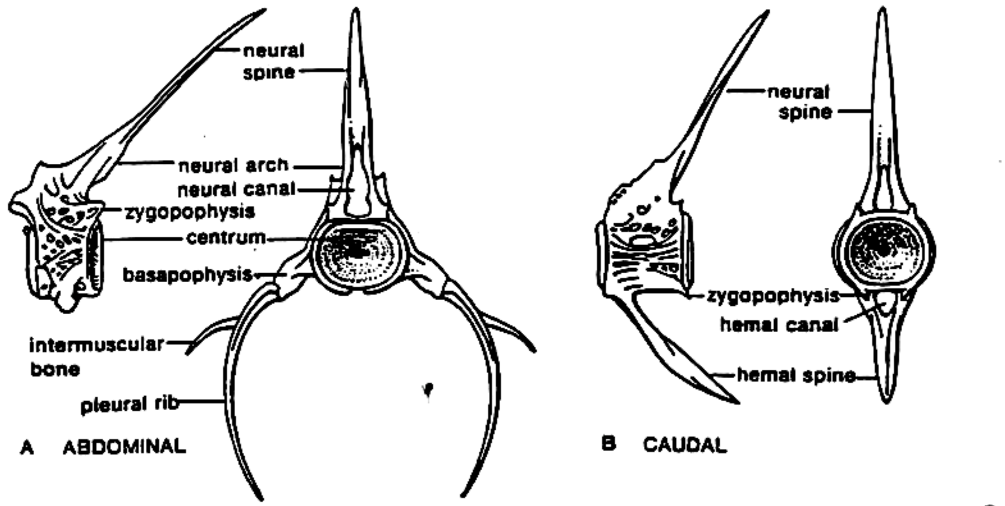
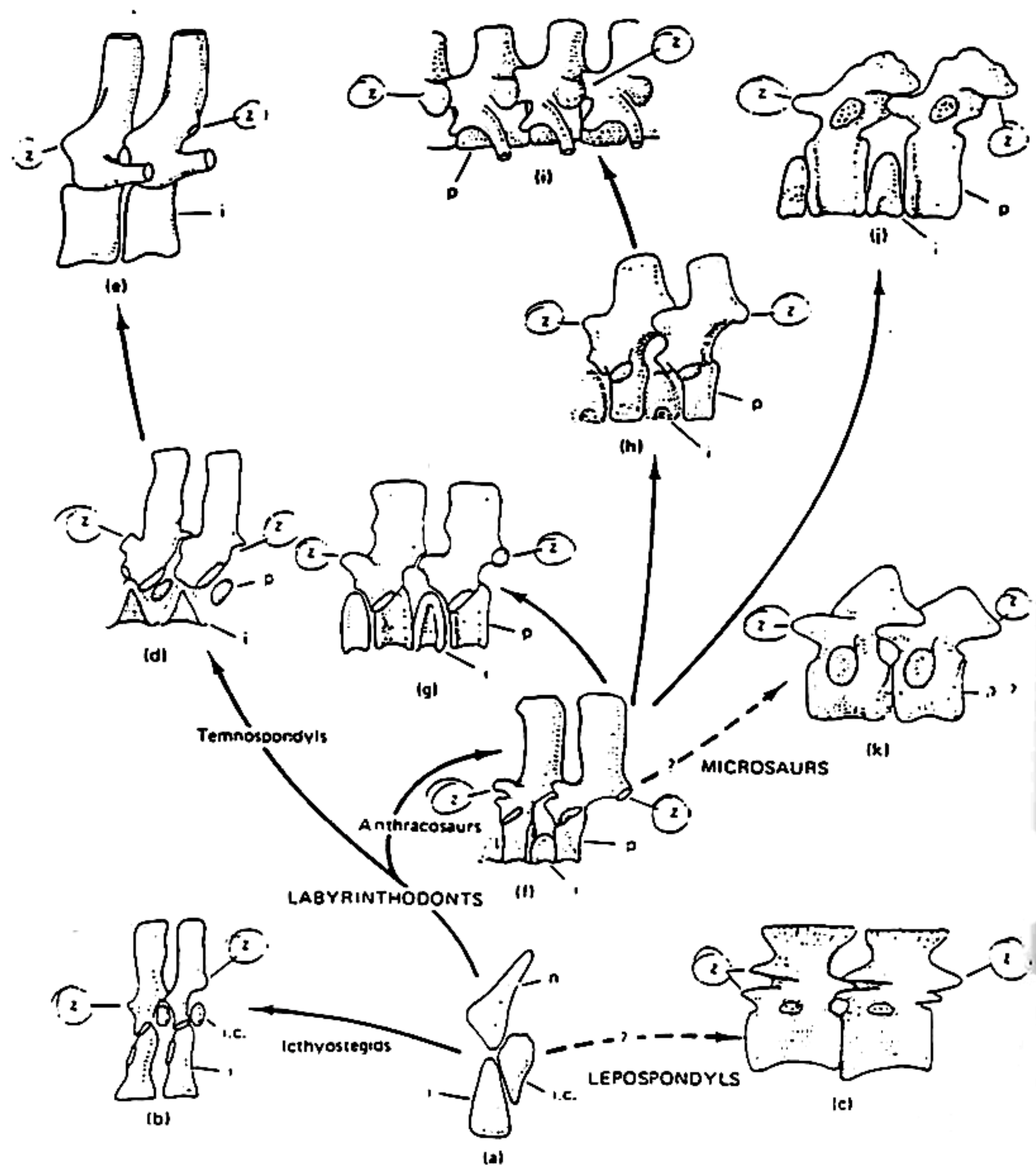


FIGURE 3–8. Vertebrae of teleost. *A*, lateral and posterior views of abdominal vertebrae; *B*, lateral and posterior views of caudal vertebrae.



Feeding Adaptations

Alligator skull –

This animal grabs onto its prey, holds it, and either swallows it whole, or tears off chunks of flesh and swallows it. Note:

1. strong mandibular symphysis (the distal end of the lower jaws are strongly fused). This allows the gator more strength and support to tear at the flesh of its dinner.
2. Eyes located on top of head. This allows the gator to keep its eyes above water, as its body is mostly submerged.
3. the sharp interlocking teeth all have the same basic shape. Thus the alligator is called a homodont.

Sea Turtle skull –

This animal uses its rigid, sharp plate to tear seaweeds and gelatinous zooplankton (jellyfish).

Predator Defense

Giant toad – Note the huge poison gland behind the eye. It is the large raised area, the lighter colored area is the tympanic membrane and is discussed elsewhere. This poison gland is an anti-predator mechanism. Unfortunately, a predator has to taste a toad and its poison gland at some point.

Horned toad – Actually, this is a lizard that has spines all over its scaly body to dissuade predators from trying to eat the horned toad. They might also secrete blood from the eyes in an effort to scare a potential predator. This would not be an effective strategy against a shark, but horned toads don't have much to worry about from sharks as they live in desert-like environments, and sharks don't, at least not for long.

Rattlesnake – These animals actually will try and get out of your way. Failing that, they coil their bodies and shake the distal end of the tail producing a rattle-like sound. This serves as a warning that a rattlesnake is very near. They may also have camouflaged coloration that serves to hide the snake from predators, such as hawks, and prey.

Stink-pot turtle – As its name implies, this turtle will release a musk-like odor when confronted by a potential predator. This will tend to drive the predator away. The turtle also has its tough shell to protect it. However, the size of this turtle makes it just about a mouthful for some animals, so the turtle relies on odor as a defense.

Lab #6 – *Necturus* (Mudpuppy) Dissection

Lab #7 – Bird Morphology and Ecotype Lab

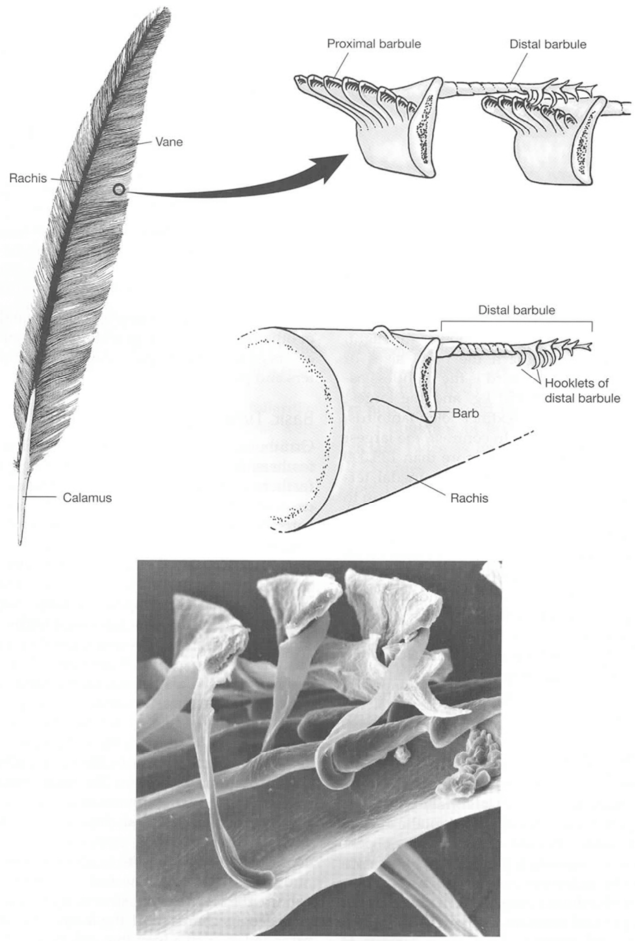
Generalities

- Evolved true flight
- Lungs for respiration
- Evolved feathers from reptilian scales
- Heart with two atria and two ventricles. Lost sinus venosus.

Feathers

Feathers are composed of 90% beta keratin, a protein related to the keratin of hair and horn of mammals, 1% lipids, 8% water and the rest of other proteins and pigments. There are five types of feathers based on structure:

1. **Contour:** Typical flight feathers (regimes and rectrices) and body feathers. They include a short, tubular base, the calamus, which is firmly implanted within the follicle until molt occurs. Distal to the calamus there is a long, tapered rachis, which bears closely spaced side branches called barbs. Barbs on either side of the rachis constitute a surface called a vane. The proximal portion on the vane has a downy texture, and is loose, soft, and fluffy. The distal portion of the vane has a sheet-like texture, and is firm, compact, and closely knit. Regimes are the wing feathers, rectrices are the tail feathers. **(B)**
2. **Down:** Fluffy feathers. The rachis is absent or shorter than the longest barb. Natal downs usually provide insulation of hatchlings and precede development of other feathers. Definitive down develops with full body plumage, such as the one associated to the uropygial gland. The uropygial gland is located at the base of the tail in most birds and secretes oil to provide waterproof dressing to the plumage.
3. **Semiplumes:** Intermediate in structure between contour and down feathers. The rachis is longer than the longest barb. They are hidden beneath contour feathers providing thermal insulation and helping to fill the contour of the body. **(A)**
4. **Bristles:** Specialized feathers with stiff rachis and barbs only on the proximal portion or without them. Around the base of bills, eyes, eyelashes to screen out foreign objects and as tactile sense organs to aid in aerial capture of insects. **(C)**
5. **Filoplume:** Fin, hair-like feathers with a few short barbs or barbules at the tip. Sensory structures that play a role in keeping contour feathers in place by adjusting them. **(D)**
6. **Powder feathers:** Difficult to classify structurally. Produce an extremely fine, white powder composed of keratin. The powder is shed onto plumage and provides another waterproof dressing for feathers.



▲ Figure 15–8 Typical vaned feather (a wing quill) showing its main structural features. The inset and electron micrograph show details of the interlocking mechanism of the proximal and distal barbules.

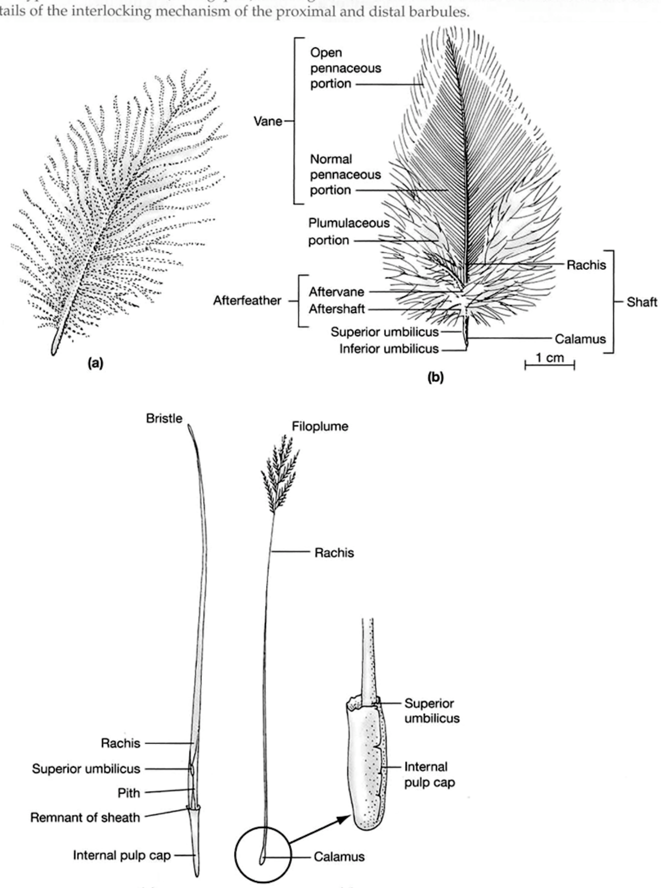


Figure 15–10 Types of feathers. (a) Semiplume. (b) Body-contour feather. (c) Bristle. (d) Filoplume.

Function of feathers

Insulation – Downs, semi-plumes, and downy portion of contour feathers hold dead air, which prevents conductive heat transfer.

Thermoregulation – Control of position of feathers to increase or decrease thickness and insulation of plumage according to ambient conditions.

Flight

Other – Mostly provided by distal portion of vane.

Social communication, concealment from predators, radiative heat exchange with environment due to coloration patterns:

- Black/brown: melanin granules deposited within feather during development.
- Red/yellow: from pigments in plants (carotenoids), changed into bird carotenoids when consumed by the bird.
- White: a structural color due to tiny, air filled spaces within feathers barbs that reflect light.
- Blue: a structural color due to spaces within the barbs that have tiny pores that reflect blue.
- Green: a combination of structural blue and carotenoid yellow.
- Pink: in flamingos is caused by carotenoids in shrimp (in captivity, they have dye mixed in with their food). However, there are several species of free-ranging flamingoes that are white in color.

Water repellence – Partially by usage of preen gland oil and physical arrangement of barbs and barbules.

Water storage – In some birds like the sand grouse, which has to fly to different areas to obtain water, special coiled barbules absorb and carry water.

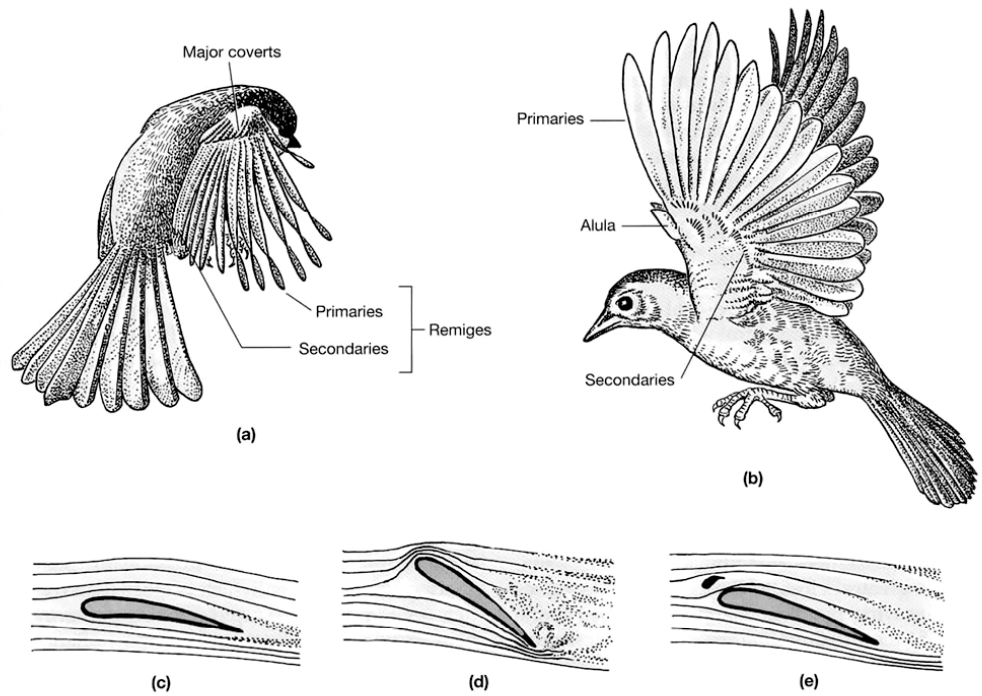
Sound protection – Incidental to beating of bird's wings in flight, with slight modification in the shape of primaries or tail feathers, or with more profound modifications in flight feathers to produce mechanical sounds.

Sound muffing – Flight feathers with a soft, velvety texture on their dorsal surfaces produce by "pubescent" barbules that project soft hair-like tips at right angles to the main surface of the feather. Exhibited in nocturnal species.

Protection of downy undercoat.

Flight

When a drop of water or other fluid falls through the air, it is shaped by the friction and pressures of the resisting air into a teardrop or streamlined form, a shape with less resistance or drag than an equal volume of some other shape. Forms with such contours – blunt and rounded in front and tapering, more or less, to a point in the rear – are found in the bodies of most birds. This is also true of fishes, which likewise face the problem of passing through a resisting, fluid medium. However, slipping through the air efficiently is not enough to make flight possible. The bird must also be supported by the air, and it must have propellers to move through air to thrust its body forward. These are the functions of the bird's wings. Each wing, moreover, like the bird's body, is streamlined in cross-section.



▲ Figure 15–11 The wing in flight. (a, b) Drawings from high-speed photographs show the twisting and opening of the primaries during flapping flight. (c–e) Airflow around a cambered airfoil. At a low angle of attack (c), the air streams smoothly over the upper surface of the wing and creates lift. When the angle of attack becomes steep (d), air passing over the wing becomes turbulent, decreasing lift enough to produce a stall. A wing slot formed by the alula (e) helps to prevent turbulence by directing a flow of rapidly moving air close to the upper surface of the wing.

Creation of lift – When the leading edge of a flat plane (wing) moves through air, it thrusts the air upward and downward so that the resultant movement of the air reduces its pressure equally on both the upper and lower surfaces of the wing. When the reduction in the upper surface of the wing is larger than the reduction in the lower surface of the wing, the air pressure against the underside of the wing will be greater than against the appraised of the wing. This differential pressure on the wing creates increased pressure against the under surface and a partial vacuum over the upper surface, or a net vertical lifting force at right angles to the surface of the wing. Flight is possible when the lifting force is larger than the weight of the object (force of gravity times its mass). There are two ways to reduce the air pressure over the wing in relation to the air pressure under the wing:

1. Creation of a cambered or curved wing – When the two surfaces of a wing differ from each other, the air pressures against them will be unequal, because the air stream must travel farther and, therefore, faster than the other, this will reduce its pressure on the wing surface. If the wing is curved so that it is convex above, and thus lengthened in breadth, and flat or concave below, and thus shortened in breadth, the air on the underside of the wing will not be thrusted to the sides as much as before. Therefore air pressure against the underside of the wing will be greater than that on the upper surface. It should be noted that the higher the chamber (curvature) of the wing, the lower the speed of the bird.
2. Increasing angle of attack by streamlining – If the leading edge of the wing is tilted upward with reference to its direction of forward motion (the angle of tilt being known as the angle of attack), the pressure on its upper surface will be greatly decreased and the lift will be further increased.

A streamlined cambered wing, that is it possesses the two traits that produce lift, is called an airfoil.

Wing loading – The area of the wing in relation to the weight that must be carried (area-to-weight ratio) is known as wing loading and is one trait that influences the performance of the wing. In general, the larger this ratio (i.e., the larger the wings in proportion to the load carried), the less power needed to sustain flight.

Reduction of drag – Drag is the backward force opposing the wing's motion through the resistant air. Both drag and lift are proportional to the area of the wing and the square of air speed, and vary according to the wing's area, shape, surface texture, velocity, and angle of attack.

Wing slots

Stalling angle – At a given speed, a wing operates at maximum efficiency at that angle of attack that gives the highest lift-to-drag ratio. When the angle of attack reaches about 15° to the direction of the wing's motion through the air, it becomes too steep. Then the air stream begins to separate from the wing's upper surface and becomes turbulent, and lift disappears. For a given wing, this point at which lift vanishes is known as its stalling angle.

Stalling speed – Since lift also varies with speed, a given load can be carried at high speed with a small angle of attack, or at a lower speed with a larger angle of attack. When velocity is reduced to a point below which the smooth airflow is disrupted, stalling occurs regardless of the angle of attack. This speed is called the stalling speed.

The disappearance of lift due to an increased angle of attack (stalling angle) or to reduced speed (stalling speed) results from air breaking away and becoming turbulent over the wing. This turbulence can be prevented so the stalling angle of a given wing can be increased somewhat, and hence the stalling speed can be lowered. Wing slots achieve this effect. For example, an open slot along the front edge of a wing will direct, over the top of a wing, a stream of rapidly moving air, which will prevent break-away turbulence at the normal stalling angle of attack. The alula of a bird's wing acts in this way. Flaps hanging diagonally downward from the trailing edge of an airplane wing have the same function. Slots enable birds and airplanes to take off and land at steeper angles of attack, and therefore at lower speed, than would otherwise be possible. The spaces that occur between the feathers, especially towards the wing tip, almost certainly function as slots.

Aspect ratio

When the air on the underside of a wing slips out from under the trailing edge, it tends to swirl upward into the low pressure area above the wing and thus create a sheet of eddies, known as trailing, which disrupt the smooth flow of air across the wing's upper trailing edge. This lift-destroying, drag-creating turbulence is particularly strong and extensive near the wing tips, where it is called tip vortex.

One way to minimize the tip vortices is to lengthen the wings so that the tip vortices are widely separated, since this makes a proportionately larger area of wing between them where the air can flow smoothly. Thus, longer wings are more efficient to reduce tip vortices and trailing than shorter wings of the same design. The ratio of the length to the width of the wing is known as its aspect ratio. Long, narrow wings have a higher aspect ratio. The aspect ratio suitable for a particular type of flight depends on the need to provide a sufficiently large undisturbed area. For example, low aspect ratio wings reduce the speed of the bird, provide great maneuverability and strength; where as high aspect ratio wings allow fast speeds, a low rate of descent when gliding, thus saving energy, need a strong skeleton and are difficult to flap.

Avian Adaptations for Flight

Weight-reducing adaptations

- Thin, hallow bones
- Extremely light feathers
- Elimination of teeth and heavy jaws
- Elimination of some bones and extensive fusion of others
- A system of branching air sacs

- Oviparity rather than viviparity
- Atrophy of gonads in nonbreeding periods
- Eating concentrated foods
- Rapid and efficient digestion
- Excretion of uric acid instead of urea

Power-promoting adaptations

- Homeothermy and high metabolic rate
- Heat-conserving plumage
- An energy-rich diet
- Rapid and efficient respiratory system
- Air sacs for efficient cooling during muscular activity associated with flight
- Breathing movements synchronized with wing beats
- Large heart and rapid high pressure circulation

Types of flight

Gliding – A gliding bird, coasting downward, is simply using weight to overcome the air resistance to its forward motion. The most proficient gliders can glide forward 15 to 20 meters while descending only 1 meter. It is the simplest type of flight and requires no propelling energy from the bird itself. Gliding has evolved independently in frogs, lizards, mammals, and birds.

Soaring flight – A soaring bird is one that maintains or even increases its altitude without flapping its wings. Soaring can be accomplished by gliding in rising currents of air (static soaring), or by exploiting adjacent air currents of different velocities (dynamic soaring).

Static soaring – Static soarers, which tend to be land birds, keep aloft mainly by seeking out and riding rising air currents. There are two sorts of air currents:

1. Slope or obstruction currents are updrafts caused when a steady or prevailing wind strikes and rises over such objects as hills, buildings, or ships at sea. A wind coming down the lee side of a mountain may strike the plain and rebound in a series of "standing waves", each with an updraft component.
2. Thermals are updrafts caused by the uneven heating of air near the surface of the earth. The air over cities or bare fields heats more quickly than that over forests or bodies of water. Since warm air expands and is therefore lighter, it rises above cooler air.

Maneuverability is particularly important to static soarers since the updrafts are often small and undependable. In order to circle in tight spirals within the updrafts, the birds need ample tails and short, broad wings – short wings for low inertia and quick, sensitive response to capricious air currents; broad slotted wings for high lift capacity. It is essential that the rate of gliding descent, or sinking speed, be no greater, than the rate of air rise in the updraft. A bird soaring in tight spirals cannot fly at high speeds. To fly slowly and yet provide enough lift to avoid sinking requires a high angle of attack and to achieve this without stalling is the static soarer's problem. The efficiency of deeply slotted, high-camber wings makes possible the combination of low speed and high lift. Each separately extended primary feather acts as a narrow high-aspect wing set at a very high angle of attack. Such a wing construction greatly reduces tip vortices, but the high angle of attack increases drag. However, since drag increases as the square of air speed, it is not a very great problem for slowly flying birds.

Dynamic soaring – On the seas steady winds, such as the trade winds, blow across the ocean surface. Their friction with the waves causes the lower levels of air to move more slowly than those higher up. As a result, wind velocity gradients are set up: wind 20 meters above the surface may be moving at twice the speed of the wind moving just above the waves. Dynamic soarers, which tend to be seabirds, exploit the velocity gradient. By gliding sharply downward with the wind, from upper, high speed levels to lower, low speed levels, the bird acquires momentum that it applies, after wheeling head-on against the wind, toward climbing back up. It is similar to a man hopping off a moving bus and using his bus-acquired momentum to run up slope at the edge of the road. As the climbing bird applies its momentum against the wind, ever increasing velocity of the wind, as the bird continues rising, acts, by increasing the bird's air speed, to extend the drive of its momentum until it reaches its original height, circles leeward, and repeats the cycle.

Flapping flight – There are many variables involved in flapping flight that only a few general principles have just recently been discovered through high-speed photography. Basically, flapping flight involves complex, screw-like motion of the wing, downwards and forwards then upwards and backwards, more rapid upwards than downwards.

Hovering flight – Support of weight without horizontal movement requires very much greater consumption of energy than forward flight and the largest hummingbirds weigh only 20 g. The principle involved is also that used for short times by larger birds in take off and landing. Lift for weight support requires horizontal movements and since the wings beat in a plane perpendicular to the body, hovering is achieved essentially by holding the body vertically.

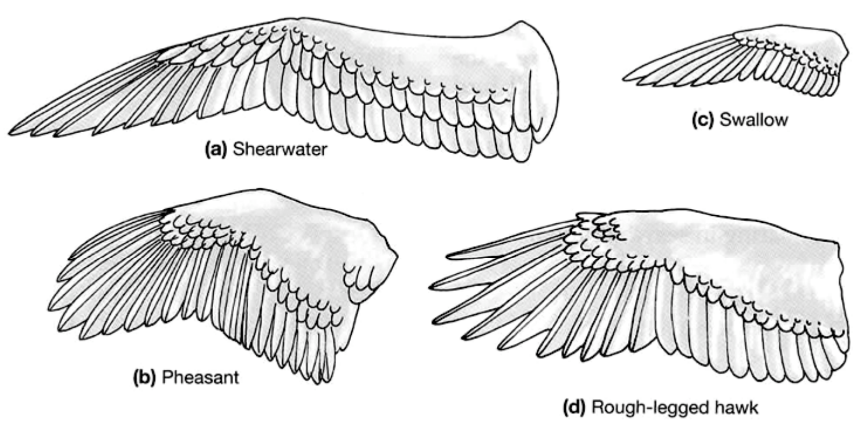
Types of wings – Wings have been classified into four major types:

Elliptical wings – Found on birds adapted to forested or shrubby habitats where birds must maneuver in close quarters. They have a low aspect ratio and a somewhat reduced tip vortex. A high degree of slotting, especially in the form of separated primaries, allows reduction in tip vortices, slow flight, and high maneuverability. Examples: doves, woodpeckers, song birds (especially ravens and crows). **(B)**

High speed wings – Characteristic of birds that feed on the wing or make long migrations. They have a low camber (flattish profile) and a fairly high aspect ratio. They taper to a rather slender tip, without slots. Examples: terns, swifts, hummingbirds, falcons, swallows. **(C)**

High-aspect ratio wings – Characteristic of dynamic soarers. They have very long and narrow wings with pointed tip lacking slots. Examples: albatrosses, frigate birds. **(A)**

Slotted-high lift – Characteristic of static soarers and predators that carry heavy loads. They posses a moderate aspect ratio, deep chamber, and marked slotting. Examples: vultures, hawks, owls. **(D)**



▲ Figure 15–15 Comparison of four basic types of bird wings. (a) Dynamic soaring. (b) Elliptical. (c) High aspect ratio. (d) High lift.

Feeding

This is a non-exhaustive list of feeding techniques in birds. Note that a bird may use more than one feeding method, may not be easily classified into one of the following methods, or may feed in a manner not covered in this list.

Fish and aquatic animal feeders

Kleptoparasitism – Piracy, e.g. frigate birds, jaeger, gulls.

Capture in the air – e.g. frigate birds on flying fish.

Dipping – Picking up from or just under the surface, e.g. frigate birds, some terns.

Pattering – Using feet in addition to wings to maintain a precise height. Able to prey on small organisms in succession, e.g. storm petrels.

Skimming – Lower jaw immerses in water to make contact and seize individual prey. Effective only in calm water and allows location of prey by touch in turbid water or at night, e.g. black skimmer.

Surface plunging – Diving from air a few centimeters into water, e.g. terns, brown pelicans.

Dive plunging – Diving from air a few meters into water, e.g. terns, brown pelicans.

Pursuit diving – Dive underwater to pursue prey by swimming, e.g. cormorants.

Coordinated – Herd prey into shallow water and scoop it from surface while floating, e.g. white pelicans.

Stabbing/ hammering – Stabbing inside a gaping mussel, or alike, while the mollusk is underwater or hammering through its shell when it is exposed at low tide, e.g. oystercatcher.

Probing – Probing the mud and sand for burrowing worms, small mollusks, and crustaceans, e.g. plovers, sandpipers.

Attracting – Paddling or exposing feet to attract small prey animals, e.g. gulls, plovers, egrets, herons.

Flushing – Tramping on soil of wet meadows or stirring up water with feet to flush small prey animals, e.g. gulls, cranes.

Shorebirds

- Shorebirds in Galveston can be observed along marshes and beaches (wetlands and the Gulf).
- Some species wade in the water as they spear fish with their bills. Other species walk beaches or tidal flats to feed on burrowing invertebrates. The length and the shape of the bill, and the length of the legs give an idea of prey and habitat for each species.
- Draw or describe the bill and legs of each specimen.
- Is it a wader and feeds on fish? Or does it capture invertebrates from the substrate?

Seabirds

- All these species are fish-eaters, however their feeding techniques are different. You can get an idea of such techniques by looking at the size of the bird, its feet and, particularly, the bill.
- Draw or describe body size, shape and size of the bill, and feet of each specimen.
- Outline a likely feeding technique for each bird.

Penguins

- Penguins are extremely cute and nicely rounded (unlike this pancaked version) seabirds that live in the southern hemisphere.

- They are well adapted to capture their elusive prey in the cold, productive waters where they live.
- Draw or describe wings, feet, and bill shape.
- How do penguins propel themselves in the water?

Aquatic filter feeders

Sucking – Suck small animal prey from surface, e.g. fulmars, prions, some storm petrels.

Sifting – Sifting small food items through a fringed and fluted beak, e.g. ducks, spoonbills, flamingoes.

Filter feeders

- Waterfowl (ducks, geese, swans) strain food from the water with their unusual bills while swimming or walking along the shore.
- Draw or describe the characteristics of the bill that allow each bird to filter its food. Notice also the webbed feet.
- Name two other vertebrates that filter their food.

Predatory

Hooked, strong bill; claws in talons to hold prey. Catching and killing may be accomplished with the bill, feet, both, or by knocking prey with body after a fast, dive down; e.g. eagles, hawks, owls, falcons.

Raptors

- Notice the differences between each bird. One is a diurnal species whereas the other one is nocturnal.
- To which category belongs each bird?
- Draw and describe the characteristics that you used to make such an assertion.

Carrion eaters – Naked heads and necks, feet adapted for walking; excellent sense of smell. Three main categories:

Rippers – e.g. king vulture
Gulpers – e.g. condor
Scrappers – e.g. black vulture

Feeders on insects and other terrestrial invertebrates

Gleaners – usually short, thin, pointed bills to pick stationary insects. Pick visually located insects from a substrate by a quick peck from a perched position. Most common method among insectivorous birds; e.g. warblers.

Flycatchers – usually broad, slightly hooked, and with long bristles at the gape bills to catch insects in the air. Capture visually located insects in the air by sallying from a perched position; e.g. flycatchers.

Aerial sweepers – fly high and fast through swarms of flying insects and make repeated captures while flying; e.g. swifts, swallows.

Probers – poke beaks into holes, cracks, soil, etc. to look for hidden animals.

Wood drillers – excavate holes to expose hidden animals; e.g. woodpeckers.

Diggers – excavate soil or litter with beaks or feet to expose food items; e.g. turkeys.

Pollen/ nectar feeders – most with long bills and tongues; e.g. hummingbirds.

Fruit eaters – e.g. toucan.

Insect eaters

- Some of these birds are very fast flyers that capture insects from the air (sweepers). Others take insects from a substrate: a leaf, a branch, etc. (gleaners).
- Draw or describe wing shape.
- Is the bird a gleaner or a sweeper?

Woodpeckers

- Woodpeckers are pretty darn funny in cartoons and magnificently adapted to their lifestyle. They feed on insects that are buried inside decaying trees. The bills of the birds are powerful enough to drill the tree and the bird has a very large tongue to extract the insect (just as the hummingbird has a long tongue to lick nectar). Did you know that a good way to recognize woodpecker species is by hearing to their different hammering pattern as they drill a tree?
- Draw or describe the shape of the bill and feet.
- Notice the different arrangement of the digits in the feet of the woodpecker compared to other terrestrial birds. Why is this so?

Granivorous

Eat seeds and nuts entire (including shell). Depend on powerful gizzards to grind up food; e.g. turkey, dove.

Hammer seeds and nuts open with beaks and pick out flesh; e.g. jays, ravens.

Crack open seeds with beaks before they are swallowed. With a short, stout, strong bill; e.g. crossbill finches, parrots, finches.

Seed eaters

Although these birds very greatly in body shape, size, and coloration, they all share the ability to eat seeds. To process seeds birds must possess the ability to masticate the seed or break it down. To do this birds use one of two structures:

1. The bill
2. and/or the gizzard.

The gizzard is basically a muscular stomach.

By looking at each of the specimens provided, discuss the role you think the bill and the gizzard play in its feeding habits. In doing so, draw and describe the characteristics of each bill.

Other methods

Lifting small rocks with bill and dropping them on egg shells to crack them open in order to eat the inner contents; e.g. Egyptian vulture.

Lifting shells, bones, crabs, nuts, tortoises with beak and dropping them onto ground to crack them open in order to eat the inner contents; e.g. gulls, crows, eagles.

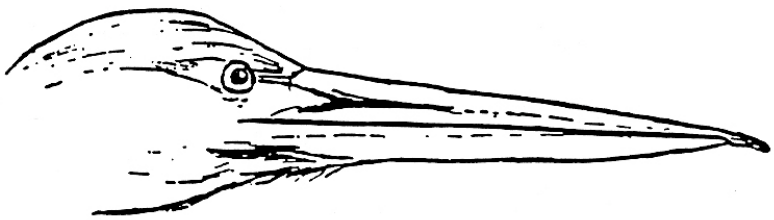
Hummingbirds

- Hummingbirds are superbly adapted to obtain nectar from flowers. The morphology of their forelimbs allows the birds to hover in the same space while they forage. Since plants take advantage of this behavior to be pollinated, some very specific interactions have evolved between species. For example, some plants have a very unusual flower shape that only one hummingbird species is able to feed from it, and thus pollinate it.
- Draw or describe the shape of the bill.
- How do you imagine the flower from where this bird feeds?

Bill types

The following are common bill types reflecting the diverse feeding habits of birds. Keep in mind that species other than the one given as an example may also have the same bill type. This is only a representative list; there are other recognized bill types as well, such as the **gibbous** bill of a scoter, the **swollen** bill of a tanager, and the **acute** bill of a warbler (Pettingill 1970).

1. **Long:** the bill is much longer than the remainder of the head, as in a heron.

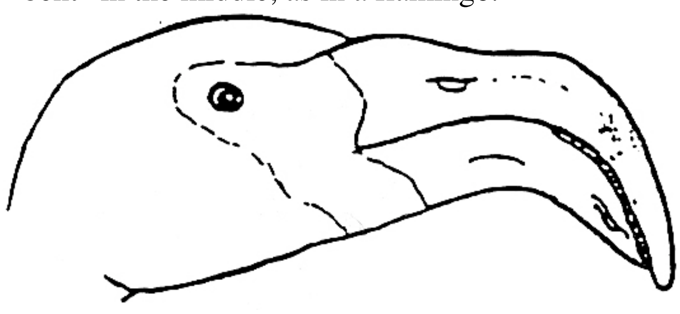


2. **Short:** the bill is much shorter than the remainder of the head, as in the sparrow

3. **Compressed:** the bill for much of its length is higher than wide, as in a kingfisher.

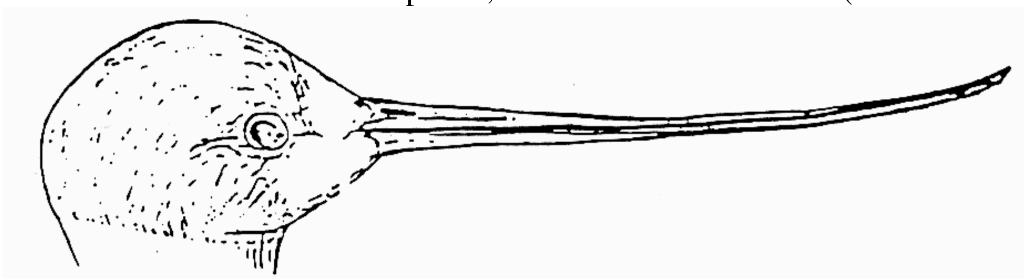
4. **Depressed:** the bill is wider than high, as in the duck.

5. **Bent:** the bill is "bent" in the middle, as in a flamingo.

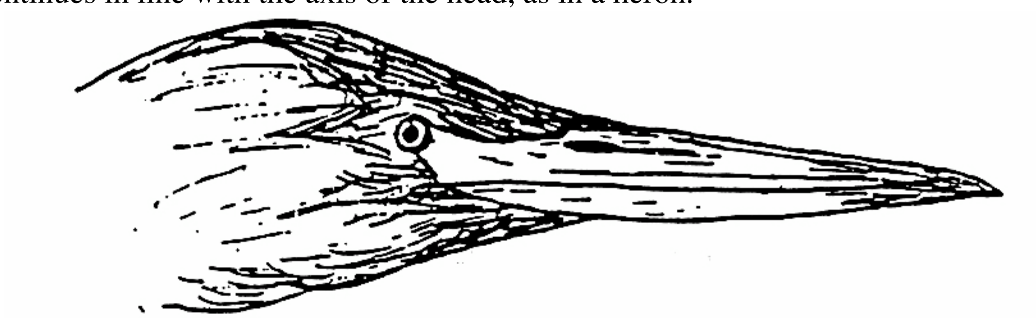


6. **Decurved:** the bill curves downward, as in the brown creeper (*Certhia familiaris*), or a curlew.

7. **Recurved:** the bill curves upward, as in the American avocet (*Recurvirostra americana*).

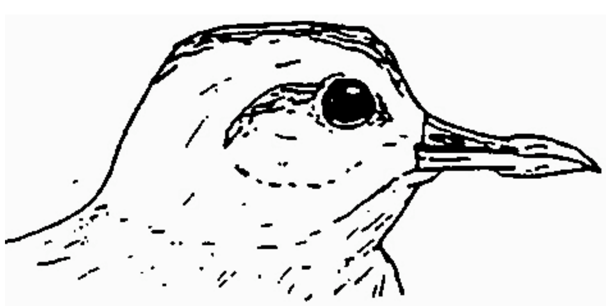


8. **Straight:** the commissure (i.e., the line along which the mandibles close) parallels or continues in line with the axis of the head, as in a heron.

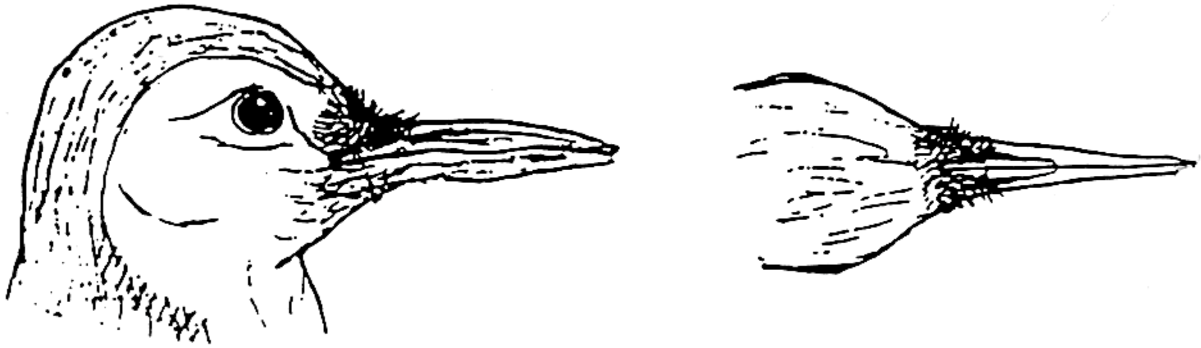


9. **Stout:** the bill shows both high and wide profiles, as in a grouse or a quail.

10. **Bulbous:** the bill is swollen at the tip or constricted near the base and tapers to a point, as in a plover.



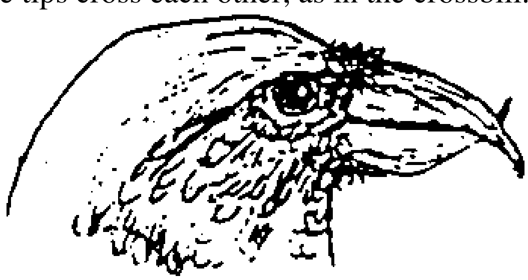
11. **Chisel-like:** the tip of the bill is beveled, as in the red-bellied woodpecker (*Melanerpes carolinus*).



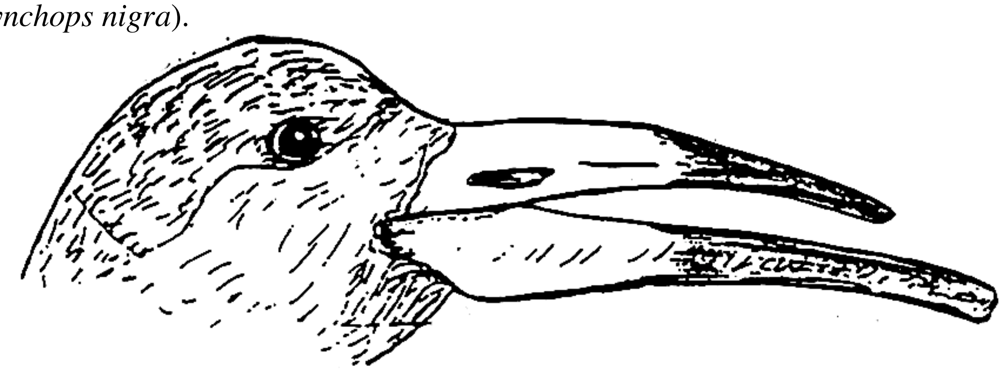
12. **Casqued:** the bill has a horn-like excrescence (epithema) developed on the bill, as in most species of hornbills (Bucerotidae) or there is an enlargement in front of the head, on the dorsal surface of the bill, a frontal shield, as in coots and gallinules.

13. **Conical:** the bill has the shape of a cone, as in the cardinal (*Cardinalis cardinalis*).

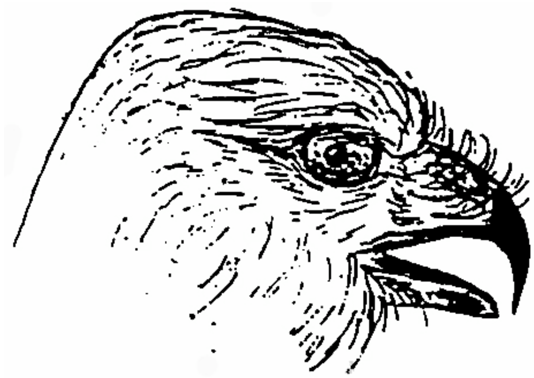
14. **Crossed:** the mandible tips cross each other, as in the crossbill.



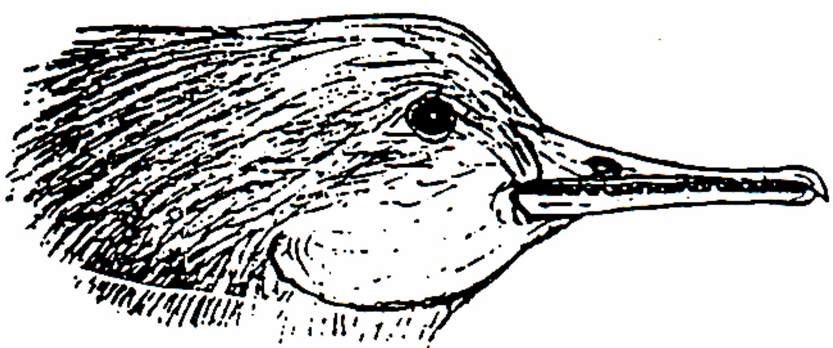
15. **Hypognathous:** the lower mandible protrudes beyond the upper, as in the black skimmer (*Rynchops nigra*).



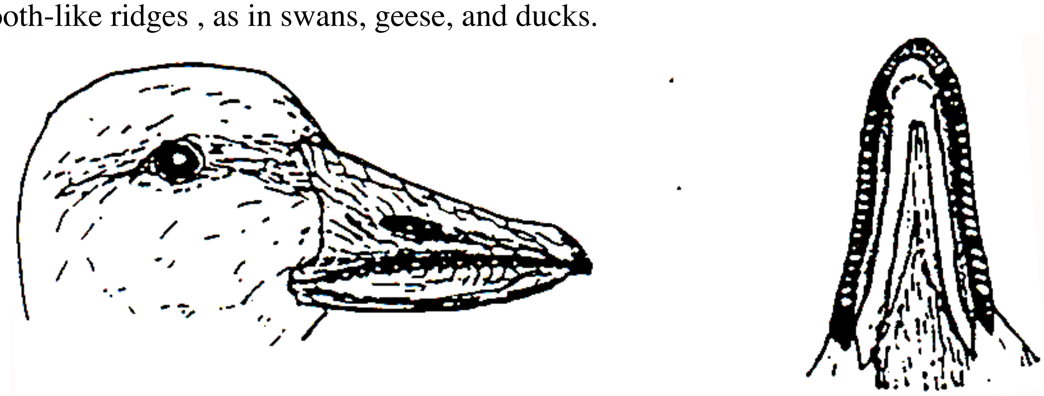
16. **Hooked:** the upper mandible extends beyond the lower, and its tip is bent over the tip of the lower, as in the hawk.



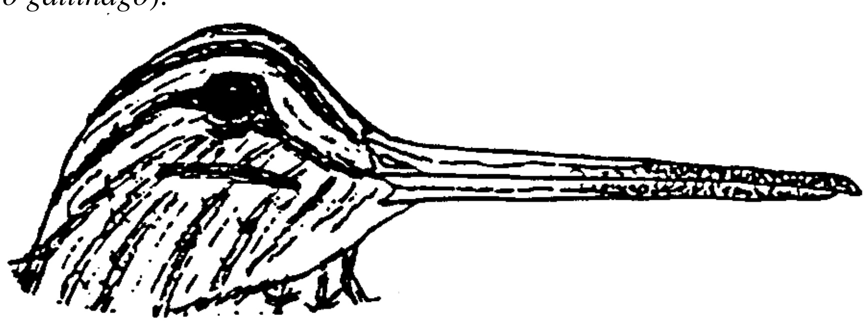
17. **Serrate:** the tomia are formed with saw-like projections, as in the merganser.



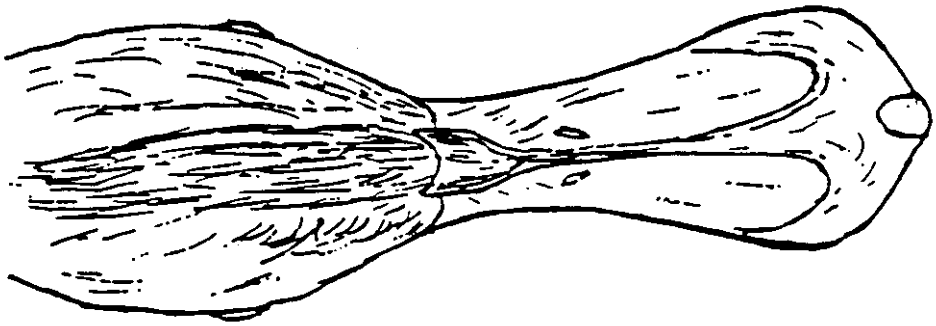
18. **Lamellate, or sieve-billed:** the mandibles have just within their tips a series of transverse tooth-like ridges , as in swans, geese, and ducks.



19. **Soft and punctate**: the bill is flexible (in life) and pitted, as in the common snipe (*Gallinago gallinago*).

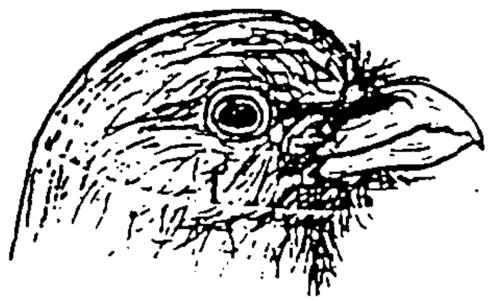


20. **Spatulate or spoon-shaped:** the bill is much wider and depressed toward its tip, as in the shoveler (*Anas clypeata*).



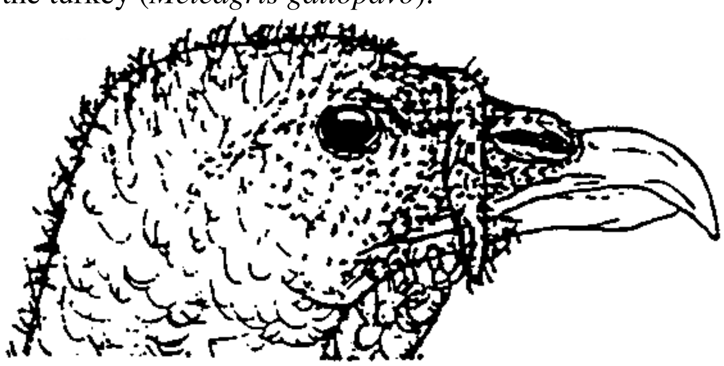
21. **Sulcate**: the bill has grooves (sulci), as in the grooved-billed ani (*Crotophaga sulcirostris*).

22. **Toothed (Dentate):** the tomium of the upper mandible has a single projection or “tooth:, as in a falcon, or several projections, as in a trogon.

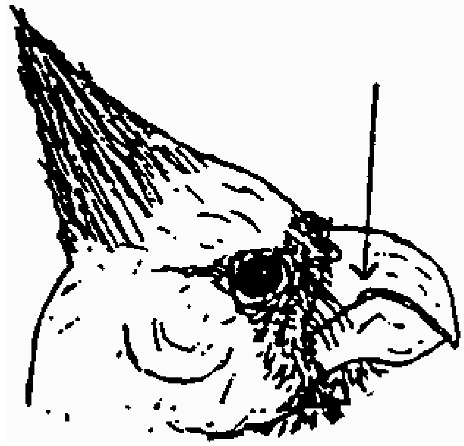


Miscellaneous characters of parts of the bill

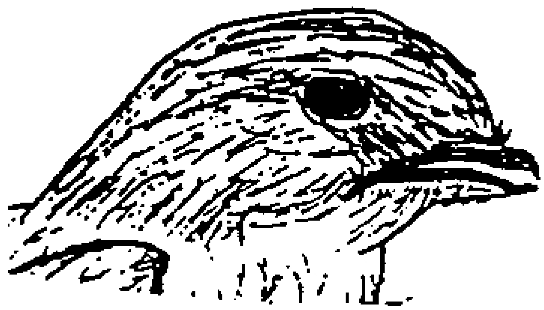
1. **Caruncülate:** the bill has a naked, fleshy excrescence, usually at the base of the upper mandible, as in the turkey (*Meleagris gallopavo*).



2. **Angulated commissure:** the commissure forms an angle at the point where the tomium proper meets the rictus, as in a finch, grosbeak, sparrow, or bunting.



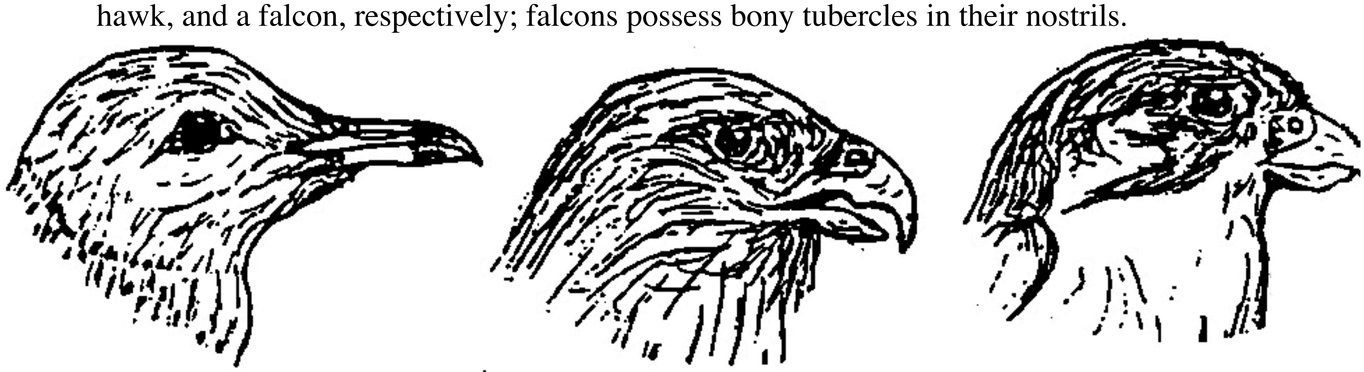
3. **Commissural point below the eye:** as in swifts, goatsuckers, and swallows.



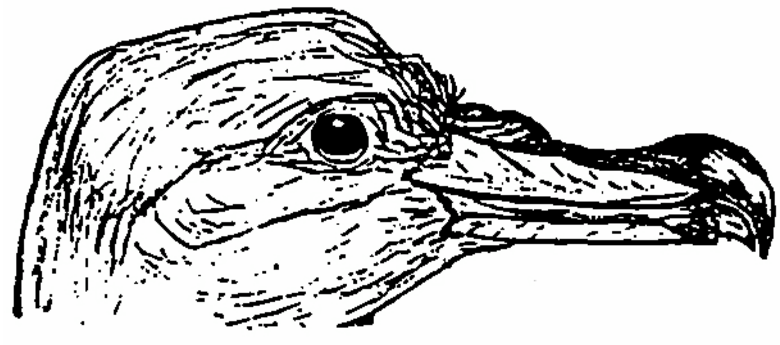
4. **Gular sac:** the chin gular region (area between the lower mandible and throat) is distended. In the pelican, the gular sac is conspicuous, outwardly membranous, and featherless. In the cormorant, it is inconspicuous and partially feathered.

A complete wall, or septum, generally separates bird nostrils; this condition is termed **imperforate**. Some groups of birds, like vultures, lack the medial nasal septum; the nostrils communicate with each other and are termed **perforate** (open). Nostrils show other characteristics:

1. **Linear, oval, or circular:** the nostril openings differ in shape, as in a gull, an accipitrid hawk, and a falcon, respectively; falcons possess bony tubercles in their nostrils.



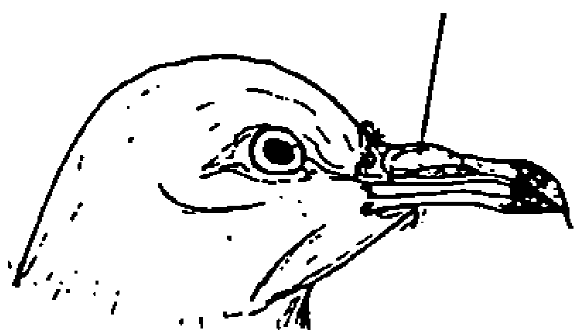
2. **Tubular:** the external nostrils occur as the ends of short prolongatid at the base of the upper mandible, as in a procellariiform.



The bill covering (rhamphotheca) is generally heavily cornified throughout. Sometimes, as in the shore birds, it is soft. Two special modifications of the rhamphotheca constitute important characters.

1. **Cere:** the distal end of the upper mandible may be horny, while the proximal portion may be thick and soft, as in a hawk.

2. **Operculum:** the distal end of the upper mandible may be horny, and the proximal portion may be soft, overarching the nostrils, as in a rock (domestic) pigeon (*Columba livia*).



Bill functions

Bird bills come in many shapes and sizes, each corresponding to a specific food type or habitat.

Bills can be described by either form or function. This, along with foot type, also dictates the environment and, or, type of feeding strategy that bird employs.

Match the bill functions to the bird forms you looked at in the previous station. Think about how the bird feeds, what environment (generally) it might exploit, and what each bird might feed upon.

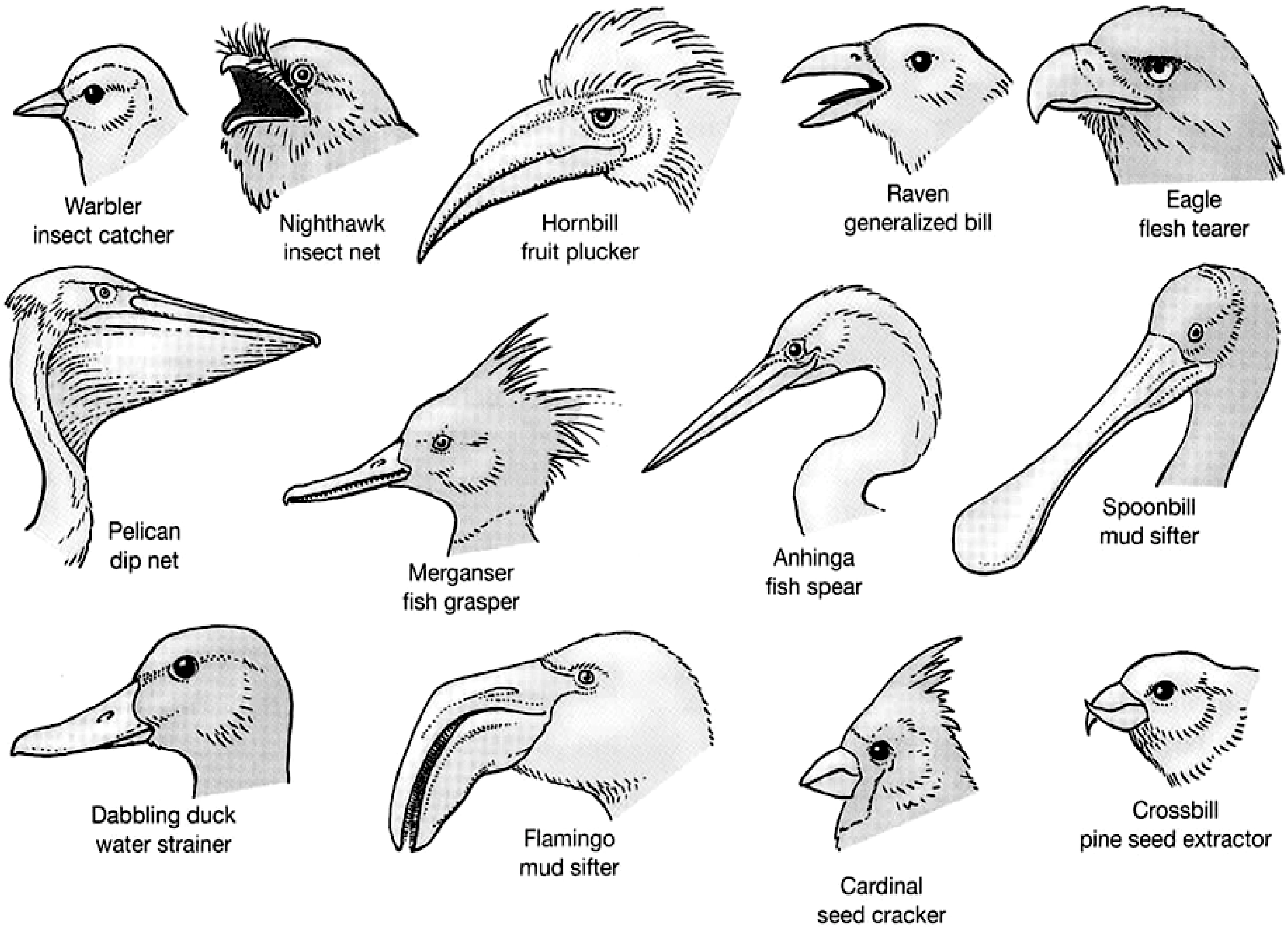
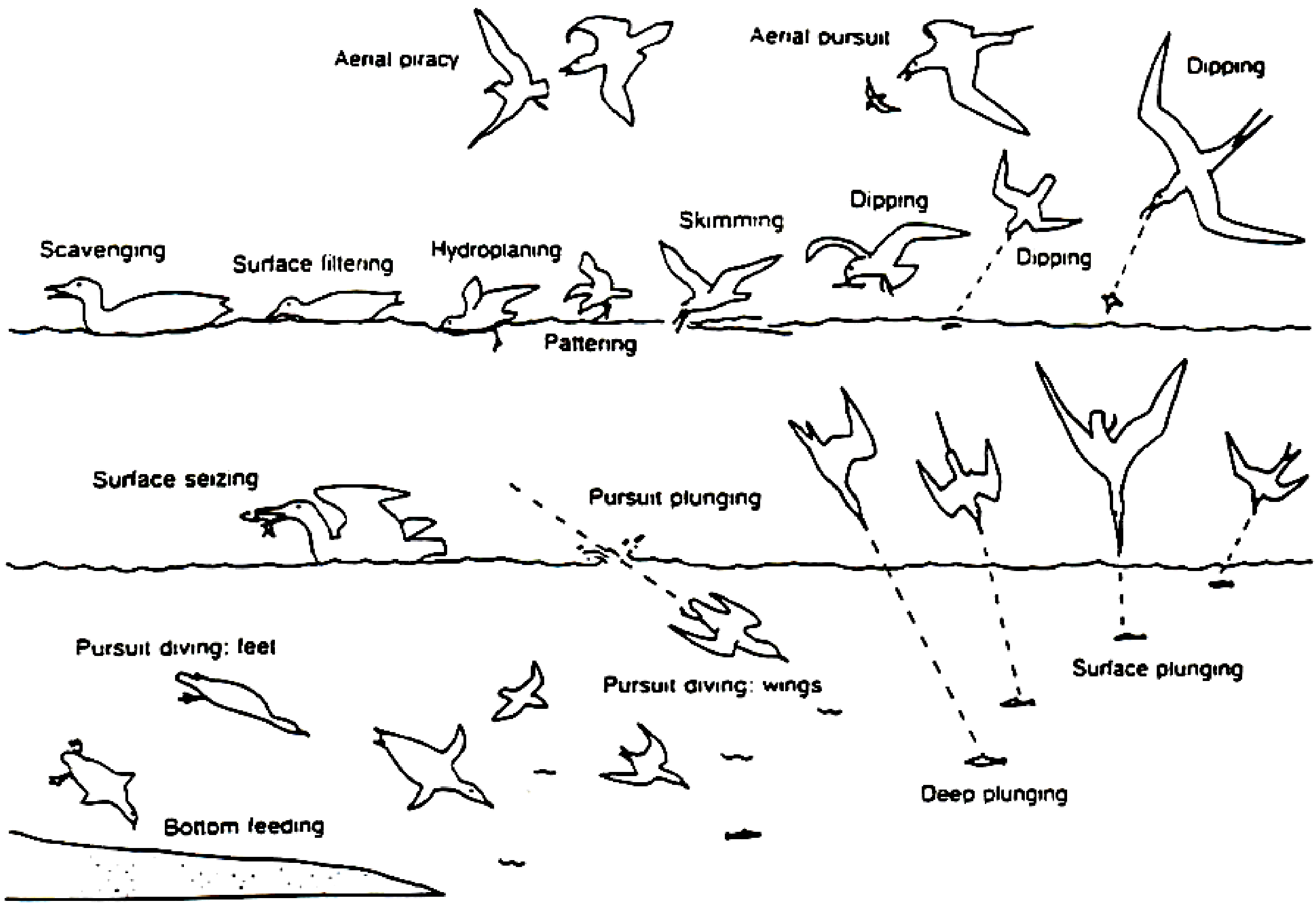


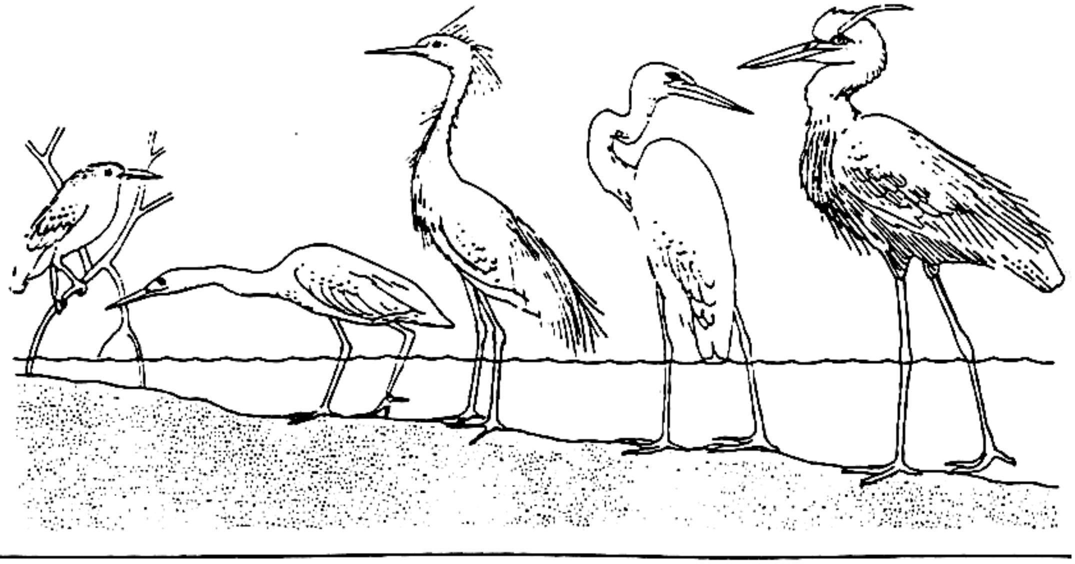
Figure 16–1 Examples of specializations of the beaks of birds.



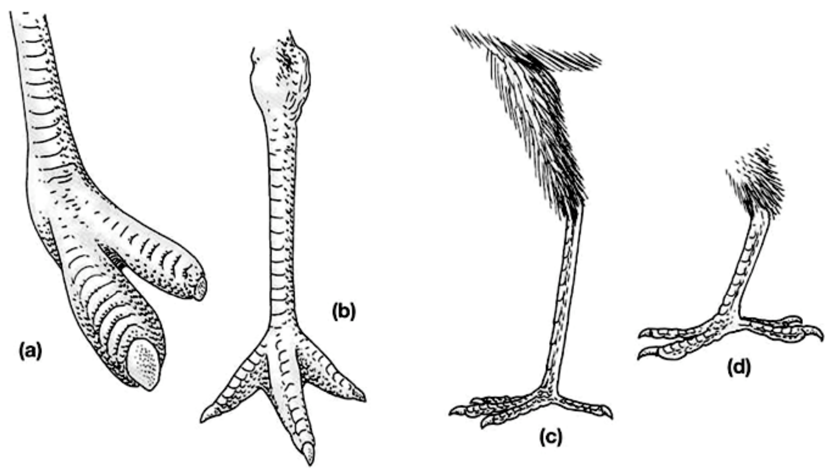
Modes of feeding of aquatic birds in water too deep for wading.

Legs and feet

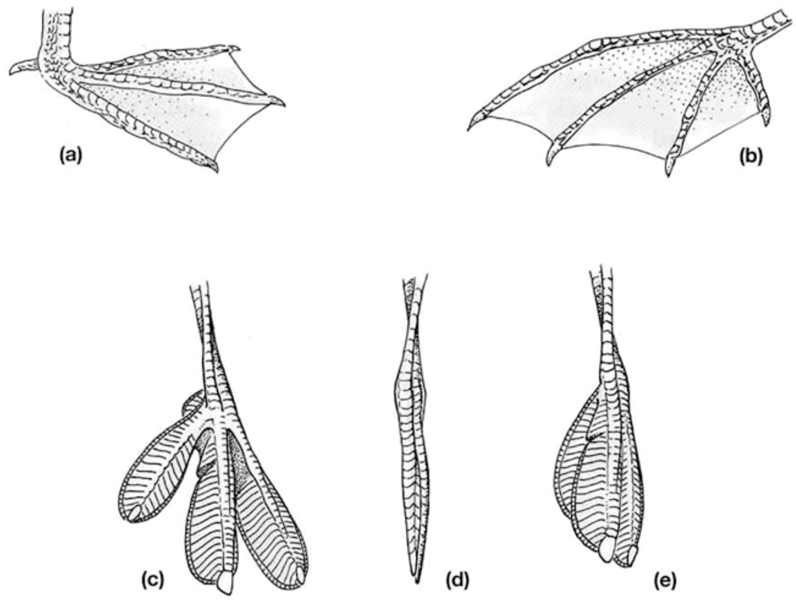
- Birds have different leg and foot types depending upon which habitat they live.
- Birds that exhibit terrestrial locomotion have heavy, powerful feet and legs, usually with reduced digits.
- Others have modified feet for grasping.
- Some birds have feet with increased surface area. This allows them to exploit environments other birds or animals cannot utilize.
- The jasana has long, thin digits which allows it to "walk on water". Its weight is evenly distributed over the length of the foot, which allows it to walk upon very delicate floating plants.
- Aquatic birds, like the duck and the cormorant have increased surface area of the foot with webbing between the digits. This allows them to use the feet for aquatic as well as terrestrial locomotion.
- The grebe takes advantage of both of these adaptations.
- You can also tell a lot about a bird by the shape and length of its legs. The longer the legs of a shorebird or marsh inhabiting bird, the deeper the aquatic habitat it can exploit. The amount of feathers covering the legs and or feet is another clue.



The water depths at which wading birds forage are determined in part by the length of their legs. From left to right this figure shows species that feed in water of progressively greater depth: green heron, little blue heron, reddish egret, common egret, and great blue heron.



▲ Figure 15–22 Avian feet with various specializations for terrestrial locomotion. (a) Ostrich, with only two toes. (b) Rhea, with three toes. (c) Secretary bird, with a typical avian foot. (d) Roadrunner, with zygodactyl foot. (Not drawn to scale.)



◀ Figure 15–24 Webbed and lobed feet of some aquatic birds. (a) Duck, showing partial webbing. (b) Cormorant, showing totipalmate webbing. The lobed foot of a grebe, showing how it is rotated during a stroke: (c) position of toes during backward power stroke in side view; (d) front view; (e) side view of the rotated foot during the forward recovery stroke.

Bird Skeleton

- The large sternum for attachment of the pectoralis and suprecoracoideus muscles.
- The placement of the sternum, towards the anterior-ventral side of the bird creates the proper center of gravity to keep the bird balanced during flight and perched.
- The bones are very thin and light, but this is deceiving unless you look at them from the inside. Bird bones are hollow, but reinforced giving them exceptional strength while providing the lightness needed for flight. Birds that cannot fly will not have bones as light as flyers, but still structurally the same.
- The "hand" bones have elongated to accommodate muscle attachment and placement of feather tracts for primary feathers used for flying.

Draw or describe skull and pectoral girdle of the bird.

Lab #8 – Pigeon Dissection

Bird Anatomy

Circulatory

- There is a complete separation of both the right and left atria and ventricles, therefore the bird is a true 4-chambered heart. The sinus venosus has been incorporated into the walls of the right atrium.
- Systematic blood enters directly into the right atrium, passes through a valve into the right ventricle. It is then pumped through the pulmonary artery into the lungs, oxygenated, retuned through the pulmonary vein to the left atrium, passing through another valve. It is then pumped out by the left ventricle through the aorta to all parts of the body except the lungs.
- The left ventricle pumps 5-10 times the pressure than the right ventricle.
- Diving birds can slow their heart rate by 50% without any effect on blood pressure.
- Spleen is very small and not an active site for blood storage.
- Amongst birds, heart beats will vary:
    - Chickadee at rest 500 beats/min. during flight 1000 beats/min.
    - Turkey at rest 93 beats/min.
    - Robin at rest 570 beats/min.
    - Blue throated hummingbird during flight 1260 beats/min.

Respiratory

- System has two functions:
    i. Supply body with oxygen and get rid of carbon dioxide
    ii. Thermoregulation: eliminate heat from flying
- Most efficient system of all vertebrates; system of air sacs and interconnecting tubes.
- Air is drawn through the lungs, not into them.
- Typically there are 4 pairs of air sacs (plus others) placed dorsally in the body, which aids the bird in keeping stable during flight.
  Flow:
    - Nasal chamber → mouth → pharynx → trachea → bronchus → bronchi → lungs → air sacs → mouth → out

Digestive

- Intense metabolism requires a rapid, powerful, and efficient digestion of food.
- Most birds have a digestive tract that is adapted to either a plant or animal diet.
- The stomach is modified into the glandular portion, the proventriculus and the masticatory section, the gizzard. A bird eating soft-bodied foods would have a less muscularized and thin walled gizzard than a bird that eats grain.
- Liver is the largest gland in the body, larger in proportion than in mammals.
    - It synthesizes sugars and fats, proteins, bile and excretes waste from blood.
- Pancreas is large and produces digestive enzymes.

Flow:
- Beak → buccal cavity → esophagus → crop → proventriculus → gizzard → intestine → cloaca

Excretory

- Kidneys twice as large as mammals by proportion due to high metabolism
- No urinary bladder, urine drains directly into cloaca where it is combined with uric acid to form a paste.
- This is an evolutionary adaptation for water retention and weight reduction for flight.

Reproduction

- Females have two types of eggs:
  - Those with male dominating sex chromosomes and those lacking
  - Sperm fertilizes an egg with → It's a boy!
  - Sperm fertilizes an egg without → It's a girl!
- Female organs are located high in the abdominal cavity.
  - Usually only the left ovary develops; this aids in weight reduction for flight as well as reducing the chances of the egg cracking if they where paired.
  - Some birds do contain two, but only the left side functions.

Nervous

- Larger cerebral hemisphere and cerebellum than reptiles.
- Olfactory small suggesting birds have a poor sense of smell.
- Optic lobes are large, therefore they are visual animals.

Skeletal

- For the ability to fly:
  - Trunk axis is short
  - Pelvis and sternum well developed for muscle attachment
  - Bones very strong, some are fused or pneumatisized (are hollow with internal cross structures for support)

Musculature

- The pectoralis is the chief flight muscle that depresses the wing.
- The supracoracoideus, lying beneath the pectoralis, lifts the wing.
- Both work as a rope and pulley system; combined make up one-fifth the weight of the entire bird.

Feathers

- Probably evolved from scales
- No intermediate stage has been found between scales and feathers
- Six types of feathers:
  - Contour
  - Down
  - Semiplume
  - Filoplume
  - Bristle
  - Powder down

Singing

- The syrinx, located within the branchi, are membranes that vibrate creating sounds. This allows a bird to sing notes of two harmonies simultaneously. Chirp.

'XTERNAL ANATOMY

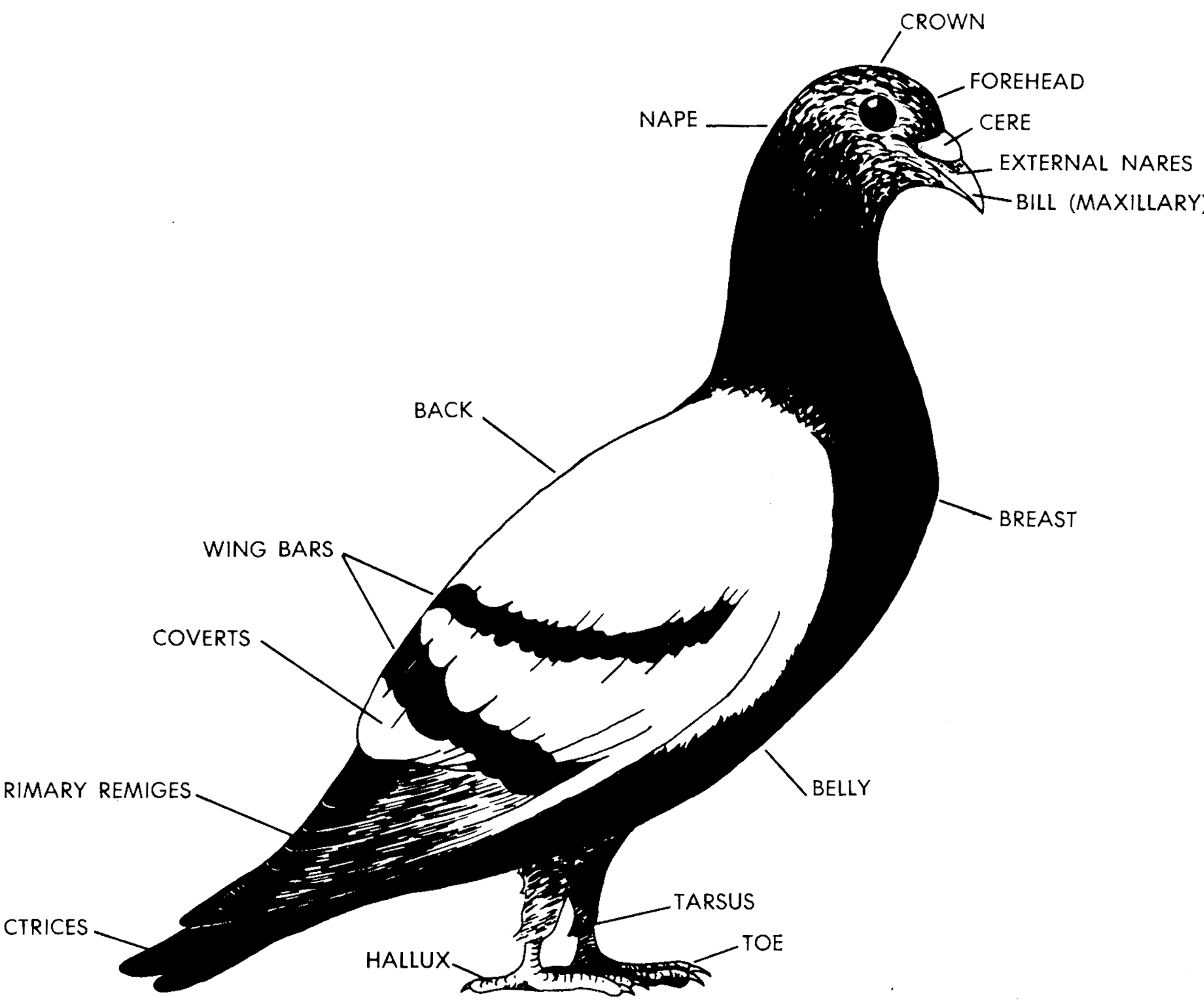
The most conspicuous structure of the head is the longated beak, consisting of upper and lower jaws en-ased in horny sheaths which functionally replace the teeth f other vertebrates. The horny sheath of the upper jaw ; pierced by a pair of slit-like *external nares* just rostral) a protuberance called the *cere* (thought to be a special ıctile sense organ). The eyes are large and possess upper nd lower eyelids and a nictitating membrane (see fig. 75). 'he opening to the external ear or *external auditory mea-ıs* is covered by the feathers of the head.

The neck is long and flexible while the trunk is firm nd immovable. Both the pectoral and pelvic appendages f birds are highly modified—the forelimbs for flight and ıe hind limbs for bipedal terrestrial locomotion and for perching. These modifications will be more easily undeı stood after observing the skeletal and muscular systems

The tail is a short, broad, "heart-shaped" structurı At the ventral base of the tail is a transverse slit-like open ing, the *cloacal aperture*. At the dorsal base of the tail : a prominant papilla bearing the opening of the *uropygi* *gland*. The colors of some birds are utilized by ornitho ogists in distinguishing species, subspecies (race) and se: In domestic pigeons, the many different breeds can b identified by their color and/or color pattern. The coloı usually found on pigeons are: blue, blue-gray, black, browı gray, and white.

In order to discuss patterns easily, the surface of th birds is divided into specifically designated areas.

The color pattern of the Rock Dove and the superf cial areas of the bird are illustrated in figure 3.



[GURE 3. External anatomy and superficial areas of the pigeon (Rock Dove).

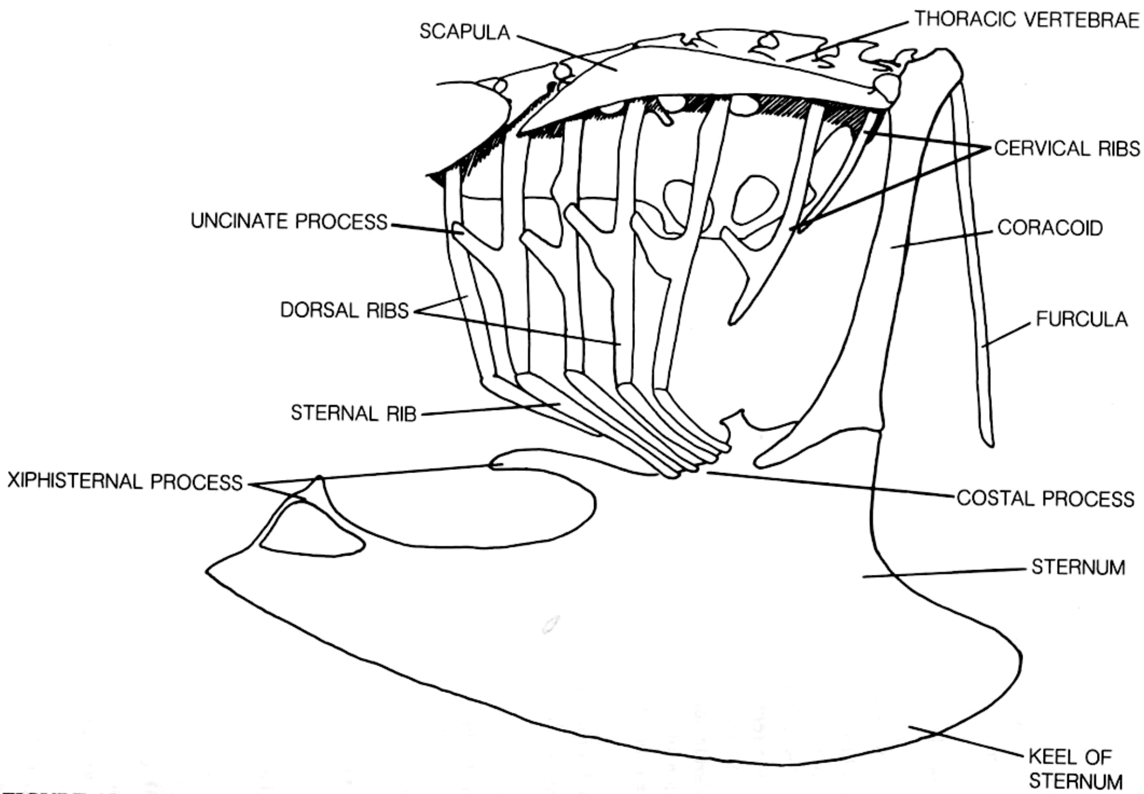


FIGURE 15. Ribs, sternum, and pectoral girdle, lateral view.

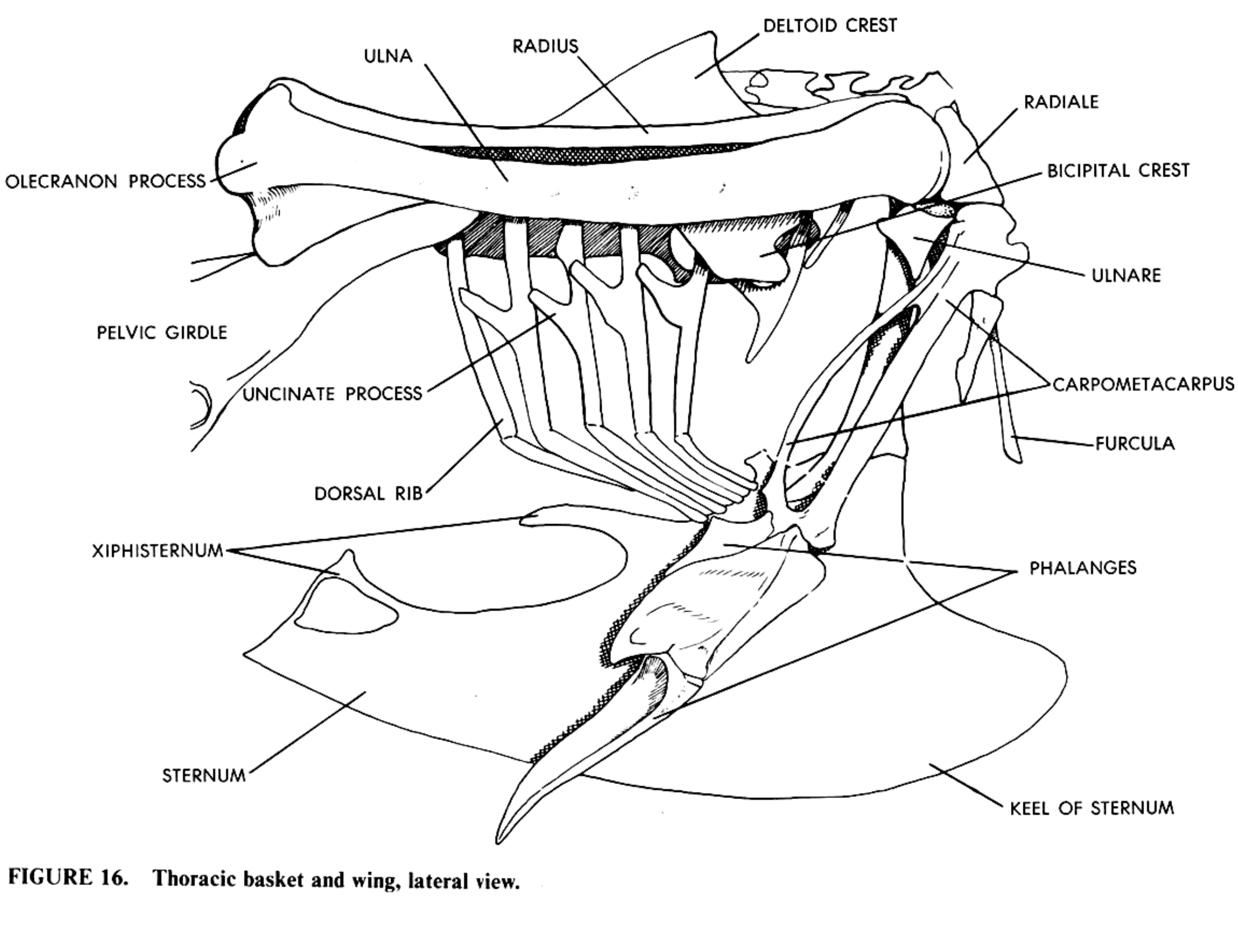


FIGURE 16. Thoracic basket and wing, lateral view.

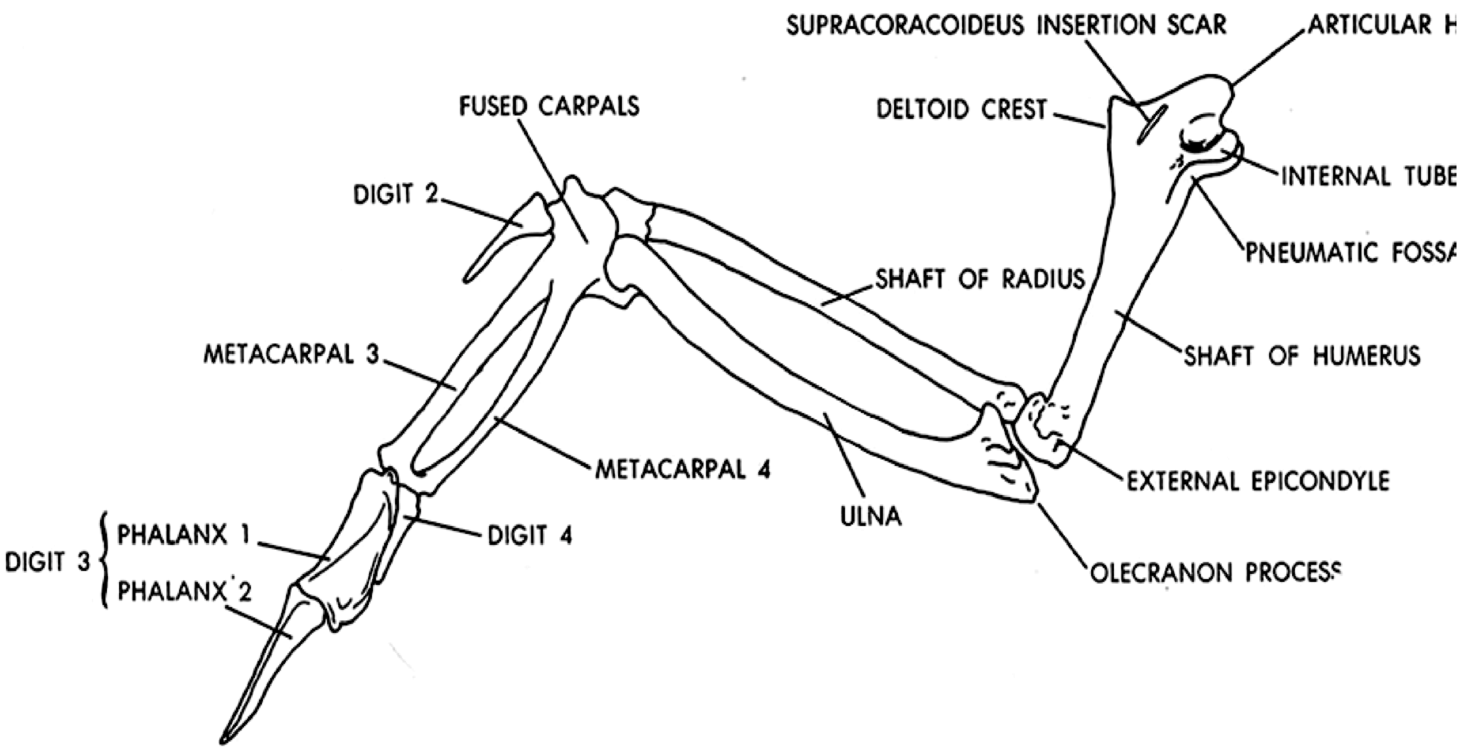


FIGURE 17. Lateral (dorsal) view of the wing skeleton.

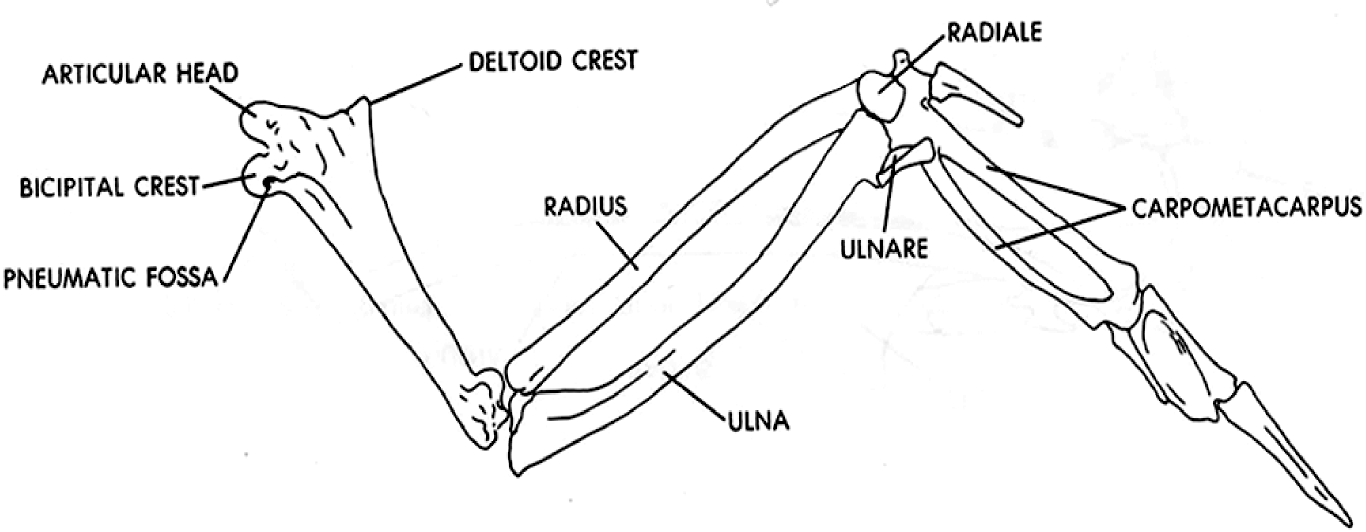


FIGURE 18. Medial (ventral) view of the wing skeleton.

SHOULDER AND WING

NAME	ORIGIN	INSERTION	ACTION
Pectoralis	Keel and body of sternum and furcula	Deltoid crest of humerus	Principal depressor of wing.

Several small muscles branch from the *pectoralis* to the skin and tendons of other muscles. A short conical branch inserts on the *tensor patagialis longus* tendon and probably represents *Mm. pectoralis propatagialis.* Four paired branches go to the skin: (1) from the clavicular region to the crop and adjacent skin; (2) from the cranial lateral region to the skin of the lateral region of the neck; (3) from the inserting tendon to the skin of the abdominal feather tract; and (4) from the caudal border to the caudal abdominal feather tract. The origin of the pectoralis is fleshy from the sternur and may be separated by first cutting the outer tendonous border of the muscle origin and then scraping the fibers loose from the sternum with a blu metal probe. Be careful not to scrape the origin of the supracoracoideus which also originates in part from the sternum and lies deep to the pectorali:

NAME	ORIGIN	INSERTION	ACTION
Supracoracoideus	Dorsal to origin of *M. pectoralis* on the keel and part of body of sternum.	Passes through triosseal canal to dorsal cranial surface of humerus.	Principal elevator of wing.
Coracobrachialis cranialis	Tendonous fibers from lateral surface of coracoid. This muscle is completely enclosed in fascia and is beneath the long head of the biceps.	Cranial corner of humerus between articular head and insertion of pectoralis.	Assists elevation of humerus.
Coracobrachialis caudalis	Lateral surface of basal ⅔ of coracoid and cranial edge of sternocoracoid process of sternum superficial to sternocoracoid origin.	Internal tuberosity of humerus.	Draws humerus medially helps depress wing.
Latissimus dorsi	Spines of last cervical and first two thoracic vertebrae.	Caudal humerus between deltoideus and triceps. Examine after triceps dissection.	Draws humerus medially. Cut through the center of this muscl A metapatagialis portion has be found in some specimens.
Rhomboideus superficialis	Spines of all thoracic vertebrae and last two cervical vertebrae; cranial synsacrum and ilium.	Entire vertebral border of scapula.	Draws scapula medially. Separa carefully and cut between origin and insertion.
Rhomboideus profundus	Spines of all thoracic and last two cervical vertebrae.	Vertebral border of scapula beneath *R. superficialis.*	Draws scapula medially.
Scapulohumeralis caudalis*	Entire lateral surface of scapula.	Humerus on the dorsal border of the pneumatic foramen.	Draws humerus medially.

*After you have studied the *Scapulohumeralis caudalis,* separate the fleshy muscle fibers from their origin on the scapula in the same manner that ; separated the origin of the *pectoralis.*

NAME	ORIGIN	INSERTION	ACTION
Serratus superficialis			
pars cranialis	One muscle bundle from fascia between 3rd and 4th ribs below uncinate processes.	Cranial ⅓ of medial surface of scapula.	Draws caudal scapula ventrally.
pars caudalis	Two muscle bundles from fascia between 5th and 6th ribs below uncinate processes.	Caudal ⅔rds of medial surface of scapula.	Assists pars cranialis.
pars metapatagialis	Fascia covering 4th, 5th, and 6th ribs.	Skin of the caudal humeral area. Insertion is usually destroyed during skinning.	Tenses humeral skin and assists feather erection. If a Latissimus dorsi metapatagialis is present it assists this muscle.

Separate carefully and cut *rhomboideus profundus* and *dorsalis* scapulae; (*latissimus dorsi* and *rhomboideus superficialis* should be already cut).

NAME	ORIGIN	INSERTION	ACTION
Serratus profundus	Dorsal lateral neck of 3rd and 4th ribs.	Medial surface of blade of scapula at approximately caudal third.	Draws scapula ventromedially.
Subcoracoscapulares—A collective name for the following two muscles.			
Subscapularis	Two heads, one from the lateral and one from the medial surface of the scapula.	Proximal end of the internal tuberosity of the humerus.	Rotates and adducts humerus.
Subcoracoideus	Two heads, (1) medial surface of clavicle apex, coracoclavicular membrane, cranial scapula; (2) caudal surface of coracoclavicular membrane and cranial edge of sternum.	Tendon of subscapularis to internal tuberosity of humerus.	Rotates humerus.
Tensor propatagialis			
pars longa	Medial surface of the dorsal tip of the furcula. This muscle is joined at the beginning of its tendon by a branch of the *pectoralis.*	By a long elastic tendon to the tendons of the wrist and the distal end of the ulna and ulnare.	Tenses the patagial membrane.
Pars brevis	The major part of the muscle is pars brevis. Pars longa consists principally of the long tendon of insertion.	By two tendons to the fascia covering M. *extensor metacarpi radialis* near the elbow.	Tenses the patagial membrane.
Biceps propatagialis	This muscle is situated in the tendonous propatagialis sheet dividing the sheet into proximal and distal halves.		Flexes the forearm (wing) when propatagium is tensed.

NAME	ORIGIN	INSERTION	ACTION
Cut and reflect the *Tensor propatagialis* to locate the following muscles:			
Deltoideus major	Two parts indistinctly separate. Cranial head beneath caudal on medial surface of acromion process. Caudal head on lateral surface of acromion of scapula.	Both heads insert together on cranial distal one-half of humerus.	Draws humerus medially and caudally.
Deltoideus minor	coracoid and acromion processes of scapula and ligaments in this area.	Proximal portion of deltoid crest of humerus.	Draws humerus dorsally and cranially.
Biceps brachii	Coracoid head from coracoid by broad flat tendon. Humeral head from bicipital crest of humerus.	Proximal, caudal surface of radius. Bellies fused.	Flexor of antibrachium.
Triceps brachii			
Scapulotriceps	Scapula caudal to origin of deltoideus major and edge of glenoid cavity.	Dorsal olecranon of ulna.	Extends antibrachium.
Humerotriceps	Caudal shaft of humerus.	Olecranon process of ulna.	Extends antibrachium.
Coracotriceps	Tendon of expansor secundariorum.	Tendon of insertion of humerotriceps.	Assists extension of antibrachiur
Expansor secundariorum	Long tendons from scapula and short tendon from medial epicondyle of humerus.	Fascia around the bases of the five proximal secondary feathers.	Assists the expansion of the wing feathers. This is a *smooth* muscl
Brachialis	Distal end of humerus.	Proximal ventral surface of ulna.	Assists *M. biceps;* flexes wing.

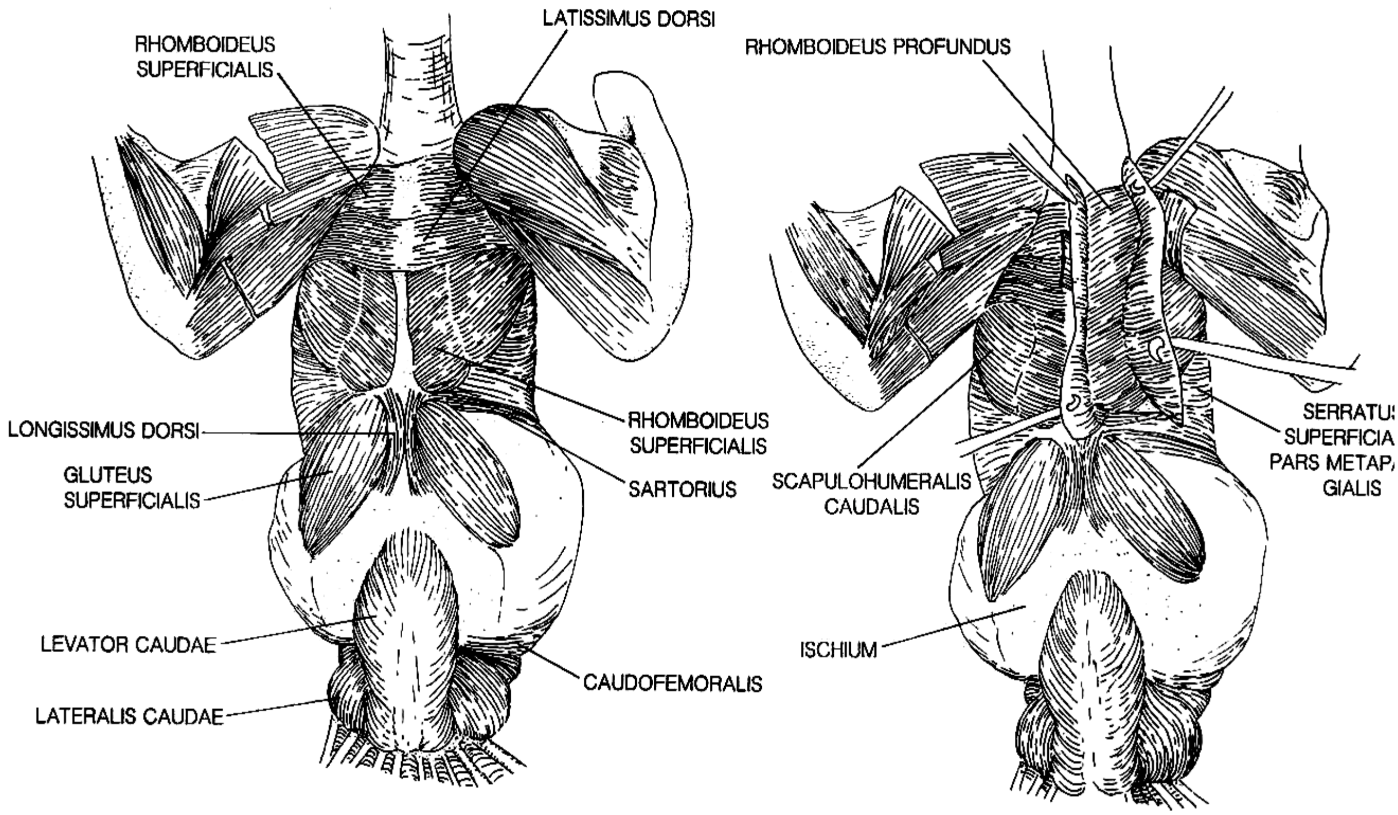


FIGURE 29. **Dorsal view of body and wing musculature. Cut and reflect the *Latissimus dorsi.* With a blunt probe at the caudal border of *Rhomboideus superficialis,* separate the fibers of *R. superficialis* from the deeper *Rhomboideus profundus* before cutting the *superficialis* as illustrated.**

Separate the lateral borders of the arm (wing) muscles from each other and pass a blunt probe beneath the muscles before cutting them as illustrated on the left wing.

FOREARM (ANTIBRACHIUM)

NAME	ORIGIN	INSERTION	ACTION
Pronator superficialis	Distal end of humerus by flat tendon.	Distal, cranial surface of radius.	Assists pronation of wing.
Pronator profundus	Distal end of humerus.	Distal end of radius caudal to above.	Assists pronation of wing.
Supinator	Lateral epicondyle of humerus with *Ext. digitorum communis.*	Cranial two-thirds of shaft of radius.	Assists *M. biceps;* flexes wing.
Ectepicondylo-ulnaris	Lateral epicondyle of humerus.	Lateral surface of ulna.	Assists *M. triceps;* extends wing.
Extensor digitorum communis	Distal end of humerus.	Distal caudal surface of carpometacarpus and pollex.	Primarily flexion. Flexes alulae extends index digit, elevates and flexes hand.
Extensor metacarpiulnaris	Fascia of *M. coracotriceps.*	Outer surface of carpometacarpus.	Flexes hand.
Flexor digitorum superficialis	Distal end of humerus.	Proximal and distal cranial surface of carpometacapus.	Flexes hand.
Flexor digitorum profundus	Proximal one-third of ulna.	Distal cranial border of carpometarcarpus; by a long tendon.	Flexes hand.
Flexor carpi-ulnaris			
pars cranialis	Distal end of humerus, ventral surface.	Caudal proximal surface of carpometacarpus by a long tendon.	Flexes hand.
pars caudalis	Proximal end of ulna. Oblique fibers insert on tendon of insertion.	Long elastic tendon to Os carpi ulnare.	Flexes hand.
Abductor alulae	Cranial surface of carpometacarpus distal to alulae.	Ventral surface of alulae.	Abducts alulae.
Adductor alulae	Cranial surface of carpometacarpus proximal to alulae.	Caudal surface of alulae.	Adducts alulae.
Extensor metacarpi radialis	Lower end of humerus by two heads that are difficult to separate.	Carpometacarpus, proximal to first digit (alulare) by a long tendon.	Extends wing.
Ulnometacarpalis ventralis	Middle third of ulna.	By a strong tendon to the carpometacarpus, proximal to alulae.	Assists pronators.
Ulnometacarpalis dorsalis	Distal end of ulna.	Proximal carpometacarpus.	Elevates and flexes hand.
Interosseus dorsalis	Dorsal surface of carpometacarpus.	Phalanges of second and third digits.	Elevates index digit.
Interosseous ventralis	Ventral surface of carpometacarpus.	Phalanges of second and third digits.	Elevates index digit.
Extensor longus alulae	Distal half of radius.	Carpometacarpus proximal to the first digit. Deep to *M. extensor metacarpi radialis.*	Extends hand.
Extensor longus digiti majoris	Caudal surface of radius.	Ligament of second digit.	Extends wing.
Flexor alulae	Cranial proximal surface of ulna and second head from proximal end of radius.	Dorsal surface of carpometacarpus beneath *M. extensor metacarpi radialis.*	Extends wing.
Abductor digiti majoris	Ligaments of the wrist.	Proximal phalanx of second digit.	Extends wing.
Flexor digiti minoris	Caudal surface of third metacarpal. Very small.	Caudal surface of third digit.	Flexes third digit.
Extensor brevis alulae	By two fleshy heads from dorsal extensor process and craniodorsal carpometacarpus and tendon of insertion of ulnometacarpus ventralis.	Single short tendon to a rostrodorsal tubercle of alulae.	Extends alulae.

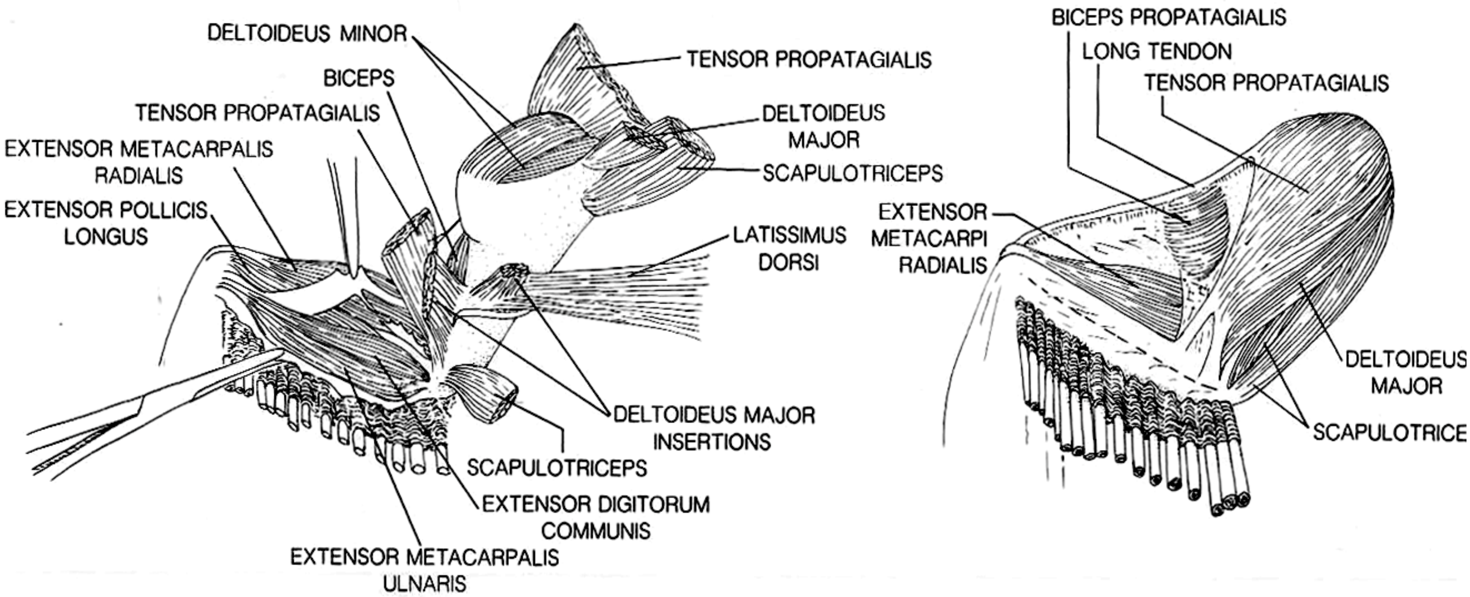


FIGURE 30. **Dorsal views of superficial (right) and deep (left) wing muscles. To expose the deep muscles, cut the superficial muscles as indicated in figure 29.**

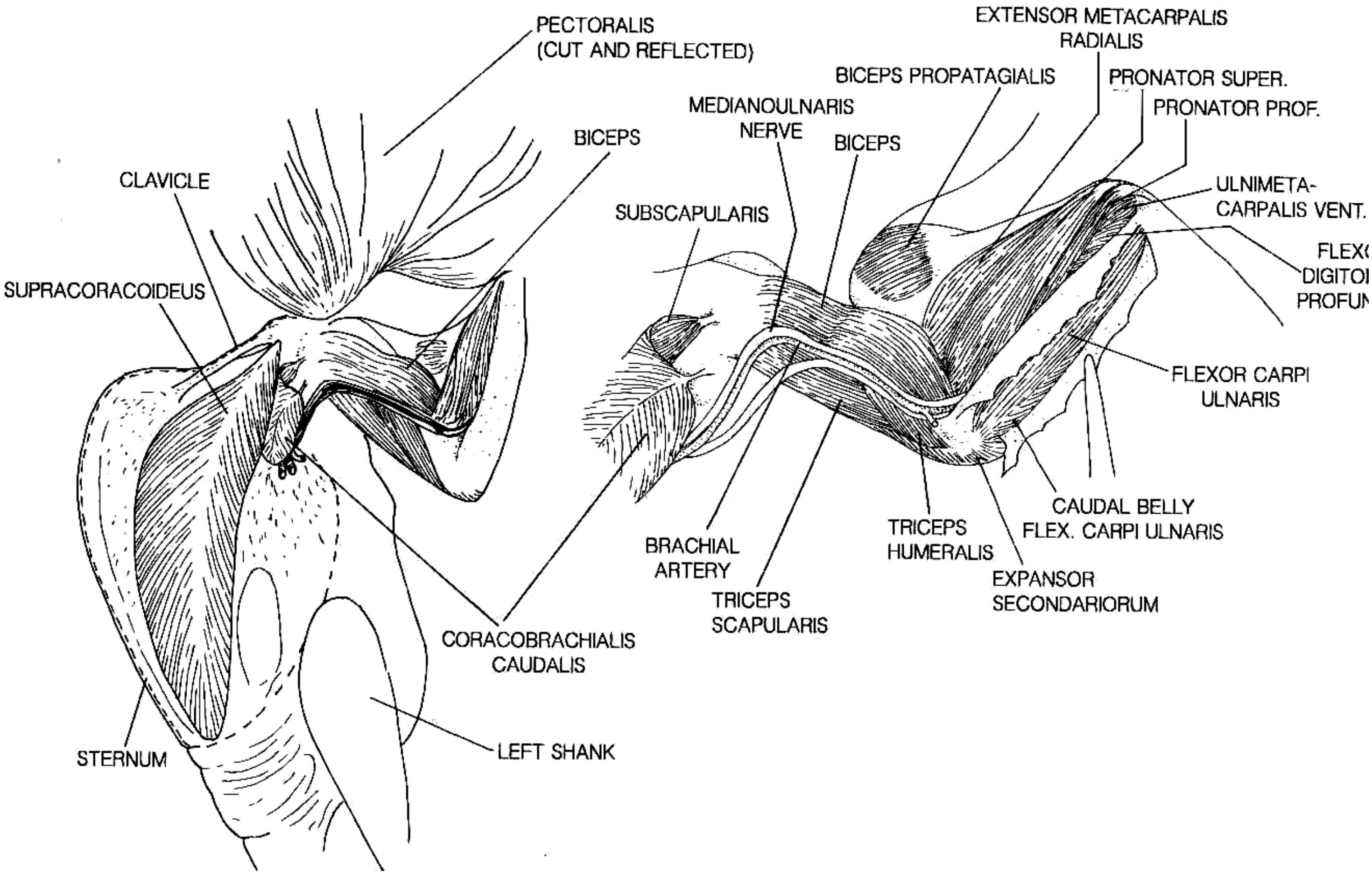


FIGURE 31. **Ventrolateral view of the left breast, shoulder and wing muscles of the Pigeon. The pectoralis is separated at its origin (outlined by the dashed line) and reflected. This requires cutting blood vessels serving the pectoralis. Details of the axillary and wing muscles are on the right. Caudal fascia of the forearm is cut to expose deeper muscles in the right hand detail figure.**

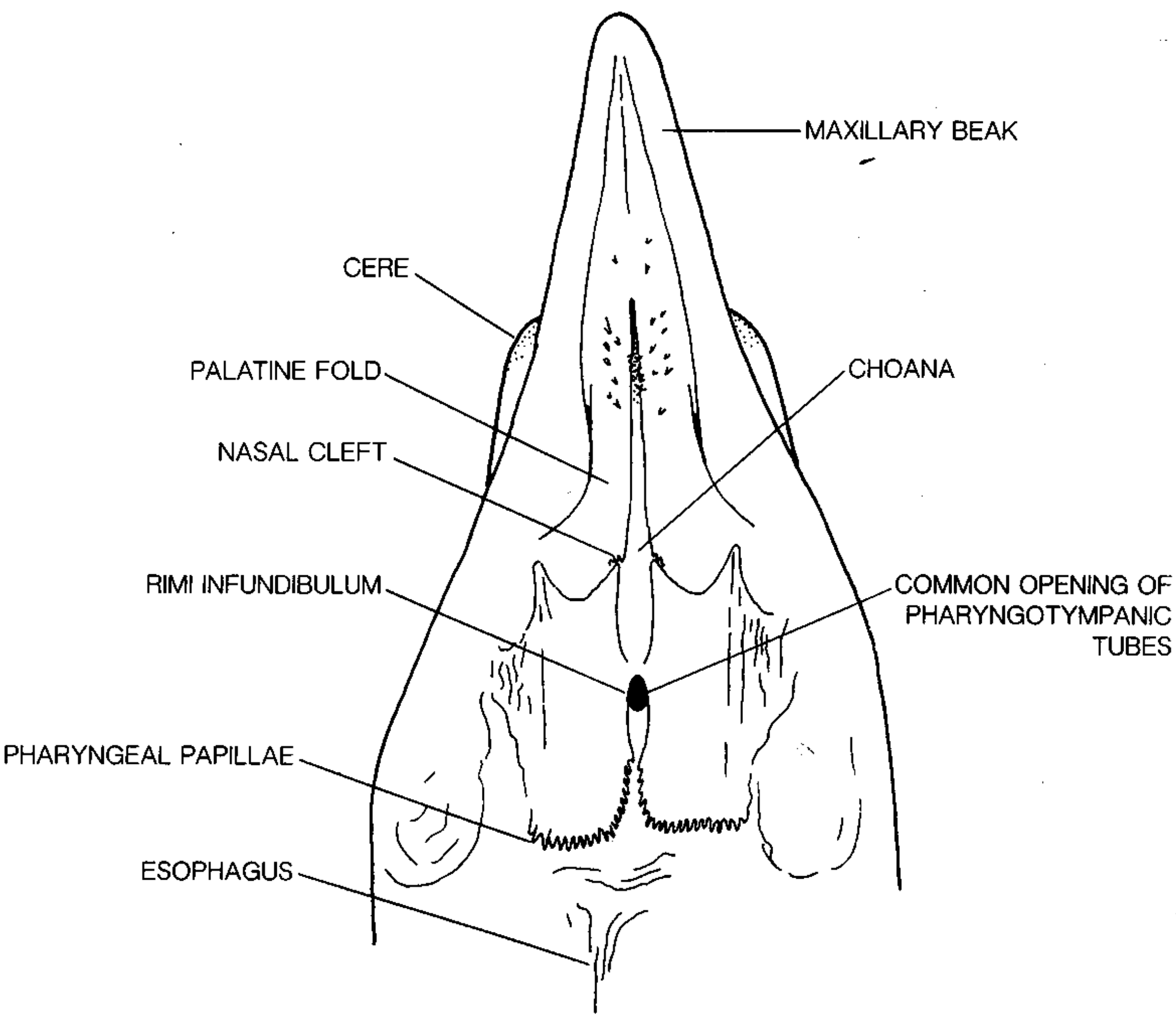


FIGURE 39. Ventral view of palate.

3. Pharynx. Beginning at the caudal end of the palatine folds, the pharynx is the common chamber of the mouth and nasal cavity, and includes the openings of the esophagus and glottis. Ventrally, the papillae bordering the tongue (lingual papillae) and those fringing the caudal border of the laryngeal prominence are rostral and caudal limits of the pharynx, respectively.
4. Opening of pharyngotympanic tubes. There is a common opening for both tubes in birds. Just ventral to the common opening are palatal folds separated medially and with conical pharyngeal papillae on their caudal border. The rostral smooth border of the folds is termed the *rimi infundibuli.*
5. Laryngeal prominence. A raised area with a slit-like opening in its center called the *glottis.* Caudally, the prominence is bordered by a fringe of conical papillae.
6. Glottis, the opening into the larynx.
7. Esophagus, the collapsed tube leading from the pharynx to the stomach.
8. Crop. The technical name for this expandib lower esophgeal sac is the *ingluvies.* It serv principally for the storage of food and regulatic of the amount of food passed to the stomach. Foc may also be regurgitated from the crop and fe to the young. Thin muscle slips from the pecto alis help to control the emptying of the crop sa

   In the pigeon, the crop is bilobed and the linir of the crop includes glandular cells which secre a milk-like substance in response to the hormor prolactin, secreted by the pituitary gland.

BODY CAVITY AND VISCERA

This dissection should be performed with the bird o its back and its head pointing away from you. Most of th abdominal musculature has already been dissected. Wit a sharp scalpel, cut transversely through the middle of th *pectoralis* and *supracoracoideus* on the side that has nc yet been dissected. Remove the musculature on the cauda portion of the sternum. With heavy scissors cut throug the keel of the sternum. Carefully cut through the side

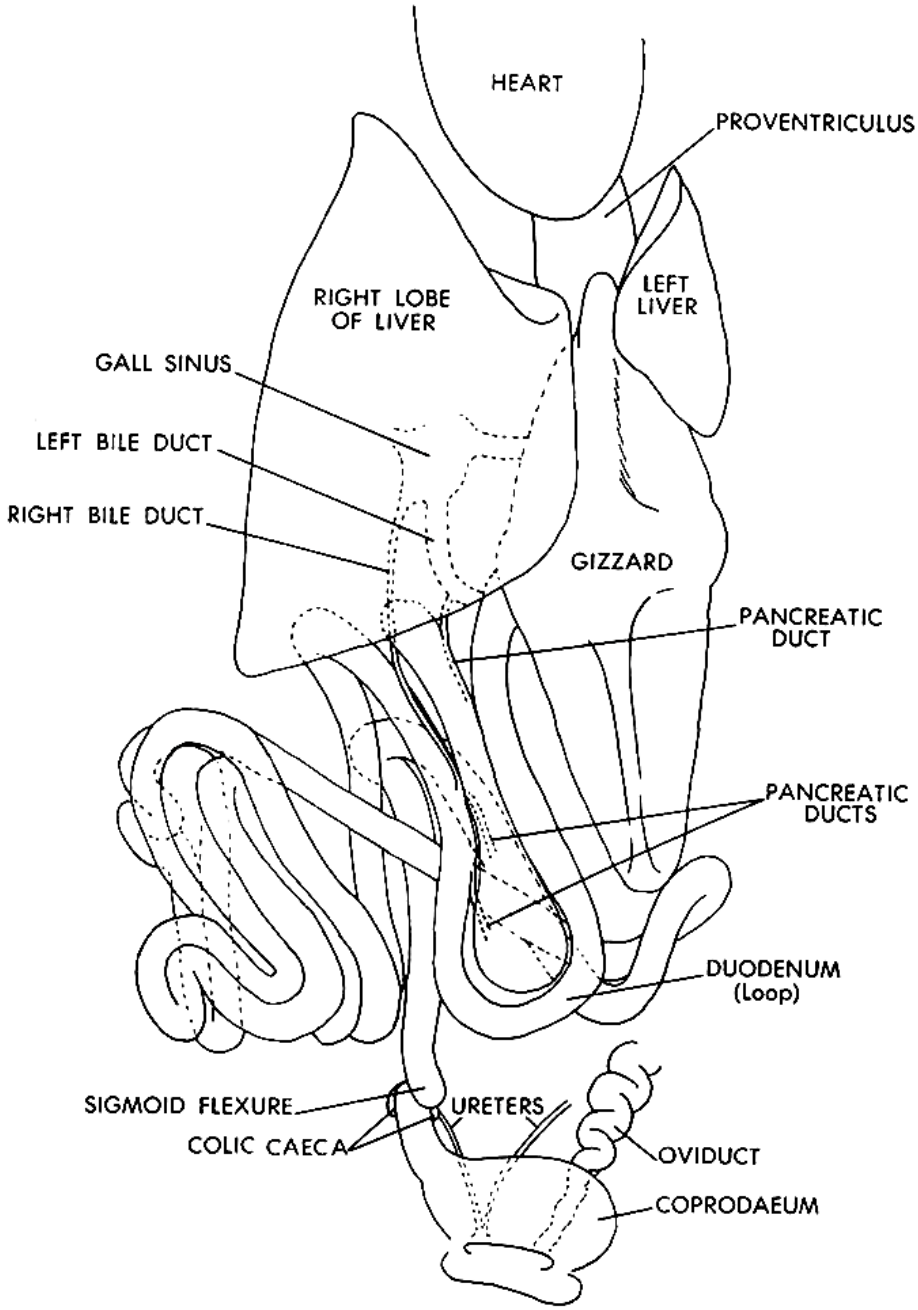


FIGURE 40. Semidiagrammatic ventral view of intestinal tract with intestines partially separated to illustrate loops and coils.

of the sternum and separate the underlying membranes from the bone. Remove the cut sternum but be careful not to sever the subintestinal vein in the midline. Cut the abdominal wall on either side of the midline to avoid cutting the subintestinal vein. After the vein is exposed, cut the vein in its center so the two ends may be rejoined later for study. The vessel lies in the ventral root of the joined *falciform* and *ventral ligaments*.

1. Membranes and mesentery. The body cavity is divided into parts by membranes which also support the viscera. Locate the following:
   a. Parietal peritoneum, membrane lining the body wall.
   b. Visceral peritoneum, membrane covering : the visceral organs except the kidneys.
   c. Ventral ligament, from the ventral body w: to the gizzard.
   d. Faciform ligament, from the ventral body w: to the ventral surface of the liver. This lig ment is continuous with the ventral ligamer
   e. Oblique septum, a partition from the later body wall to the center separating the bo cavity into cranial and caudal compartmen The center of this septum is continuous wi the pericardial sac, and the caudal thorac air sac is enclosed within it.

Respiratory System

The respiratory system of birds is complicated by a system of air sacs in the body cavities and air spaces inside many bones. For a complete dissection of this system, specially prepared specimens with a latex injection of the air sacs and spaces are essential. Unfortunately, commercially prepared injections of the respiratory systems are not reliable. In some cases the air sac membranes rupture during injections and the pericardial and peritoneal spaces, rather than air sacs, may be filled with latex. Bone air spaces are seldom well injected.*

If air sacs are to be dissected they should be studied before dissecting the trachea and lungs since air sacs often surround parts of these structures (see 6 below) and Chapter 4, Digestive System).

With scissors or bone cutters cut each rib at or near its articulation with the vertebrae. Do not simply break the ribs as this will probably damage the lungs. Remove the right wing. Continue the incision from the cloaca caudally and laterally. The right body wall may now be folded back in order to expose the viscera (figs. 42, and 45).

1. Larynx, the cranial end of the trachea containing the laryngeal cartilages. The opening into the larynx is the *glottis*. Locate the laryngeal cartilages in the walls of the larynx. Just within the glottis are the dorsal, paired *arytenoids*, and a single ventral *cricoid* that is incomplete dorsally.
2. Trachea, the air tube leading from the larynx to the syrinx in the body cavity. The trachea is held open by a series of cartilage rings which support its walls.
3. Syrinx. This is the voice organ of birds located at the bifurcation of the trachea into bronchi. The following parts may be observed.
   a. Sternotracheal extrinsic muscles extend from the sternum to the right side of the trachea cranial to the syrinx. The asymmetry of these muscles is characteristic of pigeons.
   b. Intrinsic syringeal muscles arise from trachea and extend to the lateral wall o syrinx. Both extrinsic and intrinsic syrin muscles are highly variable in birds anc used as taxonomic characters in avian sification.
   c. External tympaniform membrane, betv two widely separated syringeal rings. rings are fused ventrally to form a bas the pessulus.
   d. Internal tympaniform membrane, betv the first two bronchial rings on the m surface.
4. Bronchi, these branches of the trachea enter lung on either side and immediately branch wi the lung to the various parts of the lung an the air sacs. The walls of the bronchi are ported by half rings of cartilage.
5. Lungs, on either side of the dorsal body wall flattened tightly against the body wall. All th sacs open to the lungs.

Remove one lung from the pigeon and ins the medial surface (fig. 46). With fine poi scissors cut a section of the cranial half of the mary bronchus and remove the medial wall to pose the lateral wall. The primary bron narrows caudally and turns ventrally to ope the abdominal and caudal thoracic air sacs. E a blunt probe at the ostium of the abdomina sac and work the probe forward to the cer portion of the primary bronchus. Use a sl scalpel and cut away the caudal wall of the l and primary bronchus. This dissection will pose the interior of the primary bronchus a figure 47. A dissecting microscope will be us in examining the details of the lung.

The lungs of birds are extremely com structures and early investigators of lung a omy and physiology generated a number of conceptions and an erroneous nomenclature the small secondary tubules.

The following names are suggested by Non Anatomica Avium (1979) but other names a current usage.

*Techniques for injecting the lungs and air passages of birds are described by A. R. Akester, Journal of Anatomy Vol. 94, (1960) p. 487; and by E. J. Braun, *Bioscience* (August, 1965), pp. 545–546.

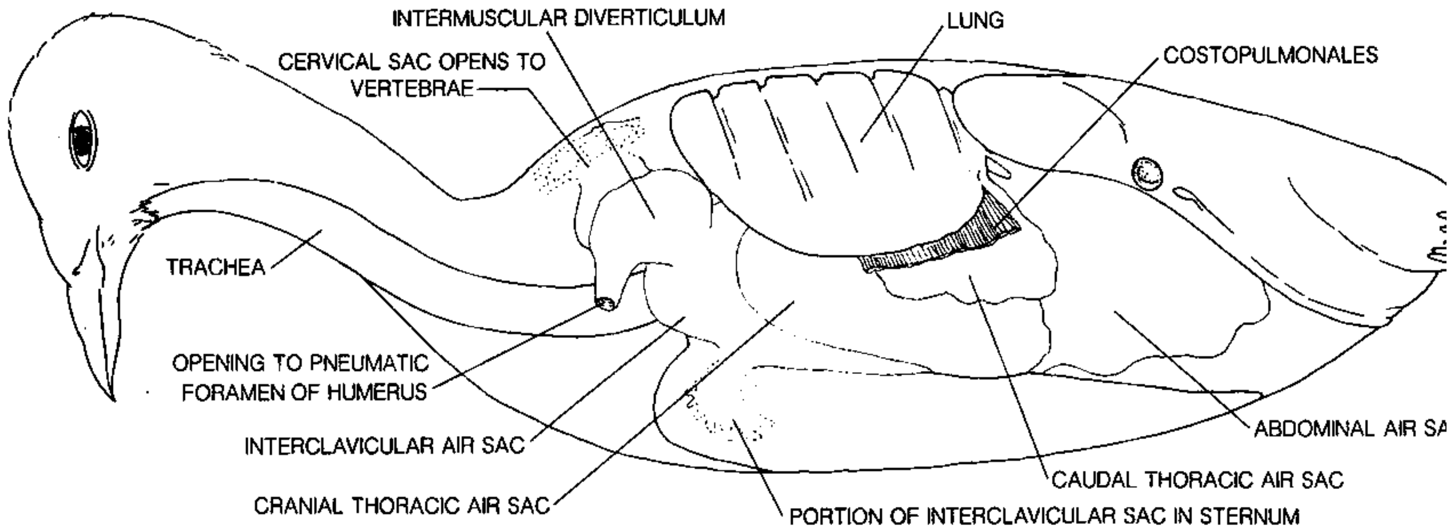


FIGURE 42. Diagrammatic lateral view of the lung and air sacs of the pigeon.

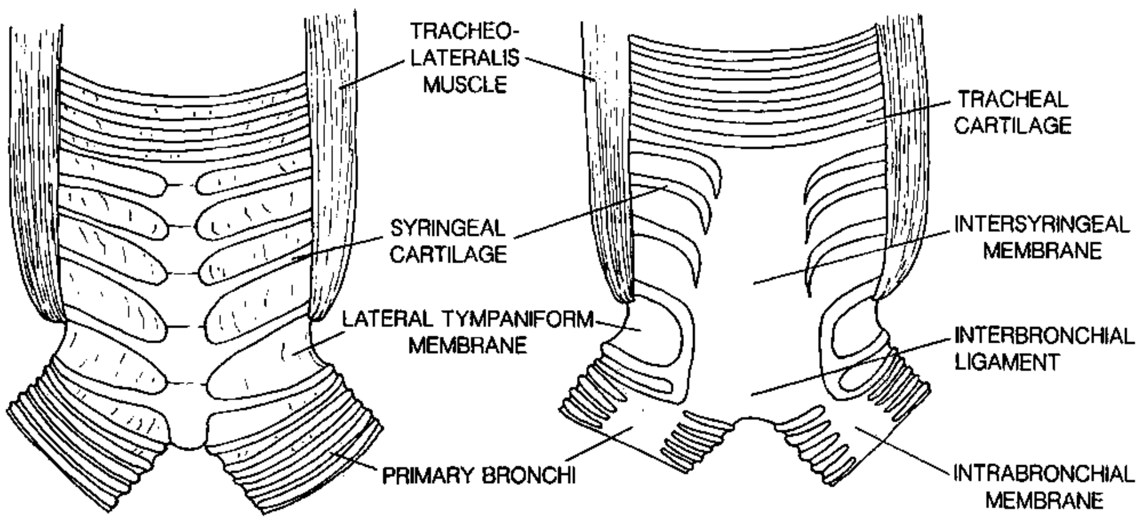


FIGURE 43. Ventral (left) and dorsal (right) views of the syrinx.

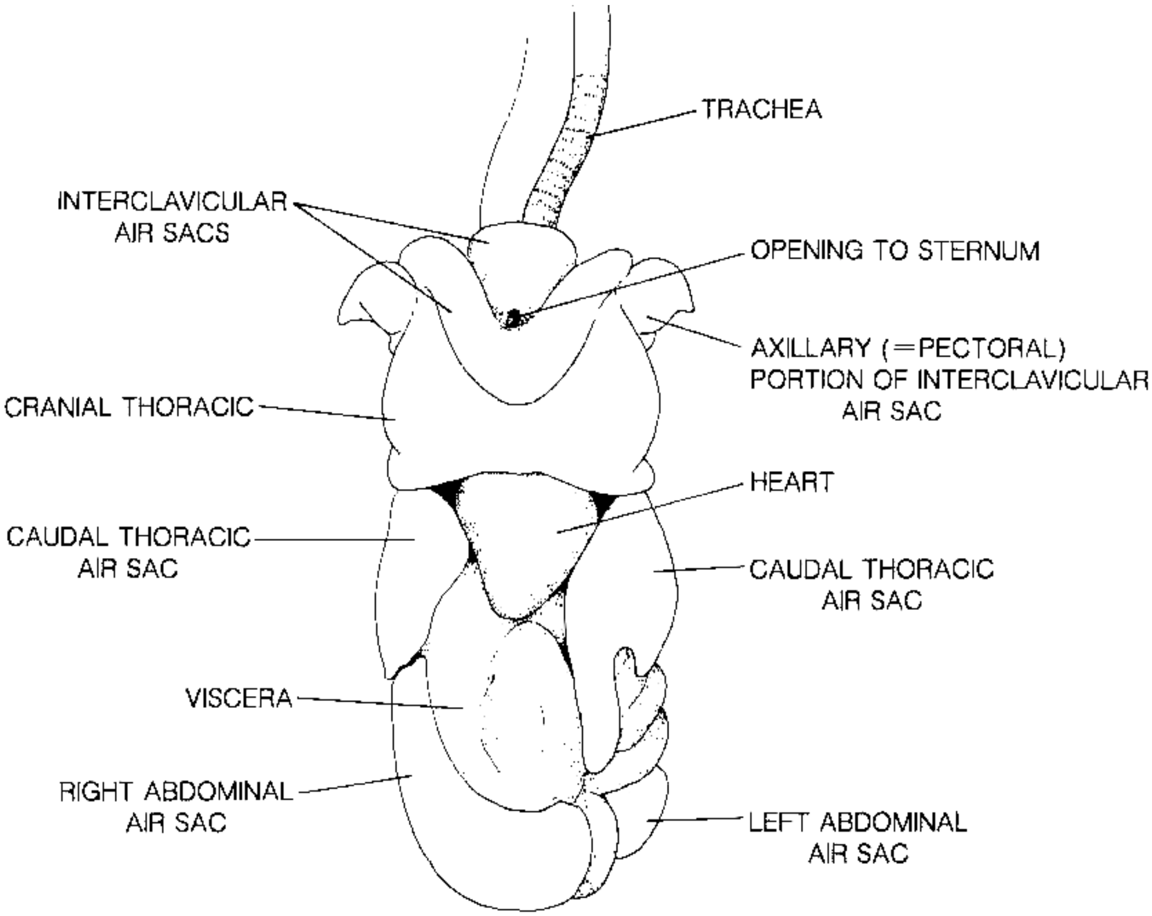


FIGURE 44. Ventral view of the air sacs, *in situ.*

Four sorts of secondary bronchi branch from the primary bronchus. Immediately after entering the substance of the lung, four *medioventral* bronchi branch from the lateral wall of the primary bronchus and arch laterally and ventrally (fig. 47) before opening to the three cranial air sacs (*cervical, clavicular,* and *cranial thoracic*). From the dorsal arch of the medioventral bronchi, tubules pass to the caudal dorsal corner of the lung and branch to the tertiary bronchi, the *parabronchi.* All of these parabronchi arch ventrally and open to *mediodorsal bronchi* from the dorsal wall of the primary bronchus. *Medioventral* bronchi branch from the ventral border of the caudal primary bronchus and open to the caudal thoracic air sac.

Finally, a set of *laterodorsal* bronchi branch from the caudal end of the primary bronchus and open to parabronchi in the lateral ventrocaudal quarter of the lung. This network of parabronchi has a less uniform arrangement of interconnecting tubules than the parabronchi between the mediodorsal and medioventral bronchi and is referred to as the *Neopulmo.*

The lungs of the pigeon contain less than 17% of the total volume of air in the body. The trachea contains about 1% and all the rest (82%) is in the various air sacs. Only the air in the lungs can exchange oxygen and carbon dioxide so the lungs with the greater exchange surface are an advantage for those birds which are active flyers and thus require a great deal of oxygen. Compared to most other birds the pigeon has a high ratio of lung to air sac volume.

The exchange of gases takes place in tiny air capillaries which branch from the walls of the parabronchi and birds such as the pigeon with smaller diameter parabronchi and air capillaries have a greater number of these tubules and hence contain a greater total air volume.

6. Air sacs. Most of these will have been destroyed by previous dissections. The remaining dissection is best performed on a specimen in which the lungs and air sacs have been specially injected with colored latex.
   a. Clavicular sac, is unpaired, but it is also the most complicated of the air sacs in the pigeon. This sac surrounds the syrinx and the cervical sacs. A ventral extension lies between the sternum and the heart and has an

Circulatory System

Specimens in which the arteries are injected with red or yellow latex and the veins with blue latex should be used. If the hepatic portal system is injected, it will have yellow latex and arteries will contain red latex.

THE HEART

1. Pericardial sac, encloses the heart. This sac is composed of the parietal pericardia and the parietal pleuraperitoneum (including in part, the transverse septum) which also lines the body wall and contributes to the double walled mesenteries. The visceral pericardia adheres to the surface of the heart and is continuous with the inner pericardia layer of the pericardial sac. The visceral and parietal pericardia contact one another at the base of the large blood vessels; the aorta, the p monary arch, the two cranial vena cava, and caudal vena cava.
2. Right atrium is the large right cranial cham of the heart receiving blood from the syste circulation and delivering blood to the right v tricle. Internally, this chamber is partially se rated from the sinus venosus by a sinoatrial 'va which, in the pigeon, has flaps that do not app to contact each other. The cranial and caudal v cava open to the sinus venosus at the borde the atrium. The right atrium is also complica by a left recess extending to the left atrium so musculature of the right and left atria are c tinuous but the chambers are separate (see f 48 and 50).

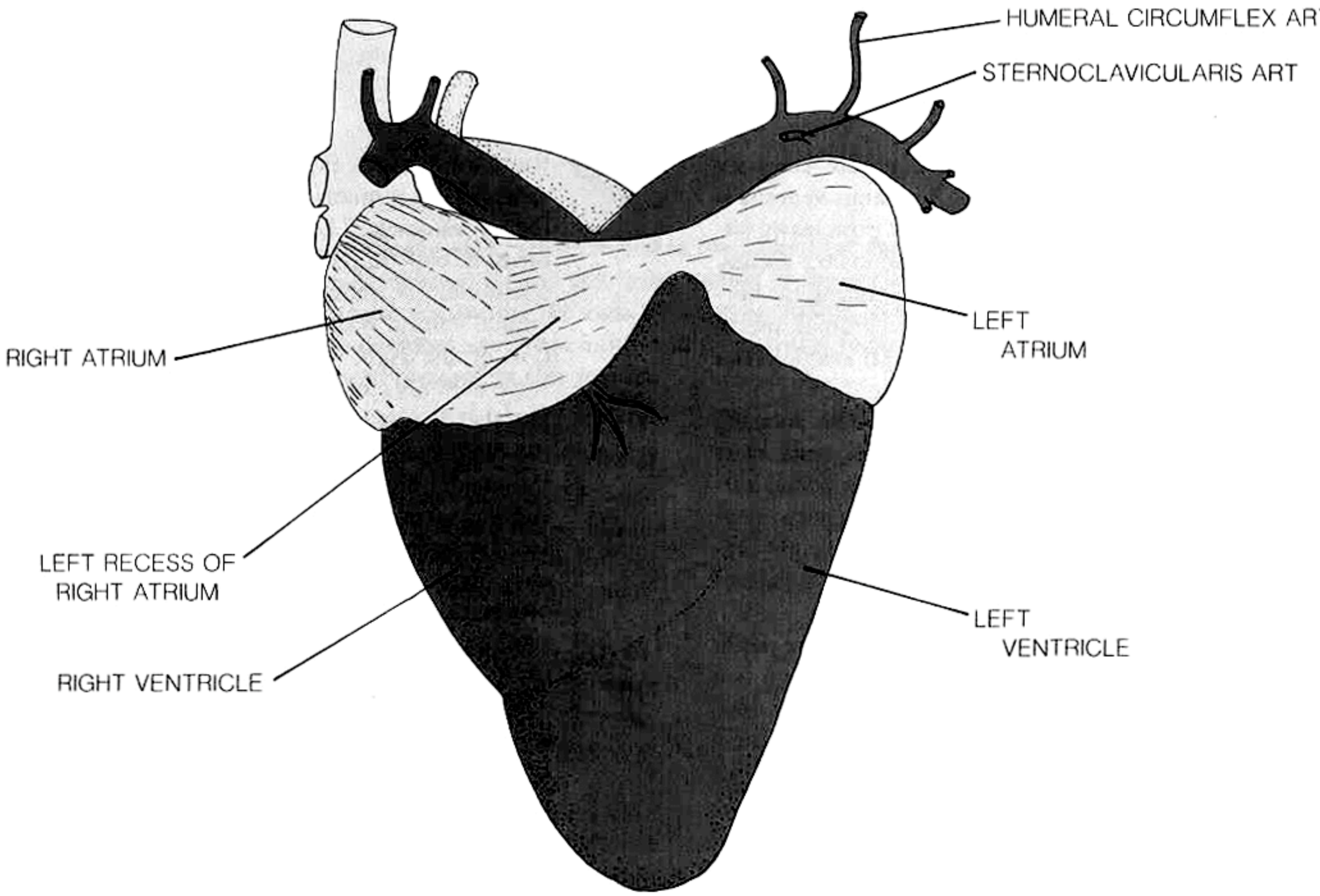


FIGURE 48. Ventral view of the pigeon heart.

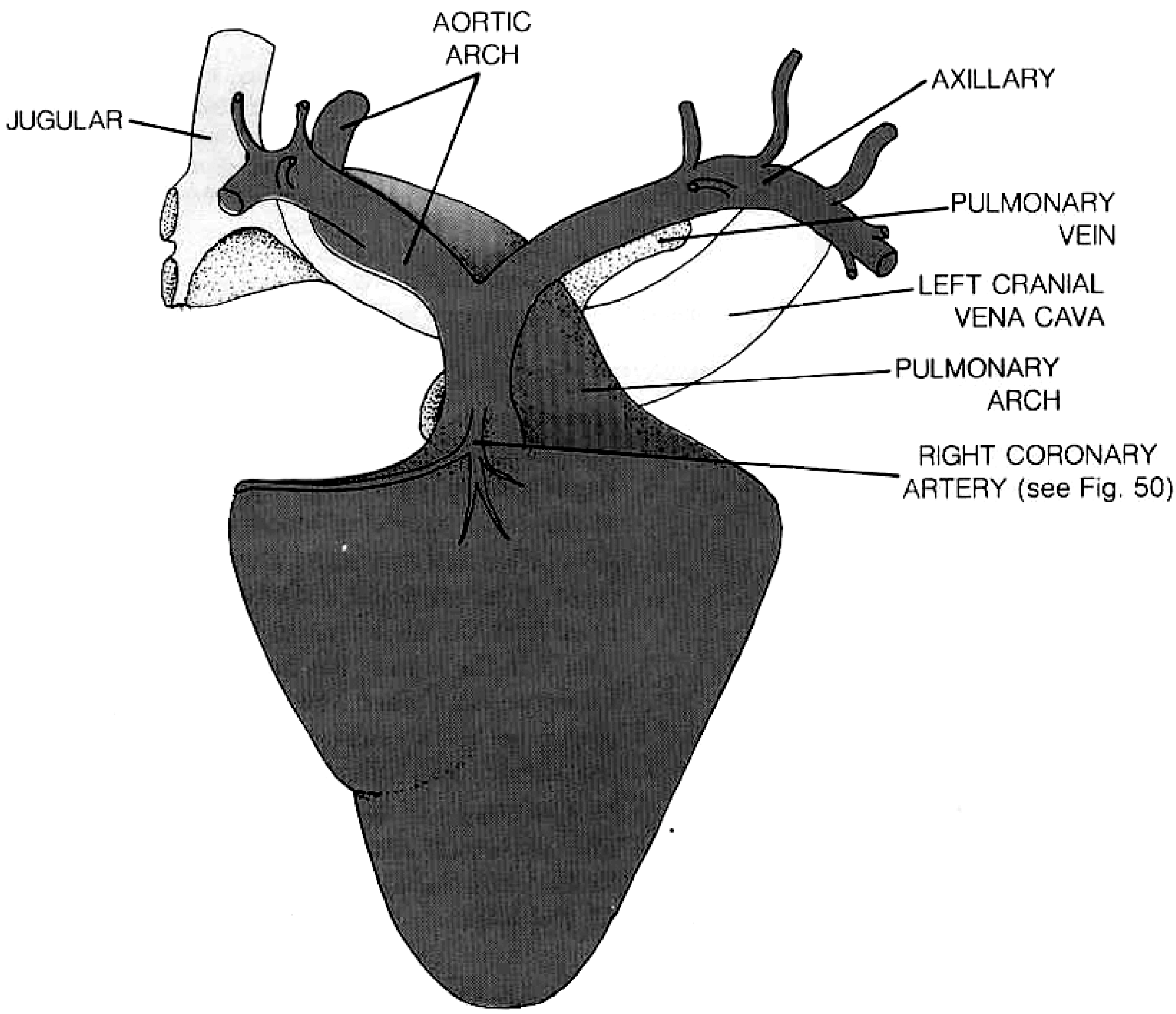


FIGURE 49. Ventral view of the pigeon heart with the atria removed.

3. Sinus venosus, is a partially separate chamber opening to the right atrium. The sinus venosus is dorsal to the right atrium and is principally situated dorsal to the aortic and pulmonary arches.
4. Caudal vena cava is a large vein entering the dorsal wall of the sinus venosus just cranial and to the right of the entrance of the left cranial vena cava (see fig. 51).
5. Cranial vena cava are two large veins entering the sinus venosus. The left cranial vena cava passes over the entire left half of the dorsal surface of the heart to enter the sinus venosus near the caudal vena cava (see fig. 51). The right cranial vena cava enters the right cranial corner of the sino-atrial junction.
6. Right atrioventricular valve divides the right atrium from the right ventricle. This valve is a single large muscular flap that has its free edge projected into the chamber of the right ventricle and its lateral and dorsal edges are continuous with the muscular wall of the right ventricle.
7. Right ventricle is the smaller of the two v cles and has a much thinner muscular wal the left ventricle. The right atrioventricular forms a 'cup' on the dorsal wall of the righ tricle and the pulmonary arch opens fro cranial ventral wall of the chamber. On co tion of the right ventricle the atrioventr valve not only closes the atrioventricular op but also directs the blood from the ventricl the pulmonary arch.
8. Pulmonary arch has a semilunar valve with cuplike parts near the base of the arch. Th monary arch divides into right and left p nary arteries to the lungs just dorsal t bifurcation of the aortic arch.
9. Left atrium is much less complicated tha right atrium. Four pulmonary veins ente dorsal cranial wall of the left atrium. Two of vein come from the right lung and two come the left lung. Blood from the left atrium p into the left ventricle through the left atri tricular valve.

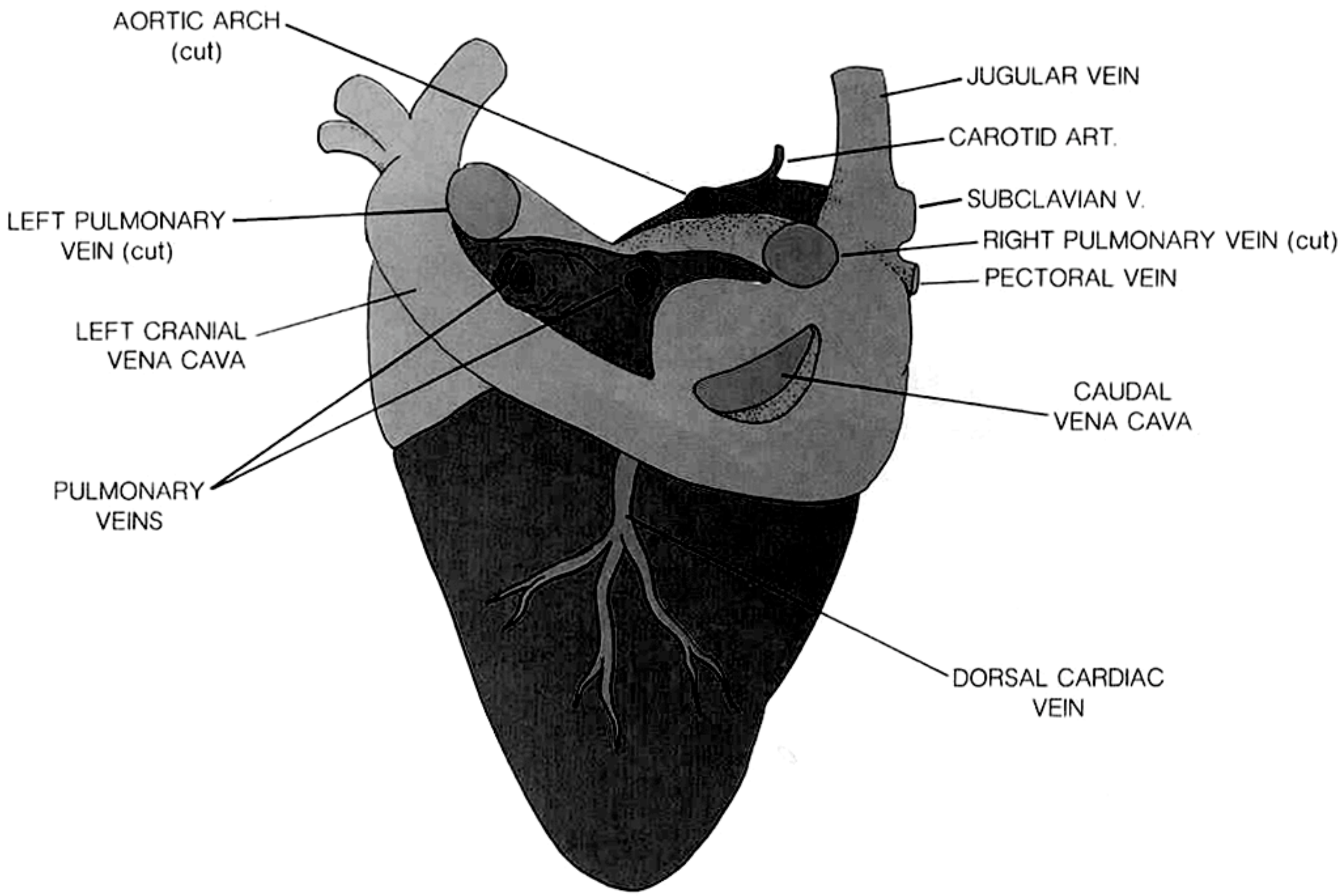


FIGURE 51. Dorsal view of the pigeon heart.

THE SYSTEMIC VEINS

Veins Cranial to the Heart

All the veins cranial to the heart drain into the right or left cranial vena cava and there are no veins corresponding to the brachiocephalic arteries which branch from the aorta. See the Heart, 2. and 5., and figure 51 for descriptions of the cranial vena cava. Each Cranial Vena Cava is formed by the convergence of Subclavian, Jugular, and Pectoral Trunk veins.

1. Jugular veins drain blood from the head and neck into the cranial vena cava. Those venous channels within the cranium and the neural canal of the vertebrae are generally 'pooled' into sinuses. The sinuses in turn open to veins which either drain directly into the jugular or into larger veins which then drain into the jugular. The right jugular vein is usually larger than the left in diameter. The jugular veins originate near the base of the cranium with the union of a Rostral Cephalic vein draining blood primarily from the jaws and ventrolateral areas of the head, and a Caudal Cephalic vein from the cranial sinuses and the dorsal and lateral areas of the head.

A. Rostral Cephalic veins have a transverse a astomosing branch which joins the right ar left rostral cephalic veins just before they ent the jugulars.
   1. Mandibular vein from the lower jaw e ters the rostral cephalic near the unic of the rostral and caudal cephalic veir The mandibular also receives a lingu vein from the tongue and an esophag tracheal vein from the upper end of tl esophagus and larynx and trachea.
   2. Maxillary vein from the upper jaw ar palate joins an ophthalmic vein from tl eye to form the origin of the rostral c phalic vein.
   3. Ophthalamic vein from the eye also r ceives blood from the ethmoid vein ar other intercranial veins and drains int the rostral cephalic vein. This vein als has connections with the venous Re Mirible Ophthalmica which also drair to the caudal cephalic vein via the e: ternal ophthalmic vein.

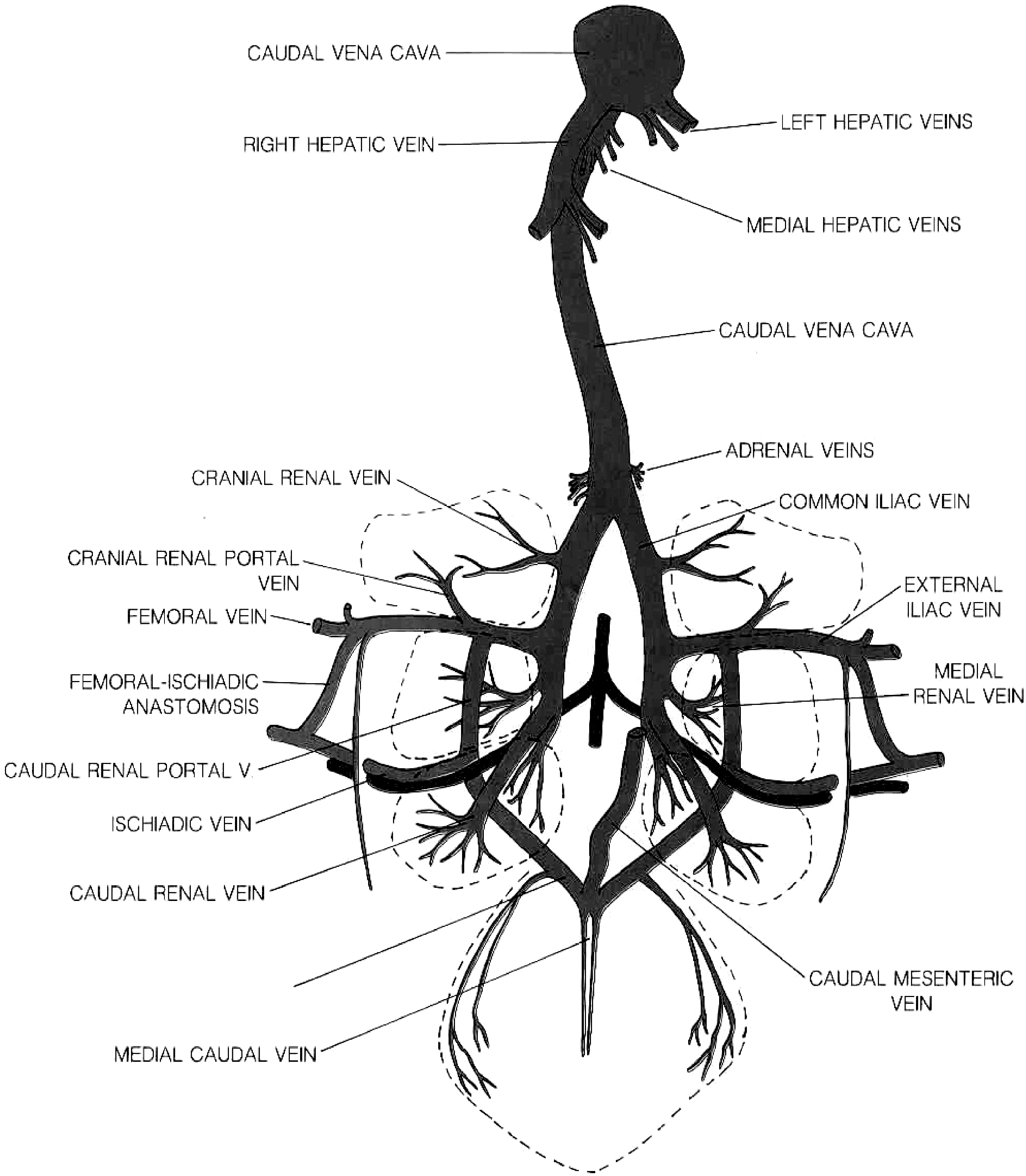


FIGURE 53. Major veins in the caudal portion of the body except the hepatic portal system which is removed (see fig. 56).

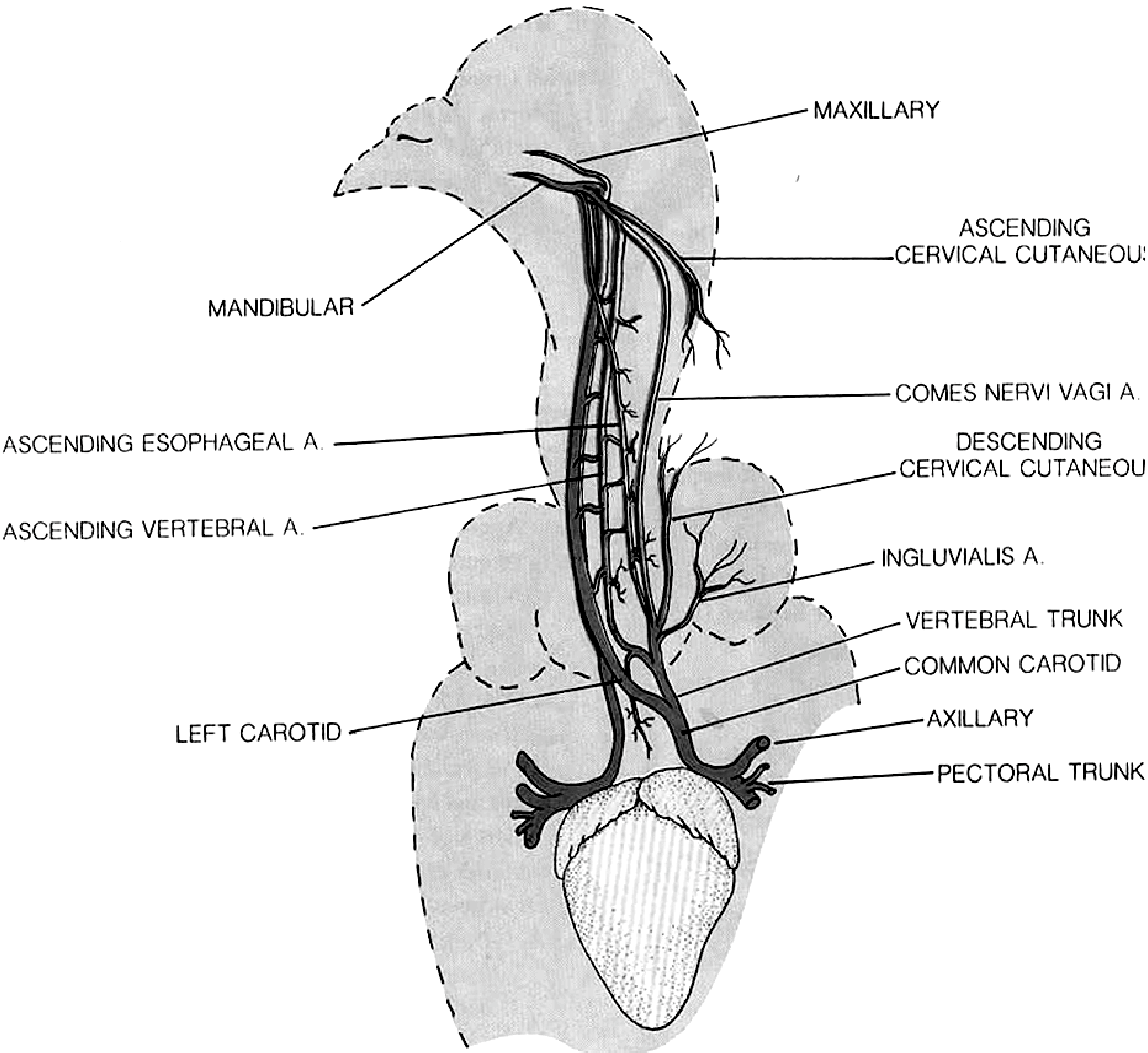


FIGURE 57. Ventrolateral view of the arteries of the heart and neck.

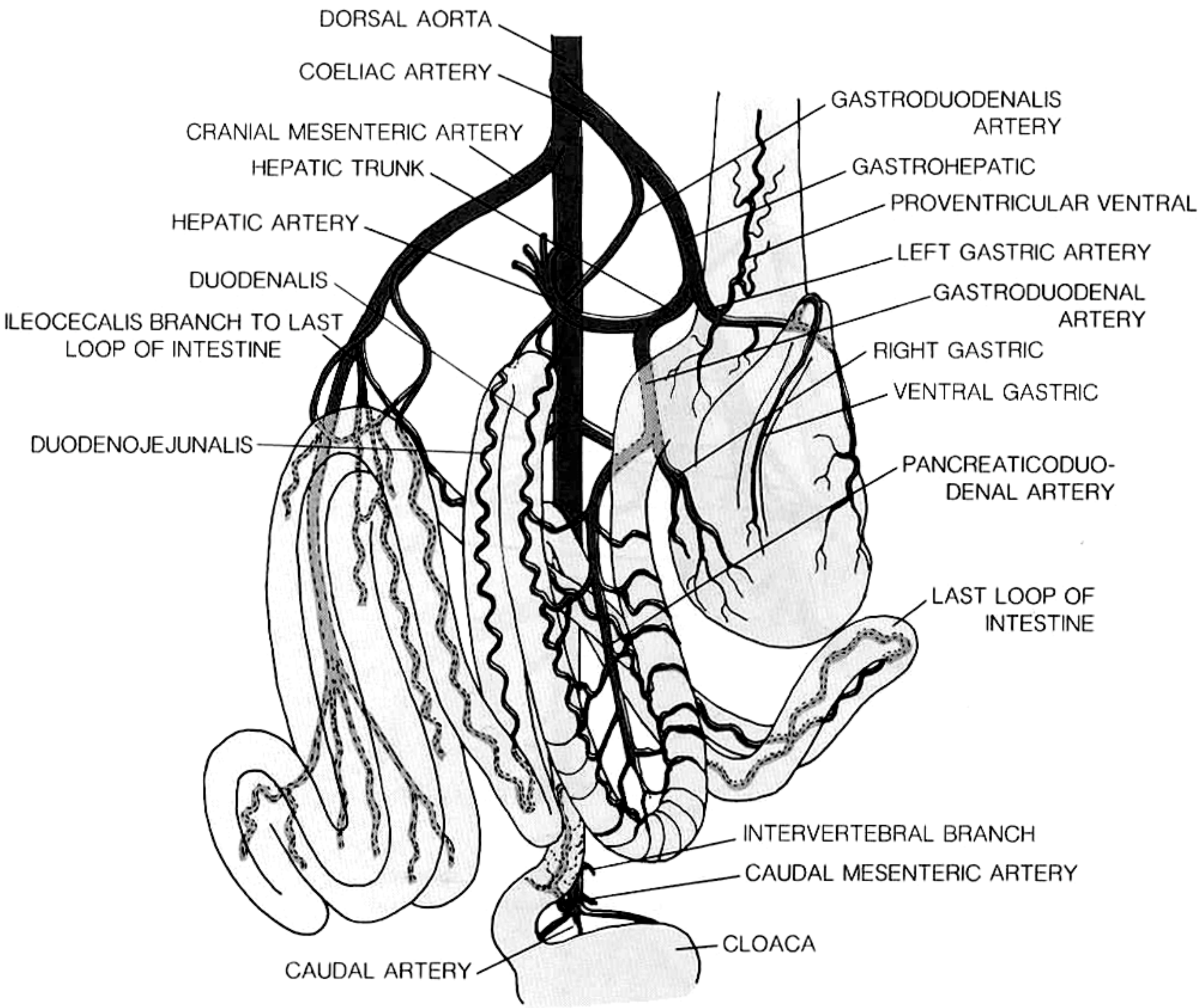


FIGURE 59. Detail of the coeliac and mesenteric arteries. Also see figure 60 for arteries from the dorsal surface of the coeliac.

duodenalis to the terminal limb of the duodenal loop and a *duodenojejunalis* to the first limb of the first jejunal loop.

D. *Gastrohepatic* is the continuation of the coeliac from the branching of the gastroduodenalis. This artery divides at the common border of the proventriculus, gizzard and duodenum into a left gastric to the proventriculus and gizzard and a right ramus serving the gizzard, duodenum, pancreas and liver.

1. *Splenics.* The spleen lies on the dorsal surface of the gastrohepatic, dorsal to the proventriculus and receives several short splenic arteries from the gastrohepatic.
2. *Left gastric* branches from the gastrohepatic and gives a *ventral proventriculus* artery to the proventriculus, a *ventral gastric* to the narrow ventral edge of the gizzard, and continues to the ventral side of the proventriculus juncture with the gizzard. The terminal portion of the left gastric anastomosis with the *dorsal gastric* which branched directly from the coeliac (see B above).
3. *Hepatic trunk* is a large trunk branching from the gastrohepatic and dividing into a combined but short pancreaticoduodenal, right gastric, and hepatic artery.
   a. The *pancreaticoduodenalis* sends branches to both limbs of the duodenal loop and to the pancreas. Those branches to the second or ascending limb of the duodenum

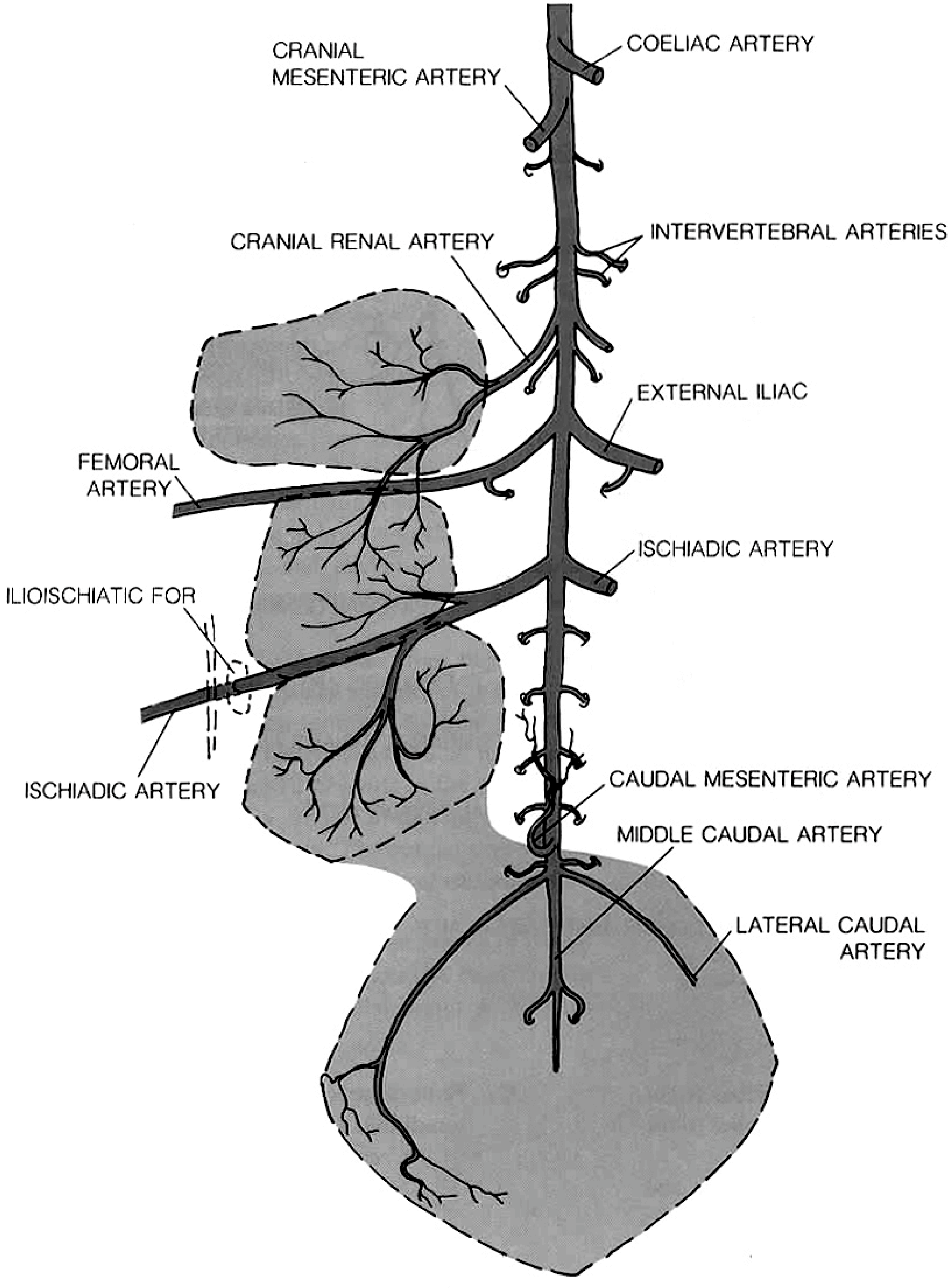


FIGURE 61. Detail of the dorsal aorta and its major branches with the abdominal viscera removed.

Urogenital System

EXCRETORY ORGANS

The venous circulation of the kidneys was described in Chapter 6 and in figure 53. Arterial blood is delivered to the kidneys from the cranial renal, renolumbar, and renofemoral arteries.

The interrelationships of these different circulatory vessels is not completely known but the following features are fairly well understood. First, all blood is drained fr the kidney through the renal veins. Second, arterial bl entering the kidney goes to the glomeruli (see fig. 64) ; enters the capillaries surrounding the kidney tubules (p itubular capillaries). Third, the venous blood (renal p tal) entering the kidney also serves the capillai surrounding the tubules but does not enter the glomer

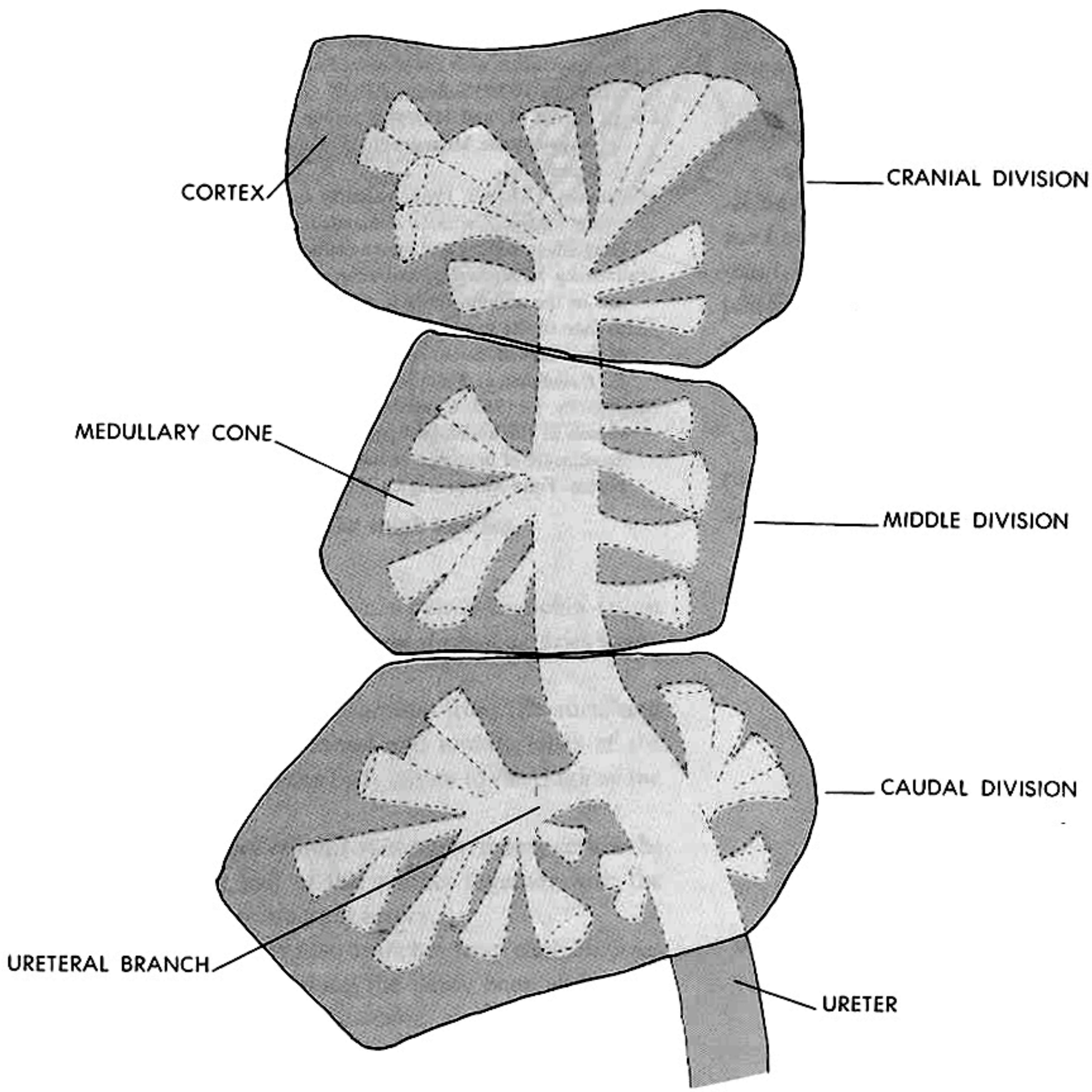


FIGURE 63. Diagrammatic ventral view of the right kidney to illustrate the renal medulla.

FEMALE

(Figure 65)

1. Ovary. The pigeon ovary consists of hundreds of ova in various stages of development held together by connective tissue, surrounded by a thin membrane and attached to the dorsal body wall by a very short *mesovarium*. Each ovum is a single cell with a nucleus located near one pole and a fatty yolk at the other. The white albumin and hard shell are produced by the oviduct as the ovum passes through it.
2. The *oviduct* is divided into (1) an *ostium* or infundibulum; (2) *magnum* or albumen gland portion; (3) an *isthmus*, which secretes the shell *membrane;* (4) *uterus* or shell gland portion; and (5) the *vagina* which may secrete the shell pigment and opens into the ventral corner of the urodaeum. The *ostium* is the cranial funnel-like open portion of the duct just dorsal to the caudal end of the ovary. The *vagina* may be identified by its thick walls but the sphincter separating the uterus from the vagina cannot be seen in a gross dissection. The magnum, isthmus, and uterus cannot be identified in a gross dissection although the location of the magnum and uterus may be approximated after the ostium and vagina are identified.

The oviduct is in several loops that are tightly bound on the ventral surface by a tough band of connective tissue. The oviduct is surrounded by membranes and attached to the dorsal body wall by a short, loose mesentery, the *mesotubarium*.

Hold the connective tissue on the ventral surface of the oviduct with heavy forceps and carefully cut away the connective tissue with a scalpel

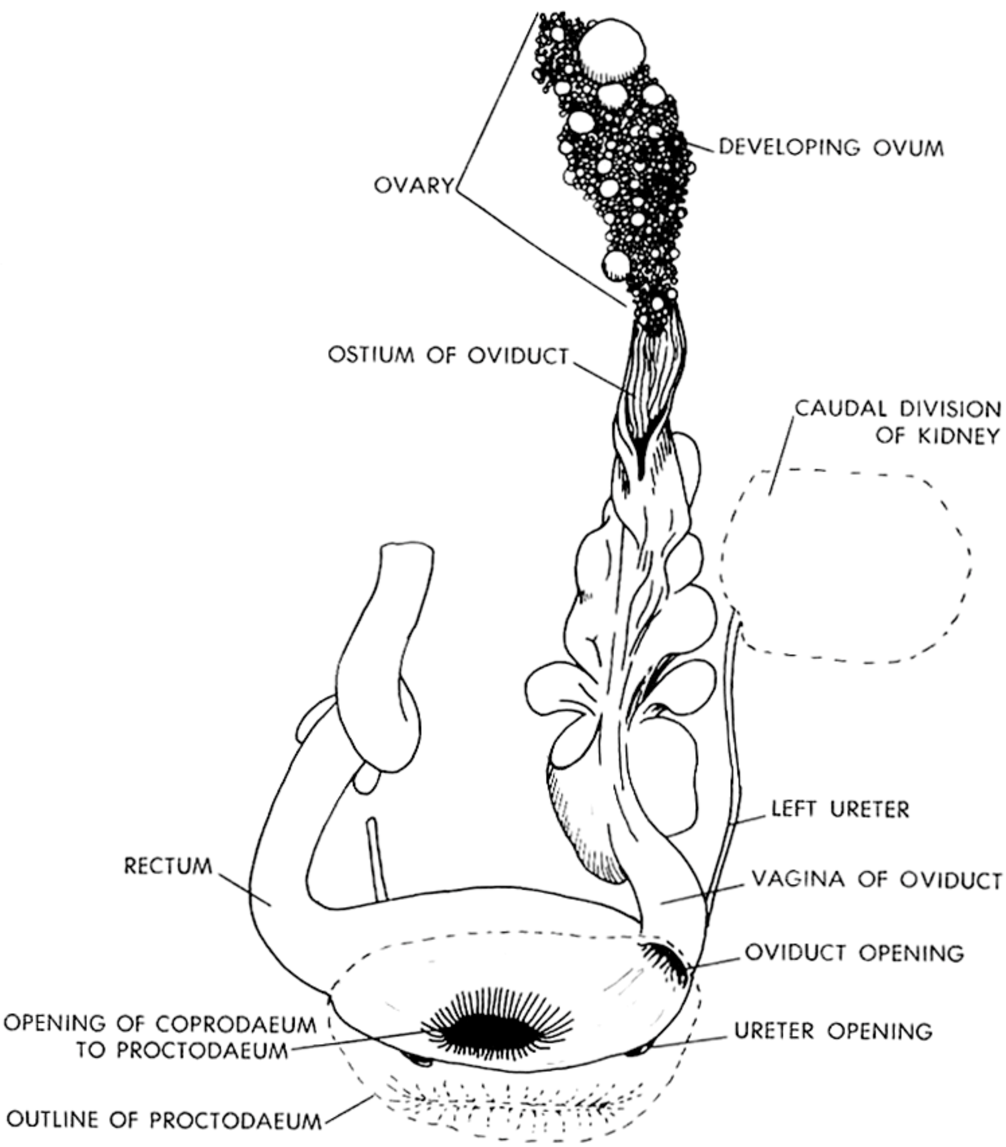


FIGURE 65. Ventral view of the female urogenital system.

or scissors. After the connective tissue is removed, or nearly so, carefully grasp the oviduct with the forceps and straighten the loops. Beginning at the ostium, cut open the oviduct lengthwise along its entire length.

The lining of the oviduct is thrown into longitudinal folds, *plicae tubariae,* through its entire length.

Caudally, the oviduct (vagina) opens to the ventral corner of the urodaeum. A small vestigial right oviduct may be attached to the right ventral corner of the urodaeum.

MALE

(Figure 66)

1. Testes. The testes vary in size with breeding conditions. The actively breeding male has large testes and the inactive animal has smaller testes. Internally the testes consists of a network of interconnected *seminiferous tubules*. The seminiferous tubules drain into *rete tubules*.
2. Vasa efferentia receive the semen from the rete tubules and empty into the epididymal tubules. The vasa efferentia and epididymal tubules are located on the dorsal surface of the testes proper.

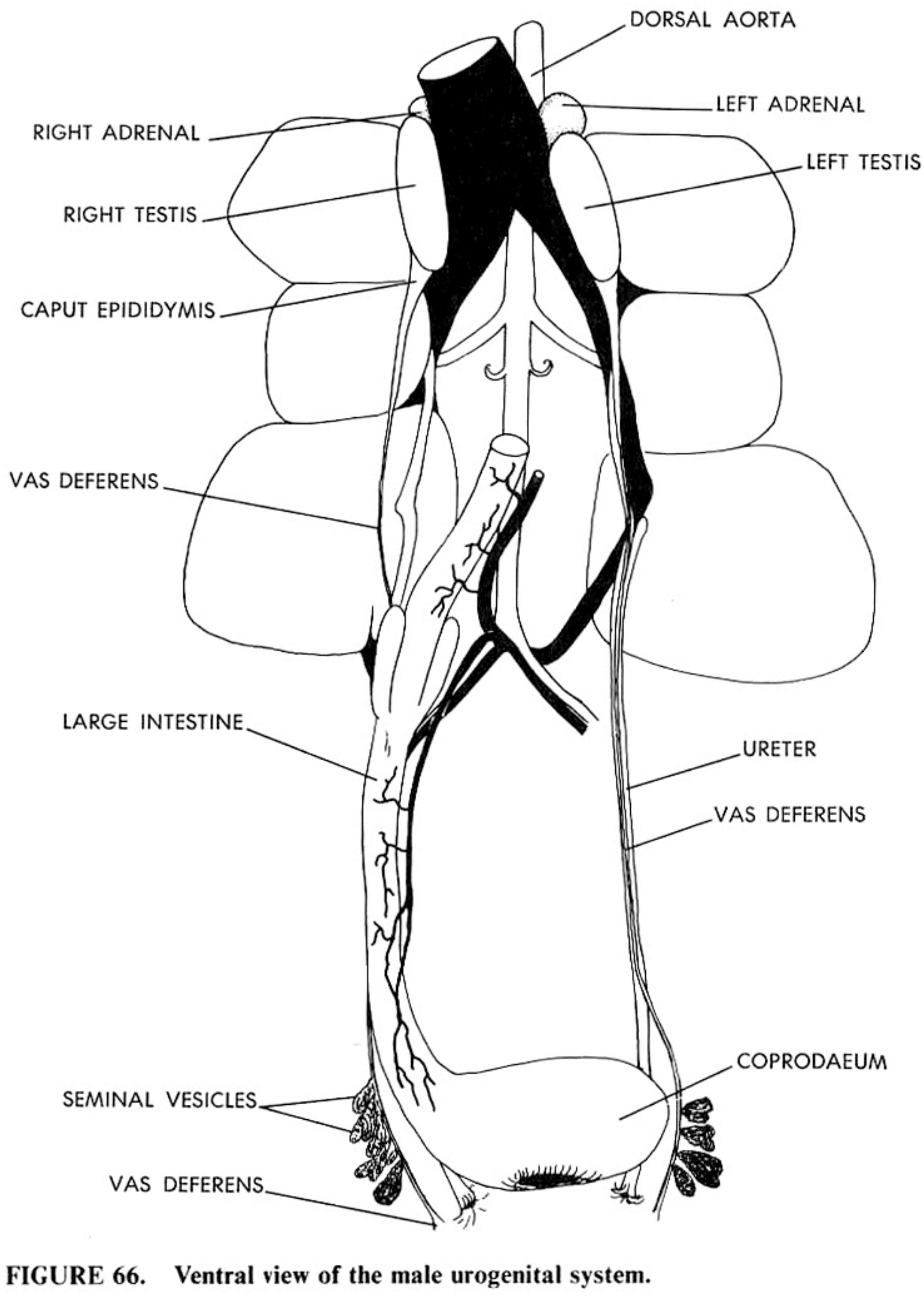


FIGURE 66. Ventral view of the male urogenital system.

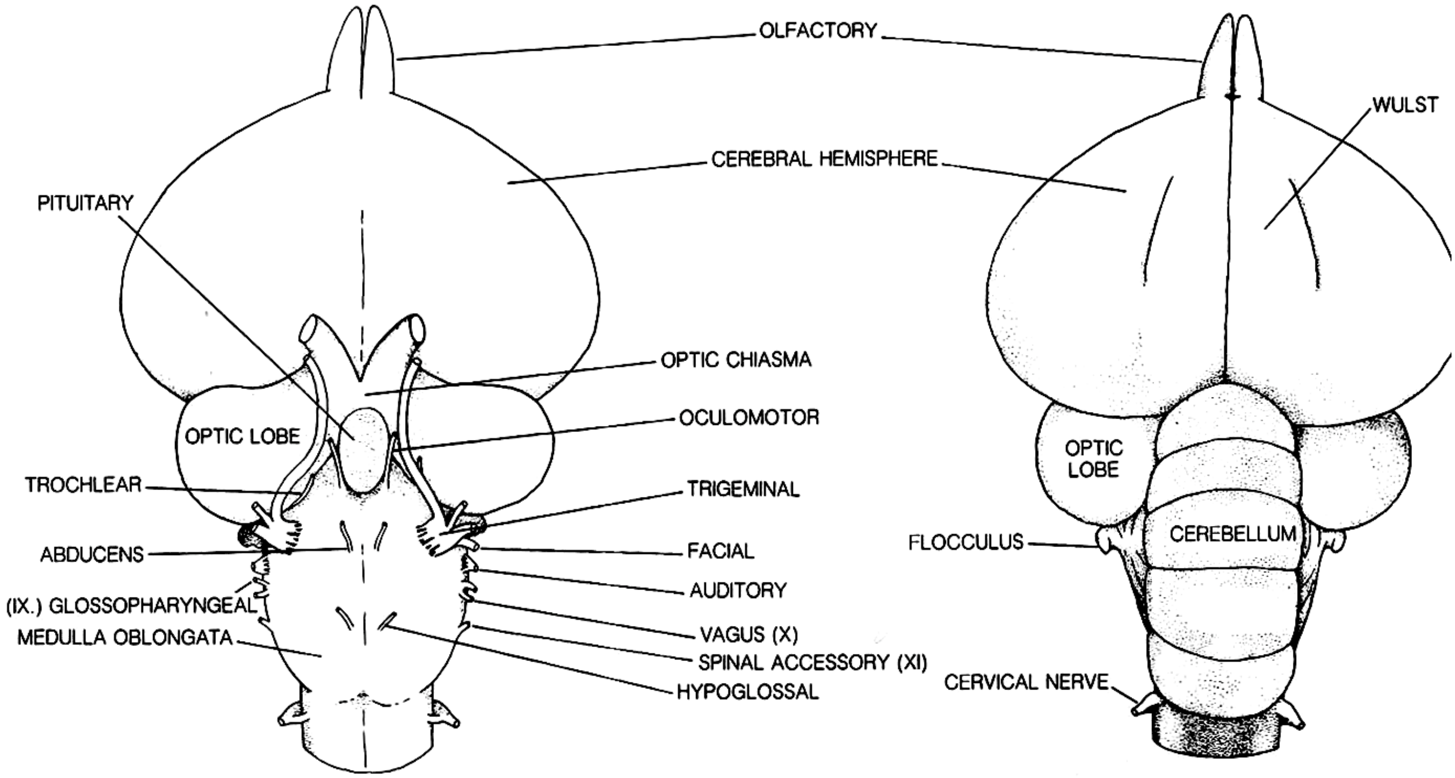


FIGURE 67. Dorsal (right) and ventral (left) view of the pigeon brain.

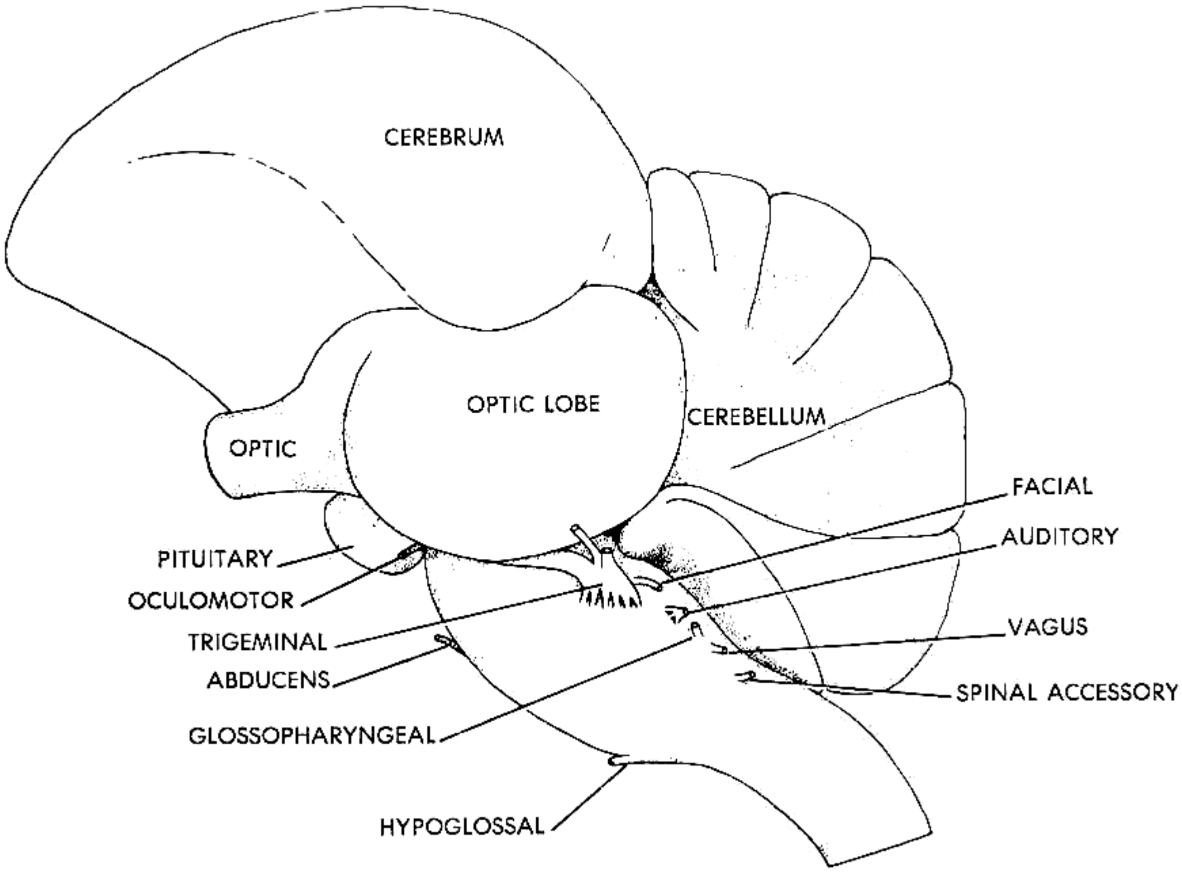


FIGURE 68. Lateral view of the pigeon brain.

MIDSAGITTAL VIEW

1. Cerebrum. The cerebrum is subdivided into four major parts: Archistriatum, Paleostriatum, Neostriatum and Hyperstriatum. The Archistriatum is located at the ventrolateral floor of the cerebrum. The Paleostriatum is just medial to the Archistriatum and dorsal to the major fiber tracts between the cerebrum and brain stem. The Neostriatum is the central portion of the cerebrum, dorsal to the Archistriatum and Paleostriatum and ventral to the Hyperstriatum. The Hyperstriatum is the dorsal third of the cerebrum surrounding the lateral ventricles. The Archistriatum cannot be seen in the sagittal view.

   The mammalian cerebrum has a cortex which may be described as a peripheral coating (*pallium*) of nerve cells arranged in layers. In birds, peripheral layers of cells occur in the optic lobes (*mesencephalon*) and in the caudal medial portion of the hyperstriatum known as the *hippocampus*. This cortex-like (corticoid) area of the hyperstriatum may be homologous to the mammalian *archicortex*. Birds do not have a *neocortex* and mammals do not have a hyperstriatum.

   Experiments have been performed on the hyperstriatum of the *Wulst* of pigeons (Cohen, *Journ. Comp. Neurology,* Vol. 131 [3]:323 and Vol. 131 [4]:559) by both destroying parts of the wulst and by stimulating these parts with an electrical current. The results of these studies show the hyperstriatum is involved in head and limb movements and possibly in respiratory and heart functions. There does not appear to be a relationship between the amount of corticoid material and intelligence (Cobb-*Perspectives in Biology and Medicine* Vol. 3 [3]:383).

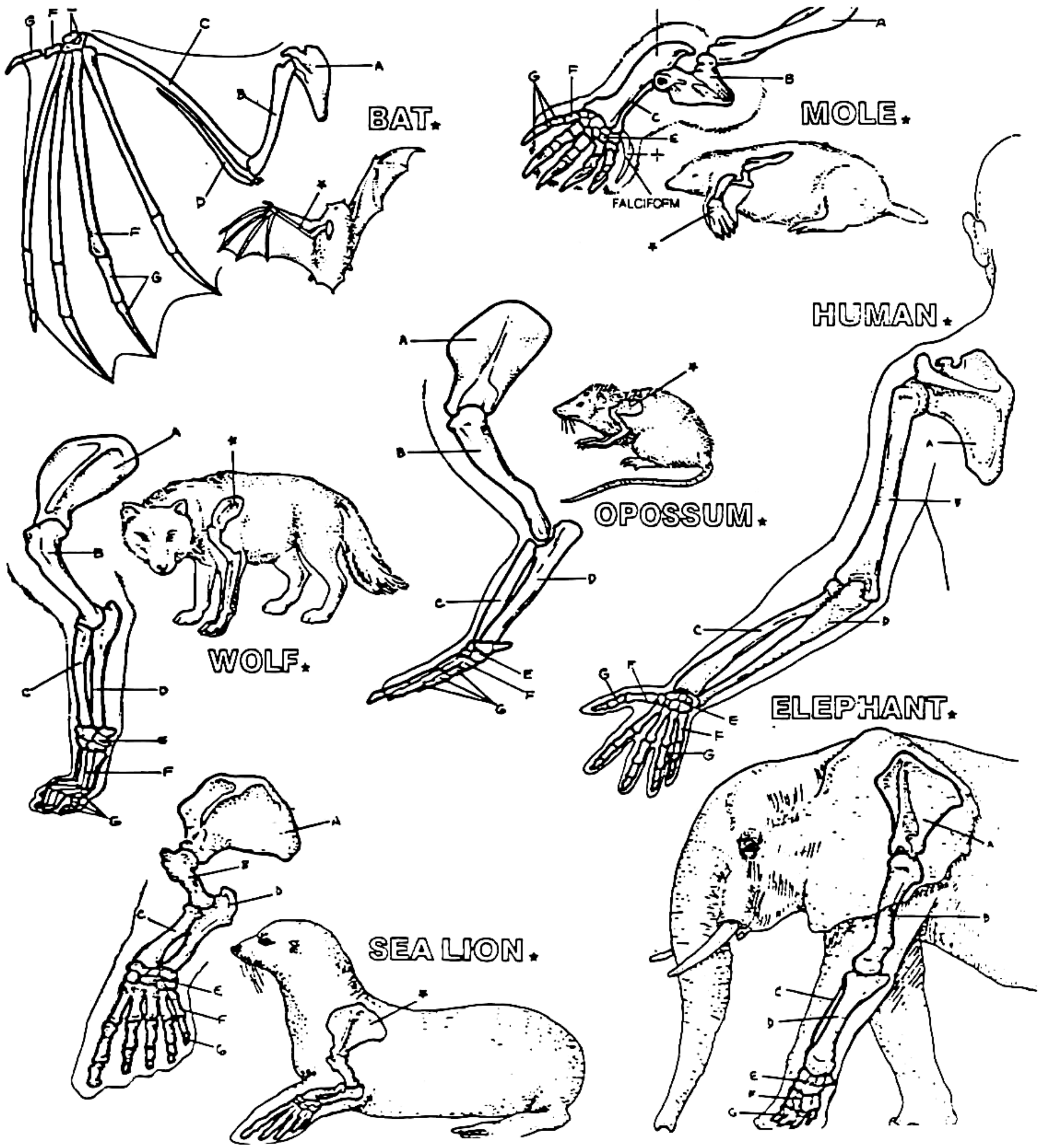
2. Olfactory bulbs are the most rostral portion of the brain and are closely linked to the cerebrum. Cobb (1960, *Perspectives in Biology and Medicine* Vol. 3 [3]:383) has established a direct relationship between the size of the olfactory bulbs in birds and the size of their hippocampal and corticoid areas. Experiments with pigeons have established the fact that they discriminate the presence or absence of environmental odors with the use of their olfactory bulbs (Michelsen. *Science,* 130: 630, 1959).

   The lateral ventricles of the cerebral hemispheres extend into the olfactory bulbs as *olfactory ventricles.*

Lab #9 – Mammal Morphology and Ecotype Lab

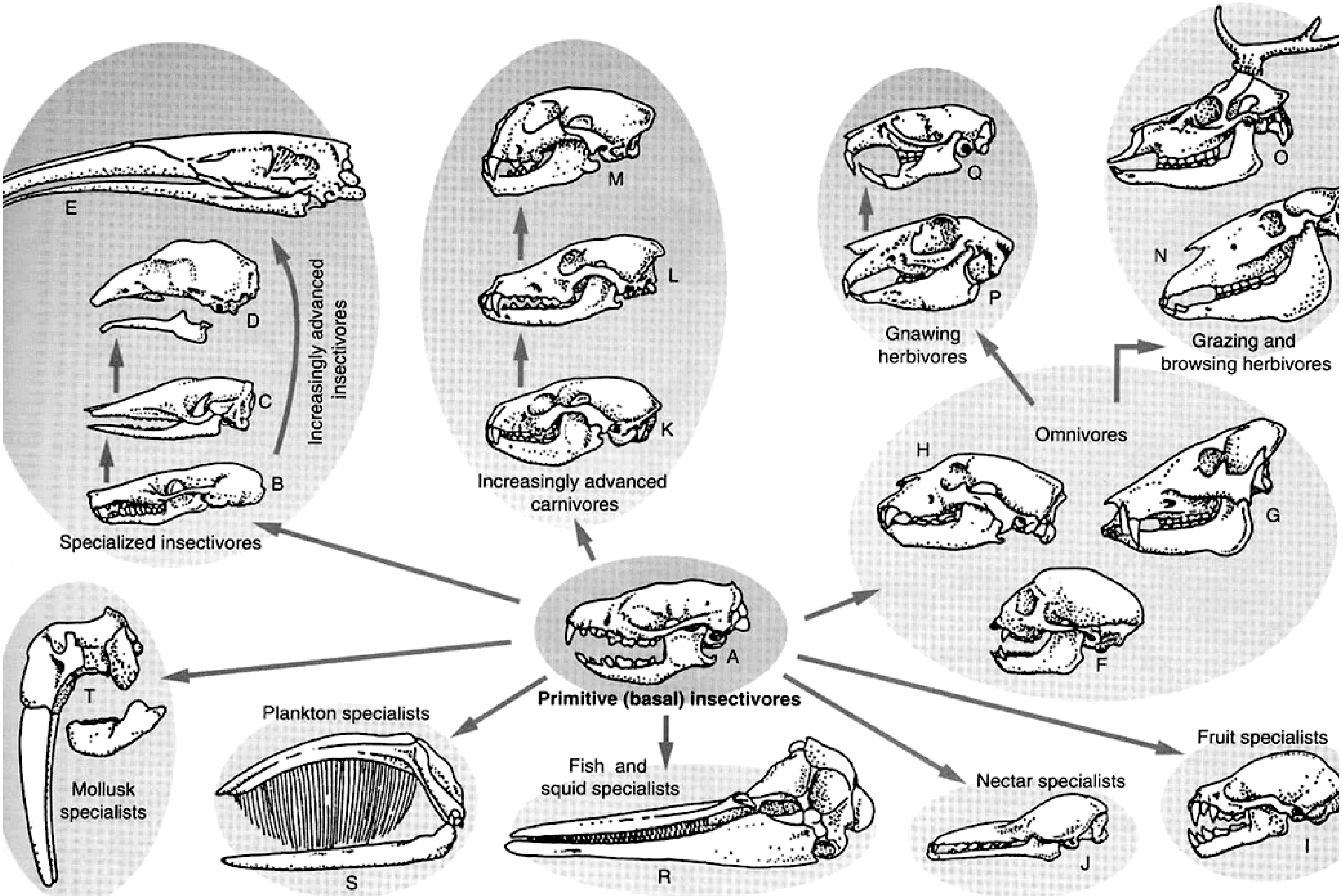
Mammalian Forelimb Evolution

Even though mammals are diverse enough to exploit almost every environment on earth, all have nearly identical forelimb structure, though the external appearance and use of each can be quite different. Note the differences in the representative mammals. Describe the needs of some of the animals pictured, i.e. – why did the forelimb need to become modified?



Mammalian dentition

The view of mammalian classification gives us an ecological understanding of mammalian diversity, though not necessarily a phylogenetic one. Basically we see which animals were able to fill different niches upon their teeth or ability to eat different prey items, not necessarily who is related to who genetically (or phylogentically).

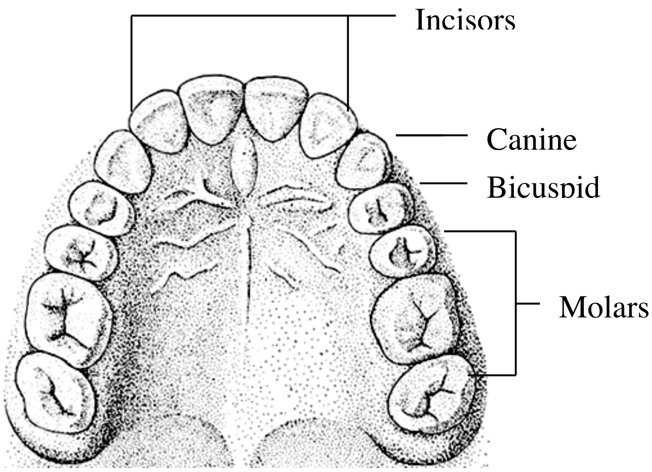


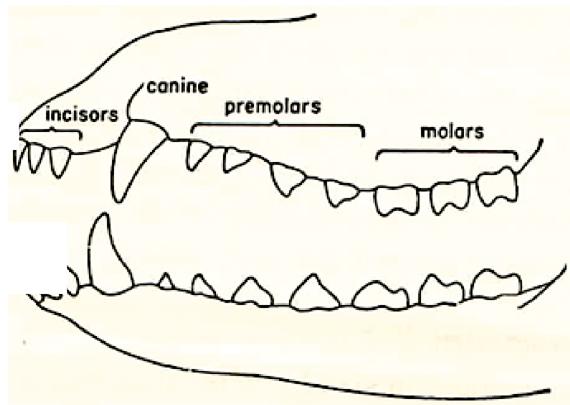
igure 6.1 Skull and dentition specialization. Feeding specializations in the dentition and skulls of mammals relate to their dietary habits:) hedgehog, (B) mole, (C) armadillo, (D) anteater, (E) giant anteater, (F) marmoset, (G) peccary, (H) bear, (I) fruit-eating bat, (J) nectar-eating bat,) raccoon, (L) coyote, (M) mountain lion, (N) horse, (O) deer, (P) jackrabbit, (Q) woodrat, (R) porpoise, (S) right whale, and (T) walrus.

Dentition refers to teeth and the arrangement of teeth within an animal's jaw. The four basic types of teeth include:

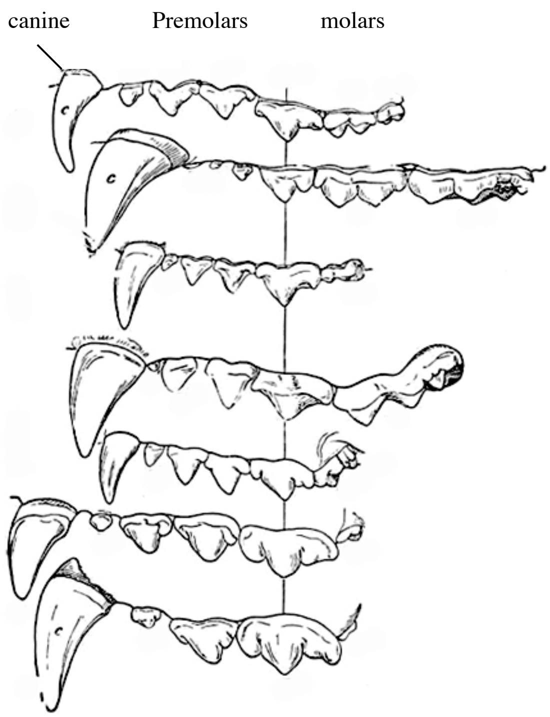
1. **Incisors –** forward or front teeth whose sharp edges provide cutting surfaces. The presence or absence of these teeth is a good indicator of an animal's lifestyle or habitat.
2. **Canines –** conical, pointed teeth located between the incisors and the first premolars, Used for gripping and tearing.
3. **Premolars –** (or bicuspids) have two conical points and follow the canines. Also used for gripping and tearing.
4. **Molars –** follow the premolars and may be flat, for grinding or serrated, for cutting, depending upon lifestyle.

Note the differences in the size, shape and number of teeth in the figure. You should be able to identify each tooth type in the species provided during this lab.





Though the four major tooth types are present in most mammals, the number and shape of each varies to a great extent.



<u>Carnivore dentition</u> – have teeth with sharp points and serrated edges for tearing and cutting flesh. Incisors are narrower and much smaller teeth, with sharp edges for piercing and cutting. The canines are highly developed and longer. Their conical shape and position in the jaw are good for holding, tearing and slashing. The premolars have two conical peaks for cutting or shearing. The molars are usually serrate and jagged, the flat grinding type of molar is usually nonexistent. Carnassial is a term used to describe the lower first molar and the upper last premolar as they come together in a scissor-like motion providing as excellent cutting surface.

Herbivore dentition – have generally flat molars and the absence of pointed canine teeth and bicuspids. Unique adaptations are seen in three distinct groups:

Rodents – (squirrels, rats) have a single pair of long, curved incisors in the upper and lower jaw.

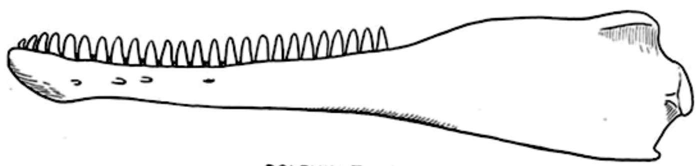
Ruminants – (cows) incisors present in the mandible (lower jaw) but absent in the maxilla (upper jaw). Molars are flat and well formed, slanting slightly inward and have ridges on their grinding surfaces.

Perissodactyls – (horses) have wide sharp edged incisors in upper and lower jaws. Molars are inward facing with flat surfaces for grinding.

Omnivore dentition – have a complete set of incisors, canines, premolars, and molars in both upper and lower jaws. The teeth reflect a combination of carnivore and herbivore structures.

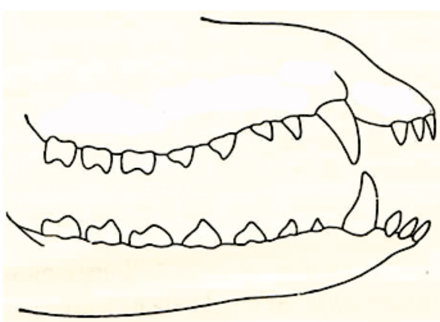
Homodont vs. Heterodont

Homodont - possessing teeth that are all the same form, and not differentiated into several tooth types. i.e. – dolphins and some other toothed whales



DOLPHIN, *Tursiops*

Heterodont – Possessing teeth that are differentiated into several different forms including: incisors, canines, premolars, and molars. i.e. – humans, cats, and cows.



Muscle attachment positions

Two major muscle groups, the ***masseter*** and ***temporalis***, work to close the lower jaw. They attach to the skull at the zygomatic arch, the cranium, and the lower jaw. The size and positioning of these muscles, when associated with other features, can help identify and animal's lifestyle or habitat.

Temporalis muscles attach along the rear of the lower jaw and anchor along the sides or top of the cranium. They provide power to the forward position of the jaws where the incisors, canines, and premolars reside.

Masseter muscle attach between the sides of the zygomatic arches and the rear portions of the lower jaw. They provide power for the back of the jaws, where the molars reside.

Carnivores – muscle attachments are located where they will give the greatest strength to muscles functioning in holding and crushing prey while the animal tears and rips the flesh. Therefore the temporalis, which runs from the lower jaw to the sagittal crest, has a tremendous amount of leverage due to it length and stability of its attachment points. The smaller masseter muscles produce the power for crushing and cutting with the molars.

Herbivores – ruminants and perissodactyls require jaw muscles for crushing and grinding plant material with the rear jaws. The temporalis muscles are relatively short, due to the anchor positions, and therefore provide limited power to the front of the jaws. The masseter muscles are much larger and stronger than the temporalis muscles. They enhance the side-to-side grinding in the back of the jaw, and also add some leverage to the front.

Omnivores – the relative size and placement of muscle attachment depends upon whether the animal exploits a more carnivorous or herbivorous lifestyle; the temporalis muscle is more laterally attached to the cranium in an animal that seeks primarily plant material and is attached dorsally in the meat-eaters along the sagittal crest.

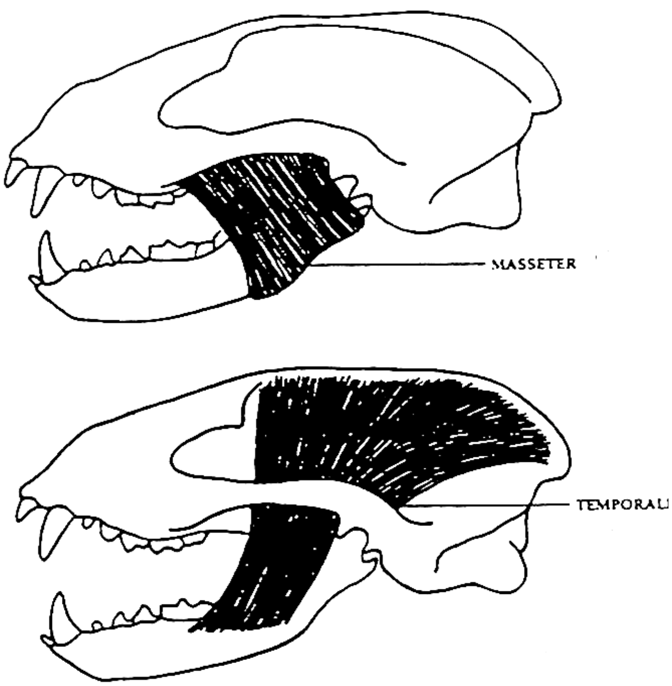


Figure 2.26.
Attachment points for the temporalis and masseter muscles on a European badger skull.

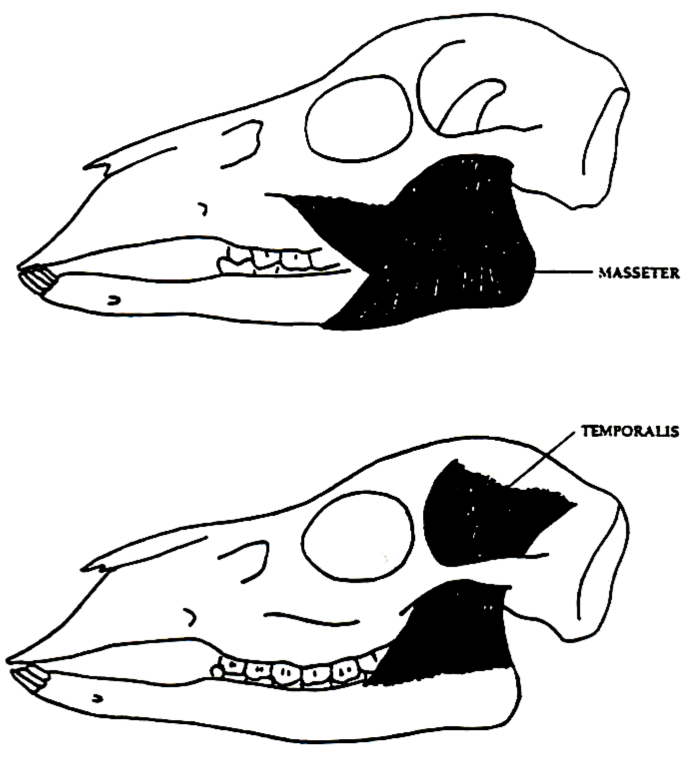


Figure 2.27.
Muscle attachment points for masseter and temporalis muscles on ruminant and perissodactyl skulls.

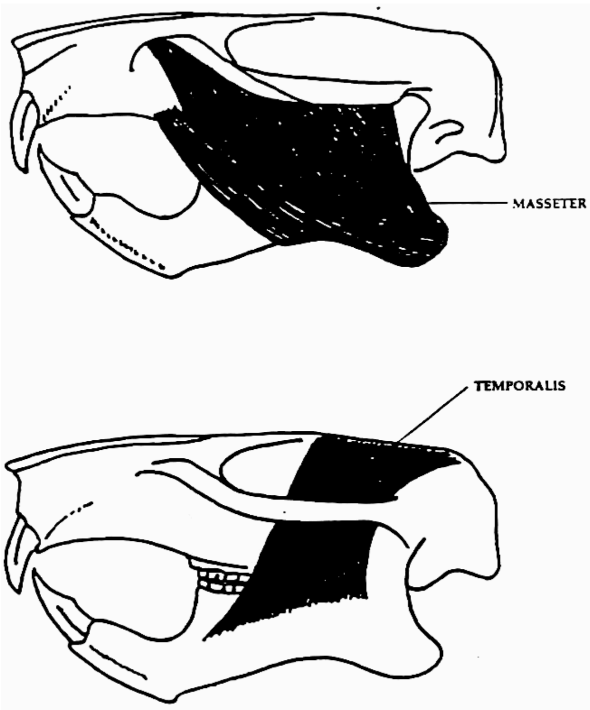


Figure 2.28.
Muscle attachment points for masseter and temporalis muscles on rodent skulls.

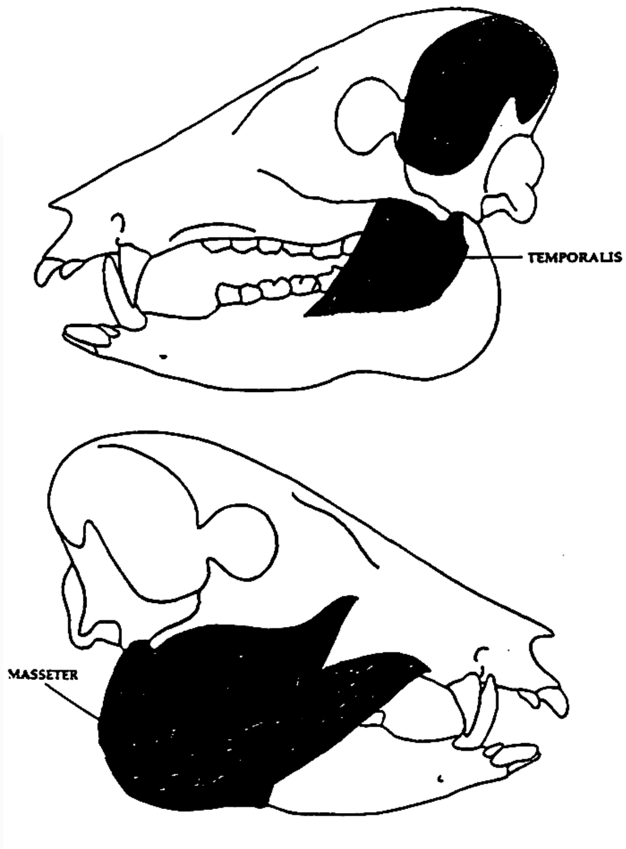


Figure 2.29.
Muscle attachment points for masseter and temporalis muscles on an omnivore skull.

Zygomatic arches

The zygomatic arches are the portions of the skull that form the cheekbones and extend to the back along each side of the skull, attaching above, and slightly forward of the ears. They are composed of two bones: the ***jugal bone***, or cheekbone, which connects with the ***squamosal bone***, which in turn connects to the cranium just above and in front of the ears. The greatest distance between the zygomatic arches on either side of the skull is called the ***zygomatic breadth*** or width.

These arches are important in classification because their size and distance from the cranium indicate the relative size of the temporalis muscles, which pass between them and connect the back of the mandible to the cranium. The larger the opening, the larger and stronger the temporalis muscles, and the more likely the animal is to exhibit carnivorous tendencies.

Carnivores – tend to have large zygomatic widths, which accommodate well developed temporalis muscles, and also provide a strong anchor position for the masseter muscles, which raise the lower jaw.

Herbivores – ruminants and perissodactyls have small zygomatic widths. This creates less room for the temporalis muscle, but provides a stronger anchor position for the masseter muscles.

Omnivores – as with many characteristics in omnivores, the width of the arches fall between that of the carnivores and herbivores, depending upon species. i.e. – are larger in bears and foxes, small in humans and pigs.

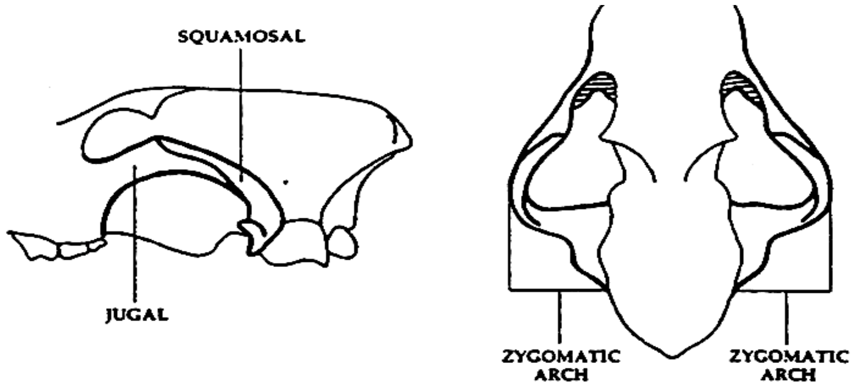


Figure 2.23.
Bold areas in this image reference the zygomatic arch and its component structures, the jugal and the squamosal. Together these structures form the zygomatic arch.

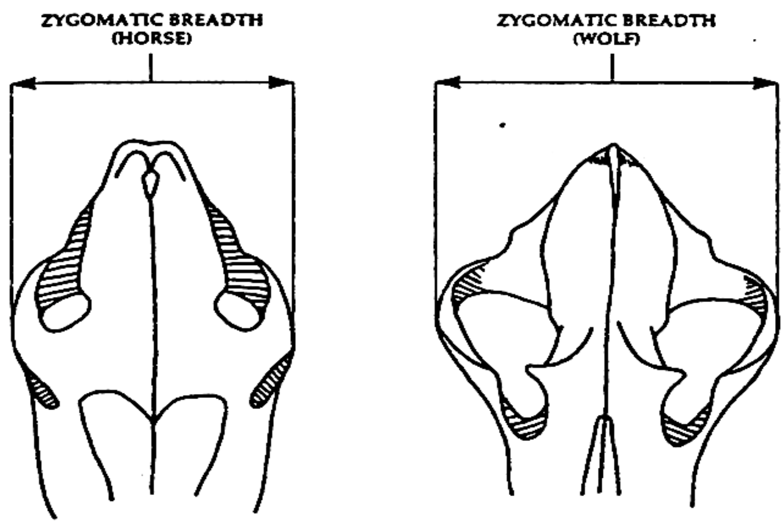


Figure 2.24.
A comparison of the zygomatic breadths of a horse and a wolf.

The mammalian cranium

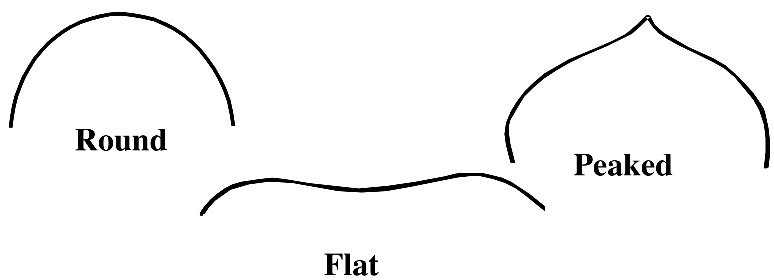
The cranium, or dome, is the portion of the skull that protects and houses the brain. This structure is important in classification because its outward cross-sectional shape often varies according to an animal's lifestyle. The back portion of the cranium comprises two bones called the ***parietal bones***. The suture line forming them forms the ***sagittal crest***, which runs longitudinally to the back of the skull. The crest can be pronounced (forming a peak), reduced (forming a slight bump), or smooth (forming a flat or rounded surface).

The cranial shape not only indicates the surface area available to anchor jaw muscles, but also muscle size and strength. Usually, the larger the crest, the larger the temporalis muscles that attach along its length; a smooth or flat cranium indicates smaller temporalis muscles that must anchor farther down its sides to maintain sufficient stability. In cross-section, three generalized shapes are common:

1. Smooth-rounded – found in human and deer
2. Smooth-flat – found in cows

3. Peaked – found in dogs and cats

Carnivores – have pointed (peaked) appearance due to the pronounced sagittal crest, which provides an anchor for longer, more developed temporalis muscles.
Herbivores – ruminants and perissodactyls have smooth-rounded or smooth-flat crania. These house smaller temporalis muscles due to lack of surface area for attachment. Rodents can be rounded and smooth, but also exhibit slight peaks to the sagittal crest.
Omnivores – have a variety of cranial types with a combination of carnivore and herbivore traits.



Orbits

Orbits, or eye sockets, form the framework that supports and protects the eyes. Their shape, size, and position in a skull can indicate the animal's environmental lifestyle. Eye socket positions in mammals range between two extremes: rotated facing forward or rotated sideways facing outward form the side of the head.

Binocular vision – forward facing eye sockets permit the fields of vision of each eye to overlap. This allows the brain to perceive the same image from two different perspectives from which it can fix an object in space. This gives the animal the ability to sense depth, distances, and three-dimensional images. However, the peripheral vision is limited.

Monocular vision – side facing eye socket require the eyes to face outward in opposite or near- opposite directions, a position in which their fields of vision do not overlap. The animal's perception is limited to flat, two-dimensional images, preventing the sensing of depth and distances. The peripheral vision is excellent, increasing the ability to see farther to the rear and detect motion.

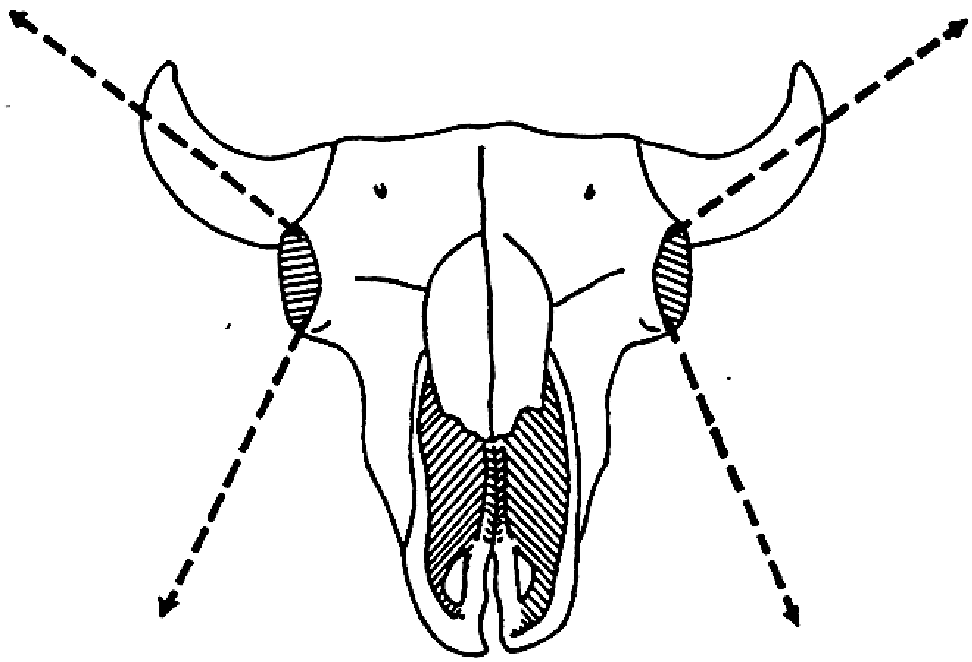


Figure 2.22.
The independence of sight that produces monocular vision, illustrated using the orbital structures of a bison.

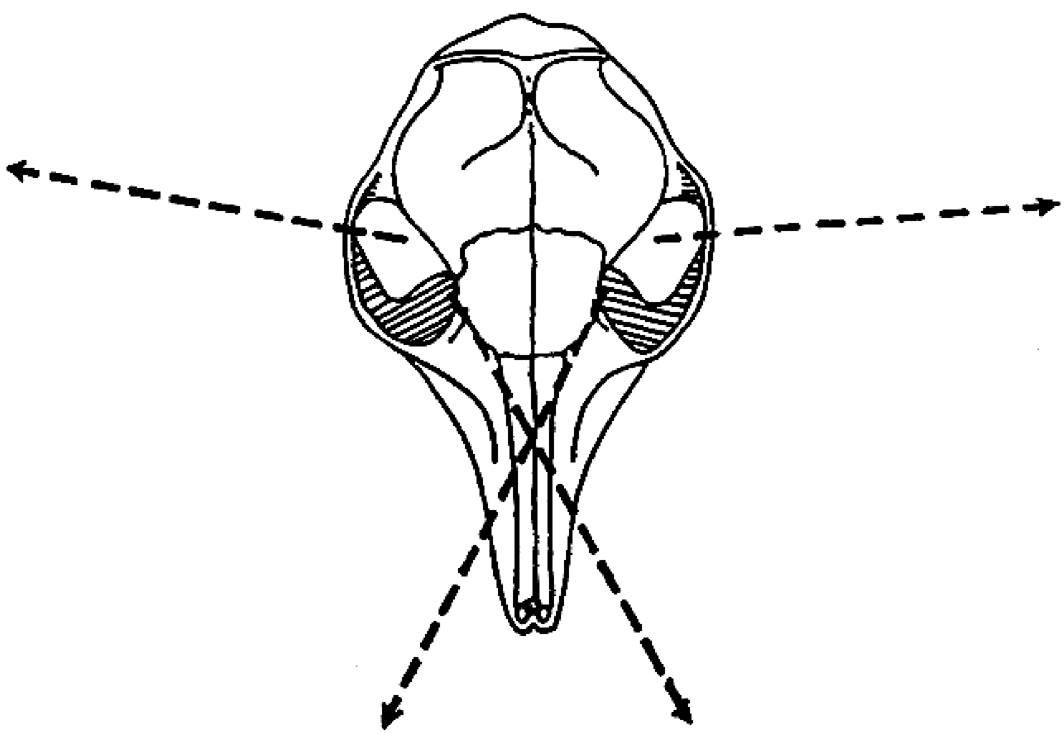
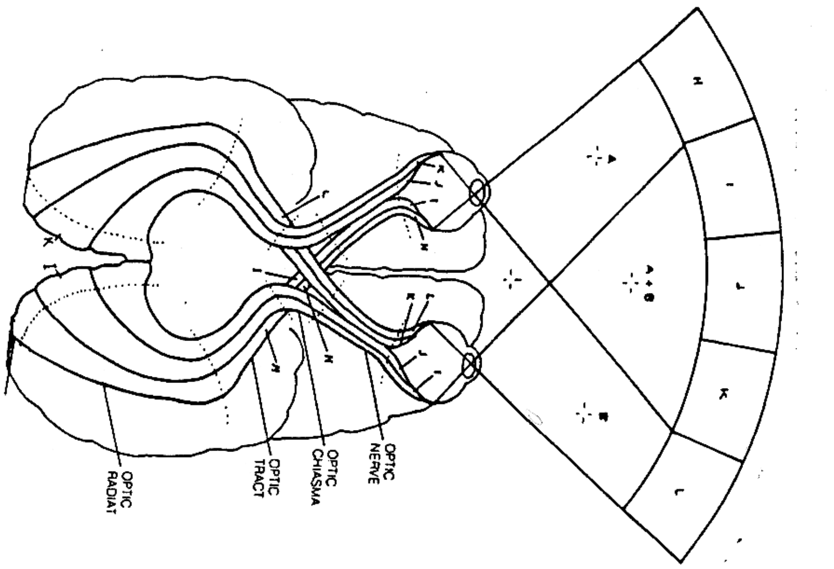
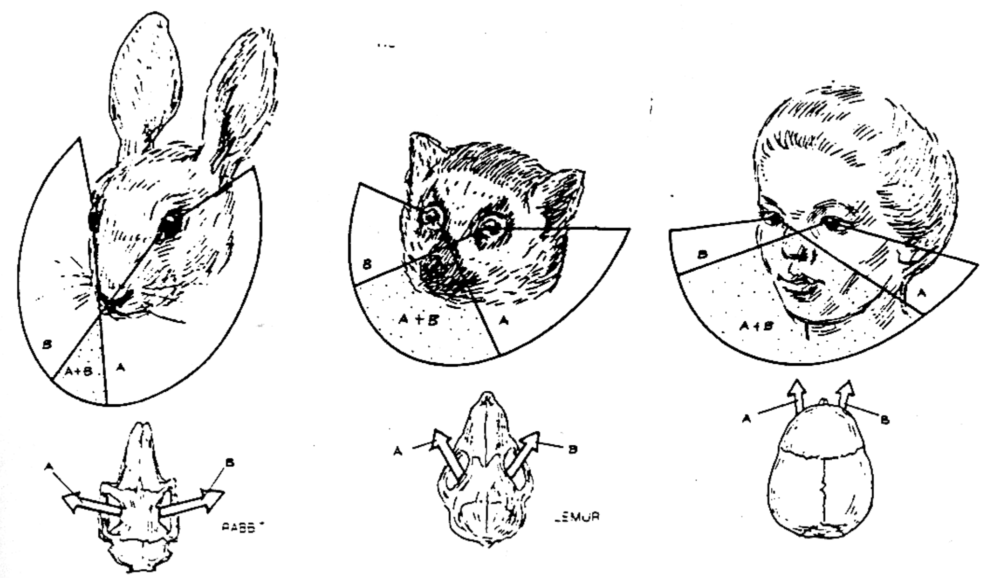


Figure 2.21.
The overlapping of sight fields that produces binocular vision, illustrated using the orbital structures of an elephant shrew, a nonnative of North America.





Nasal cavities

Sense of smell is vital to almost all animals. The nasal cavity, home to the olfactory organs, is the portion of the skull that houses and protects the sinus membranes. The cavity's size and shape often affects the placement of the eye sockets in the animal.

Carnivores - are usually short and blunt (felines), but can be short and narrow (otters).

Herbivores – are usually long, though the width varies among species. i.e. Wide in cows, narrow in deer, short and pointed in porcupines.

Omnivores – cavities come in three general shapes:

1. short and flat – humans
2. long and narrow – opossums
3. long and medium wide – bears

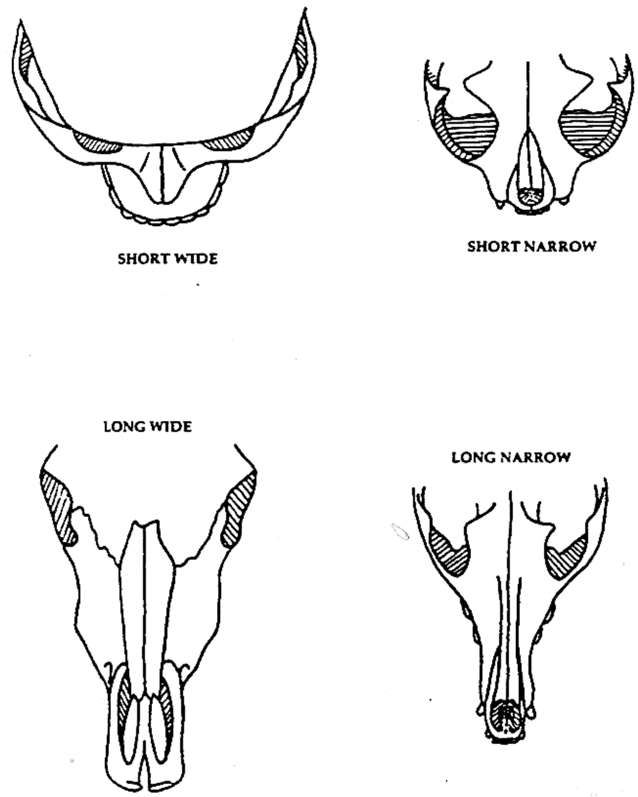


Figure 2.17.
A comparison of four basic nasal structures.

Horns and antlers

Horns

- As seen in the goat, are permanent structures.
- There are different types of horns. The most common ones are those found in the bovids (antelopes, cattle, goats, etc.) and consist of a bony core projecting from the skull and covered by a hard keratin. Keratin is a structural protein like the one found in you fingernails and hair.
- Both sexes posses them

Antlers

- Bony cores invested with hairy skin that nourish and protect the growing antler. They are similar to the horns of giraffes.
- They shed annually
- With the exception of female reindeer (caribou) only males grow them.
- They are often used in ritualize fighting
- They represent a large energy expenditure

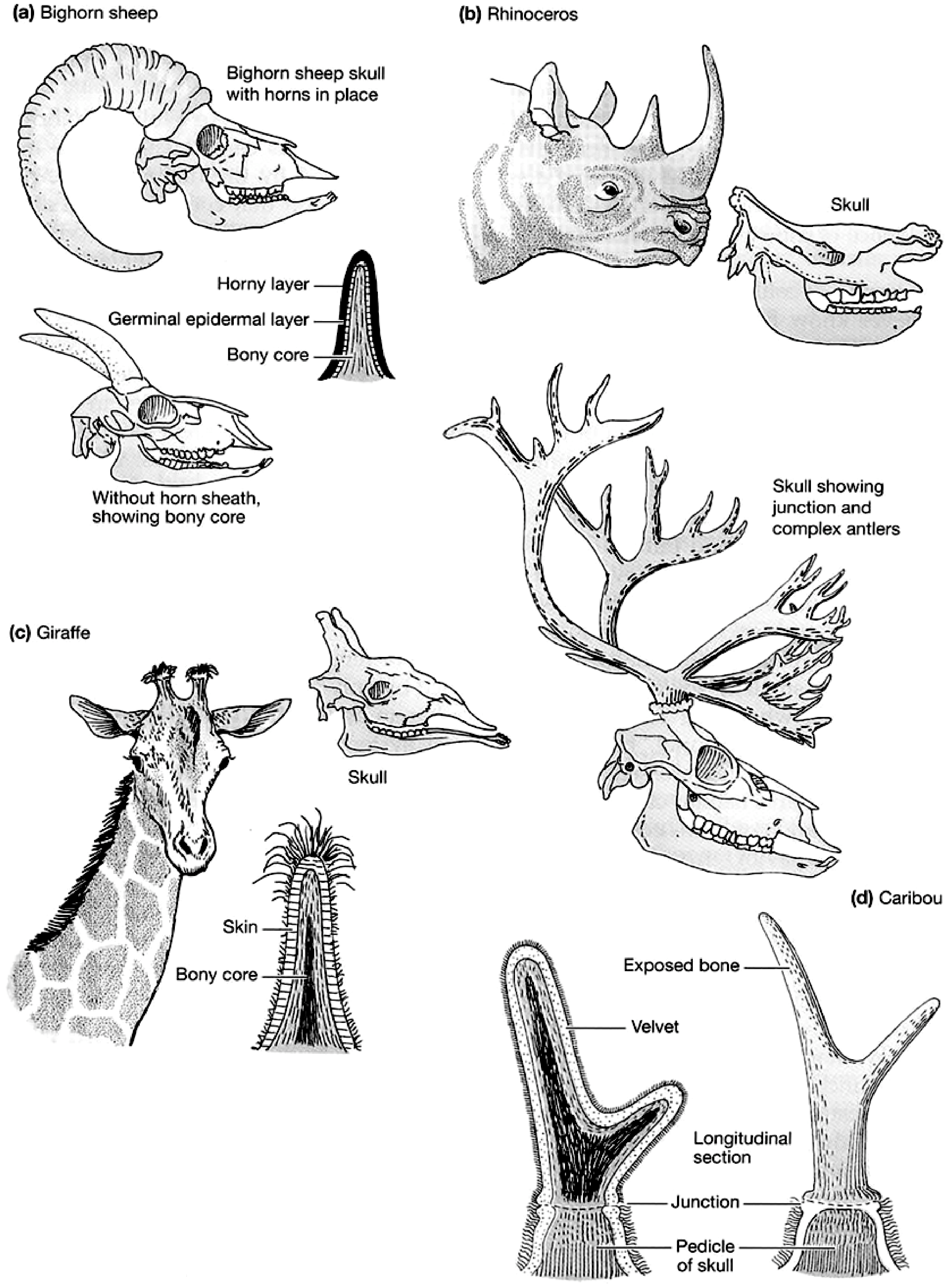


Figure 22–9 Cranial appendages. (a) Horns of a bighorn sheep. (b) Rhinoceros horns. (c) Giraffe ossicones.
) Antlers of a caribou.

Monkey skeleton

- Looking at the skeleton of this mammal can tell you much about its natural history.
- The long digits on hands and feet, and long tail are indicative of arboreal (or tree) living. Compare these digits with those of the rat, who is adapted to more generalized living conditions, such as sewers and apartment buildings.
- The large eye sockets means that vision is important to these animals, probably in watching for predators that search the tree branches for prey. These predators include large snakes and cats.
- Large, well developed brain case (large relative to the rat, for example).
- The nearly "floating" pectoral girdle that is attached to the clavicle, which attaches to the sternum, or breastbone. This arrangement allows the monkey great flexibility and range of movement of its forelimbs. This is necessary, since the forelimbs are used primarily for locomotion through the trees.

Hair

Hair has a variety of functions in modern mammals including: camouflaging from predators, signaling to other members of its species, and primarily insulation.

The insulative capabilities of hair depends upon its ability to trap air, which actually does the insulating. The length of the hairs as well as the density of hairs in a coat are what determine this. The denser the coat, the greater the insulation qualities, especially in an aquatic environment.

Describe how the hair of each specimen provided enables each to exploit its environment. The animals can be divided into: burrowing, aquatic, and terrestrial. For the terrestrial animals, explain how the hair type fits the habitat (from the map provided).

Habitats

Habitats can be dictated by the amount and quality of fur an animal possesses. For each of the skins provided, match it to its correct habitat map and discuss the properties of its fur that allows it to exploit the specific environment.

Habitats

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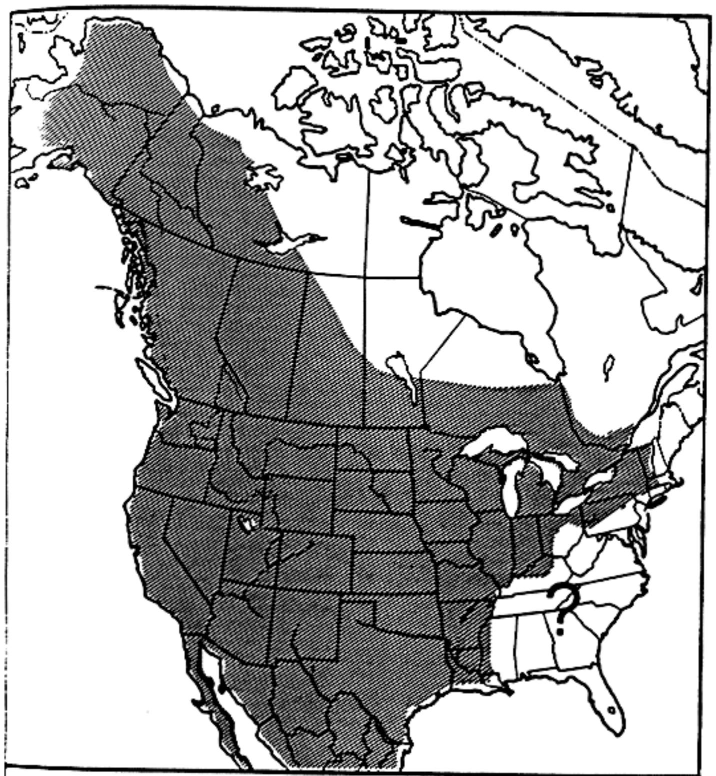
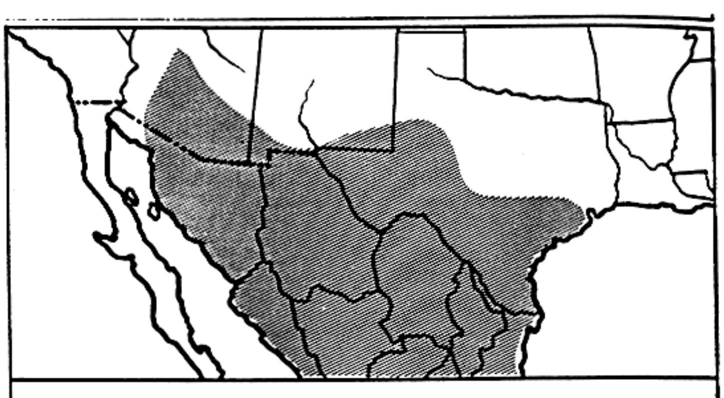
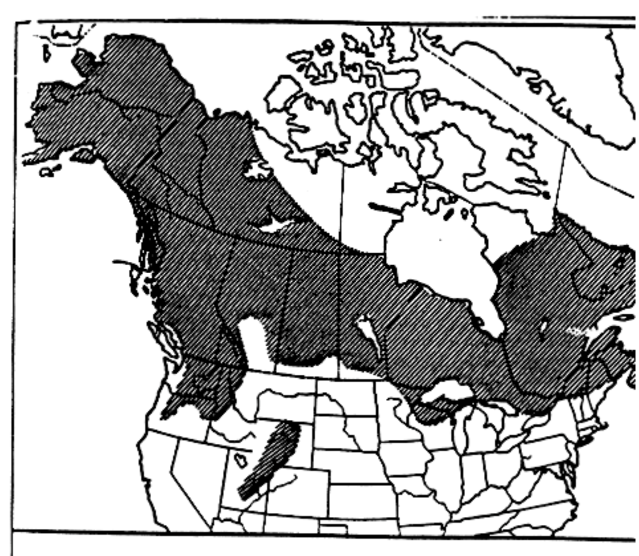


Coyote, *Canis latrans*, 69, **Pl. 7**



Peccary, *Pecari angulatus*, 213, **Pl. 19**



Lynx, *Lynx canadensis*, 80, **Pl. 8**