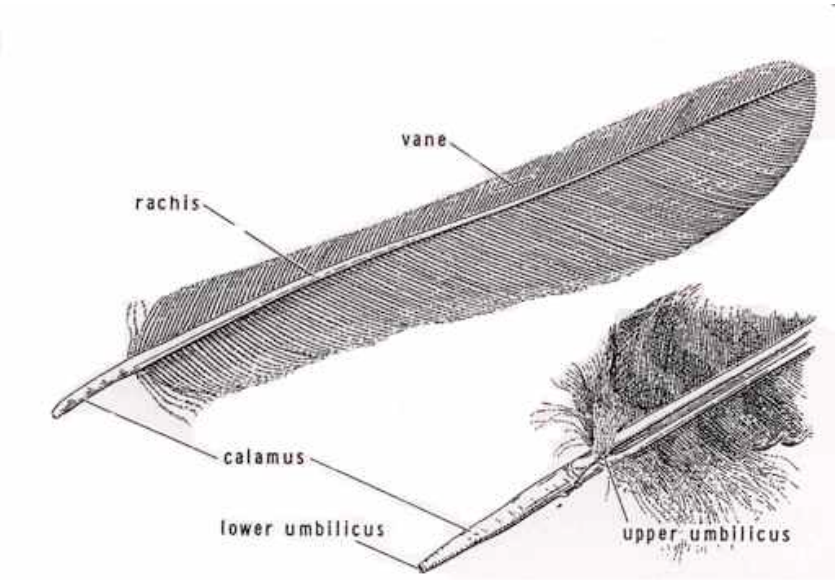
Classification of the Major Taxa of Birds

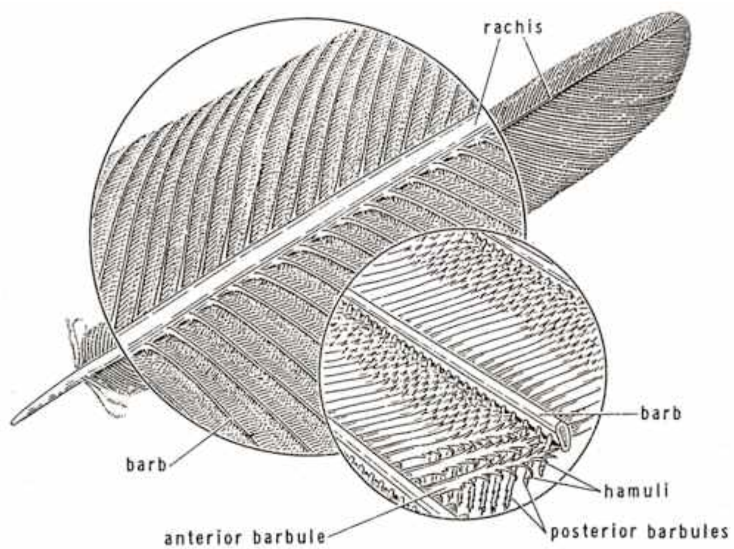
	examples
Phylum Chordata	
Subphylum Vertebrata	
Class Aves	
Subclass Archaeornithes	extinct Jurassic fossil birds
Subclass Neornithes	all modern birds
Infraclass Paleognathae	includes ostriches and kiwis
Infraclass Neognathae	all other modern birds
Order Podicipediformes	grebes
Order Sphenisciformes	penguins
Order Procellariiformes	tube-nosed seabirds
Order Pelecaniformes	pelicans
Order Anseriformes	waterfowl
Order Phoenicopteriformes	flamingos
Order Ciconiiformes	herons, storks, New World vultures
Order Falconiformes	diurnal birds of prey
Order Galliformes	fowl-like birds
Order Gruiformes	cranes, rails
Order Charadriiformes	shorebirds, gulls
Order Gaviiformes	loons
Order Columbiformes	pigeons and doves
Order Psittaciformes	parrots
Order Coliiformes	mousebirds
Order Musophagiformes	turacos
Order Cuculiformes	cuckoos
Order Strigiformes	owls
Order Caprimulgiformes	nightjars
Order Apodiformes	swifts and hummingbirds
Order Trogoniformes	trogons
Order Coraciiformes	rollers, kingfishers
Order Piciformes	woodpeckers, toucans
Order Passeriformes	perching birds

THERMOREGULATION

Birds and mammals are endothermic. This means that heat generated by metabolism is used to warm their bodies and keep their body temperature maintained within a relatively narrow range.

One mechanism to balance heat gain and loss is through insulation. Any material that traps still air is a good insulator against conductive heat transfer. A major thermoregulatory adaptation in birds is the development of feathers. The insulating power of feathers is related to their ability to trap still air. The structure of feathers is admirably designed for this. The mechanism of conductive insulation relies upon an outer shell of non-conducting material that covers an inner core with a high conductivity.





Structure of a typical flight feather

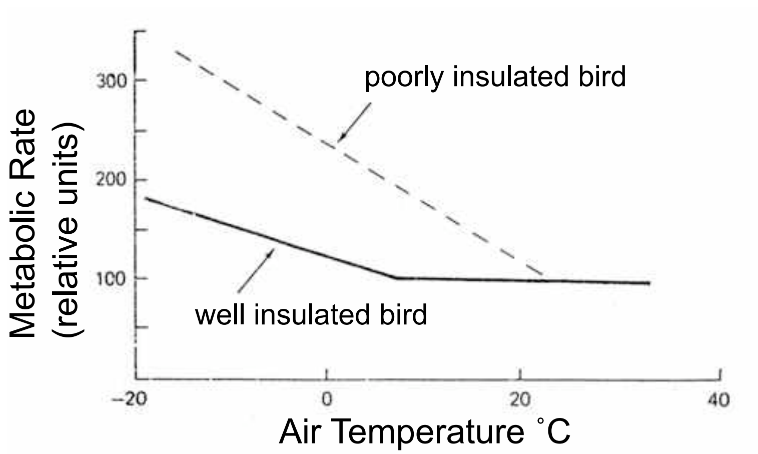
There are different types of feathers. Look at three types under the microscope and at examples of feathers displayed here.

THERMOREGULATION

Pound for pound feathers are an excellent insulation material, better than mammalian hair and most natural or synthetic material. Look at the following table comparing thermal conductivities of various substances. Note that down approaches the value of a column of still air.

Substance	**Conductivity** g cal / cm2 sec °C
Copper	0.99
Glass	0.0025
Water	0.0014
Soft wood	0.0009
Cotton wool	0.0004
Sheep wool	0.00025
Wider down	0.00016
Still air	0.00006

Control of heat loss to a cold environment is an important regulatory function of an endotherm; birds employ their plumage in a very effective way as an insulation against heat loss.



FEATHERS

Feathers are peculiar to birds and constitute their principal covering. Like the sheath of the bill, the scales of the feet, and the claws on the toes, feathers are horny, keratinized outgrowths of the skin or integument. They develop from tiny pits or follicles in the skin, just as do hairs of mammals.

The scales on the feet of birds are clearly of the reptilian type and feathers probably evolved from comparable scales, becoming lengthened and elaborated to occupy greater space. Except in initial development, scales and feathers bear little resemblance to each other, and there are no known structures in either reptiles or birds, living or extinct, that provide any evidence of linkage between scales and feathers.

The two most important functions of the bird's feathers are to provide insulation - thus reducing loss of body heat - and to make flight possible by giving a streamlined contour and increasing the surface of the wings and tail. Through their coloration, feathers also aid certain species in concealment, in sex and species recognition, and in numerous displays.

FEATHERS HAVE A NUMBER OF FUNCTIONS IN BIRDS:

1. different types of feathers have different functions
2. thermoregulation
3. flight
4. social communication: species, sex and age identification
5. camouflage
6. water repellancy
7. display
8. sound production in some species (grouse, doves, etc.)

ADAPTATIONS FOR FLIGHT

Birds fly as the result of several evolutionary inventions--feathers, endothermy, wings and pectoral muscles, hollow bones, a special respiratory system, and a large powerful heart among them. Birds have reduced their weight considerably by modifying bone anatomy, fusing bones, losing teeth, jaws and jaw muscles. As a result the length of the tail has become reduced (counter-balance mechanisms).

Weight-reducing adaptations	*Power-promoting adaptations*
Thin, hollow bones	Homeothermy and high metabolic rate
Extremely light feathers	Heat-conserving plumage
Elimination of teeth and heavy jaws	An energy-rich diet
Elimination of some bones and extensive fusion of others	Rapid and efficient digestion
A system of branching air sacs	Highly efficient respiratory system
Oviparity rather than viviparity	Air sacs for efficient cooling during muscular activity associated with flight
Atrophy of gonads in nonbreeding periods	Breathing movements synchronized with wing beats
Eating concentrated foods	Large heart and rapid high pressure circulation
Rapid and efficient digestion	
Excretion of uric acid instead of urea	

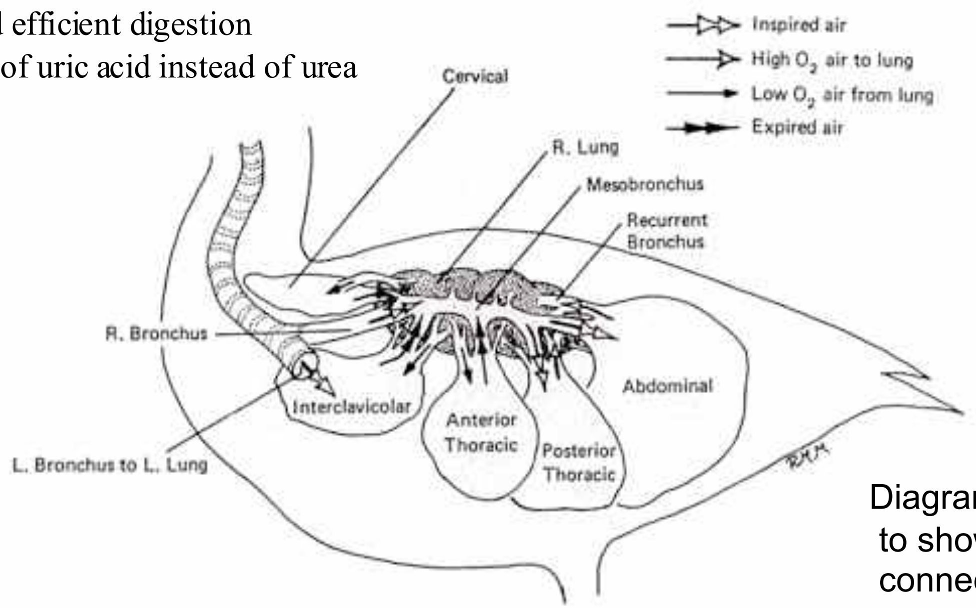


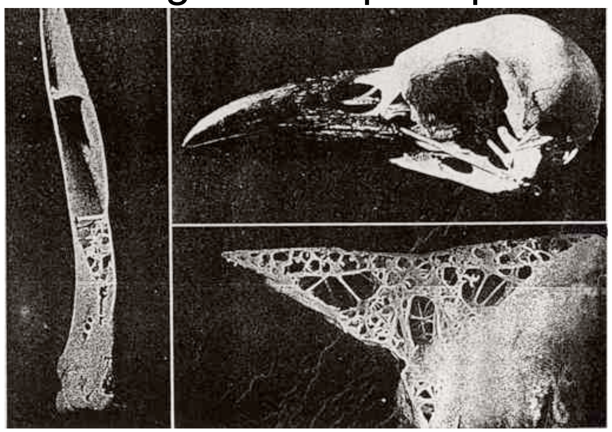
Diagram of the avian respiratory system to show the relation of lungs to the connecting air sacs in a bird's body.

ADAPTATIONS FOR FLIGHT

Several of birds' evolutionary adaptations for flight:

<u>Skeletal system</u>: avian skeleton is much lighter in relation to total body weight than a mammal of similar size. So in the frigatebird (1.5 meter wingspread) the skeleton weighs less than the weight of its feathers. <u>Hollow tubes</u> have a much greater strength than the solid rods of the same mass; the avian skeleton has taken advantage of this principle.

The humerus of a Golden Eagle, cut open to show its hollow interior.



The skull of a Common Crow which has been cross-sectioned between the eye sockets.

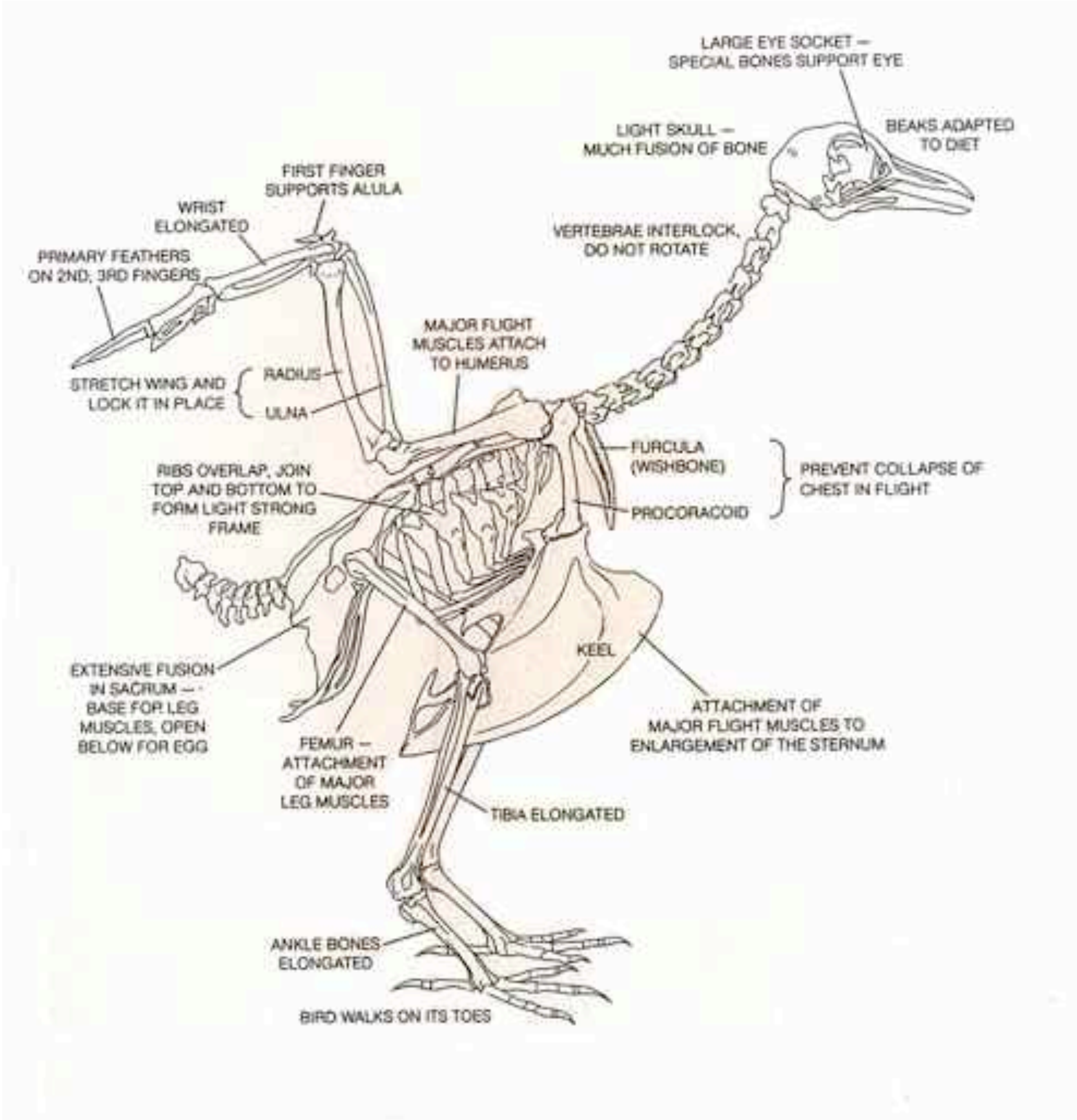
The above section magnified about three times. The network of bony braces provides rigidity with extreme lightness.

<u>Pectoral muscles</u> provide the motive force for flapping flight, so in a strong flying bird (pigeon or falcon), the breast muscles make up more than 30% of the body weight, whereas gliding and soaring species that flap less usually have reduced keels on their sterna and smaller pecs.

<u>Nervous system</u>: successful flight also demands a high degree of neuromuscular coordination and navigational ability. Birds have relatively large brains, comparable to those of rodents (much larger than lizards). The rather large avian forebrain and cerebellum are supplied with numerous association centers, esp. for coordination of muscle activity.

<u>Sensory systems:</u> birds rely mostly on visual information for flight, so the optic lobes and the eyes themselves are large. The sense of smell is not highly developed in most birds, on the other hand.

ADAPTATIONS FOR FLIGHT



The skeleton of a typical bird, the pigeon, showing some of the chief functions of its various parts.

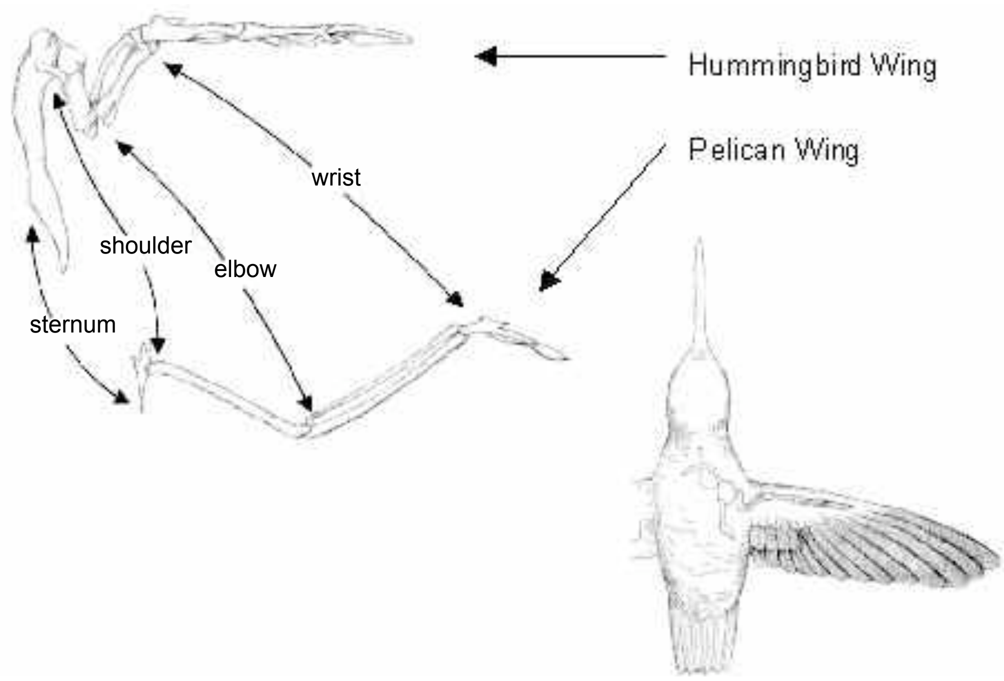
WING TYPES

The evolution of feathers and wings allowed the reptilian ancestors of birds to acquire flight. Wing structure and function are closely related, whether you are examining a bird or a plane. The fact that birds “flap” their wings makes it more difficult to study the aerodynamics of birds.

The habitat and lifestyle of each type of bird determines wing characteristics. For example, the proportions of the various segments of the wing vary from a power flier to a soaring bird.

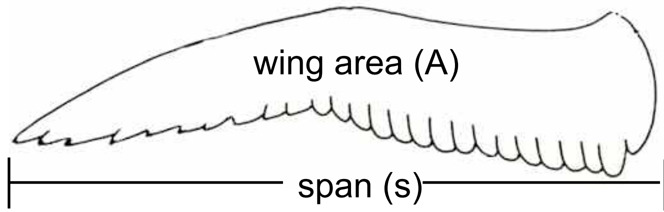
Hummingbirds, which have very fast, powerful wing beats that require maximum propulsive force from the primaries, have hand bones that are longer than the forearm and upper arm combined.

In contrast, a marine species like the pelican requires powered flight as well as gliding and soaring. The three segments of its wings are all about the same length.



WING TYPES

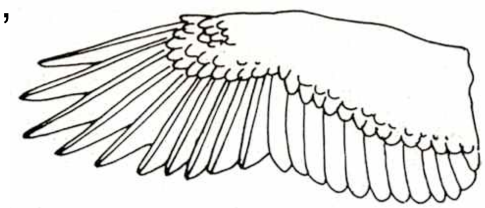
The birds' environment also influences the shape of their wings, and thus their aerodynamics. Birds that typically fly in open-country have long, pointed wings, whereas birds that fly in dense vegetation have short, rounded wings. This affects the aspect ratio of the wing, which can be calculated as the wing span squared divided by wing area: aspect ratio = s^2/A. Four basic types of wings are explained and illustrated below.



a) high aspect ratio wings - very long and narrow flat wings; no slots (i.e. spaces) in the (outer) primary feathers; found in birds that rely on high-speed, low-altitude dynamic (high wind) soaring (*albatross*, *shearwater*)

b) elliptical, or low aspect ratio wings - short rounded wings with a reduced tip; usually large number of slots in the outer primary feathers; found in birds that require fast takeoffs and rapid maneuvers in forested or shrubby habitats (*dove*, *woodpecker*, *grouse, quail, pheasant*)

c) slotted high lift wings - moderate aspect ratio (moderate length and breadth); broad, short wings; marked slotting in primaries, which increase lift and gliding ability; found in static soaring birds (seek out rising air masses) that carry heavy loads of captured prey (*vulture, hawk, owl, eagle, stork)*

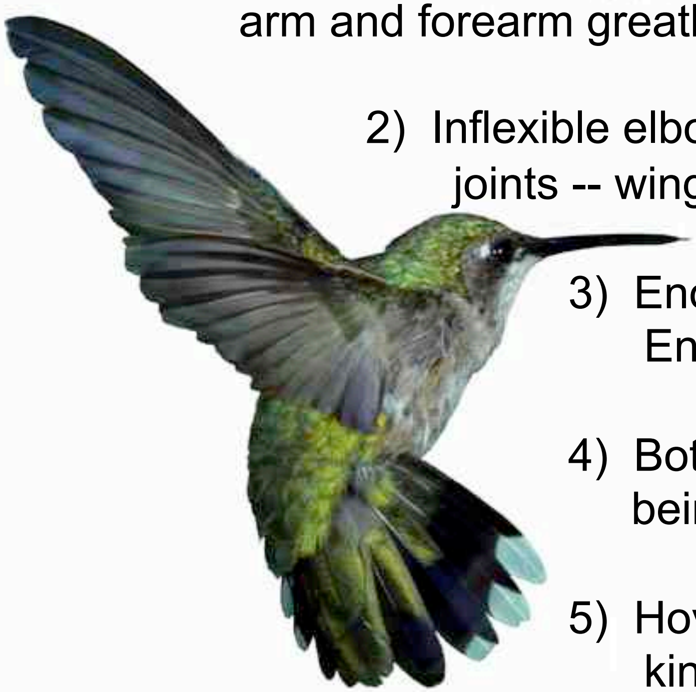


d) high speed wings - high aspect ratio with flat wings (relatively long and narrow), wings taper to a point and lack slotting (no spaces); found in birds that attack prey in flight, dive, or make long migrations (*falcon, loon, kestrel, loon, swallow)*

HUMMINGBIRD FLIGHT

Hummingbirds are amazing little birds. They typically are extremely small, weighing less than 3 grams, yet have a heart rate greater than 600 beats/minute and a remarkable flying ability. Hummingbirds are able to hover virtually motionless and can even fly backwards for short distances. They have very fast, powerful wing beats, requiring maximum propulsive force from the primaries, have hand bones that are longer than the forearm and upper arm combined, and only 6-7 secondaries in the inner wing. Numerous adaptations allow such a remarkable ability to fly. These include:

1) The skeleton of the wing is almost all hand bone, with the upper arm and forearm greatly reduced.



2) Inflexible elbow and wrist joints, very flexible shoulder joints -- wings function as a variable pitch propeller (helicopter)

3) Enormous breast muscles can account for 30% of body mass. Entire flight muscle mass is huge relative to body size.

4) Both wing elevator and depressor muscles are large due to lift being generated in both up and down motion.

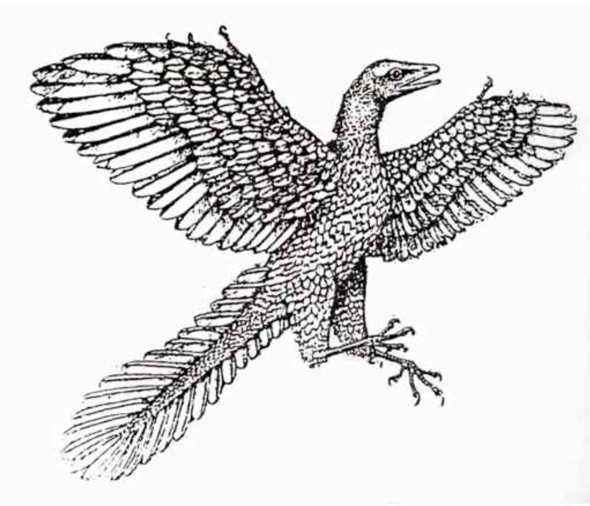
5) Hovering flight is very energetically expensive, no forward kinetic momentum can be used to oppose gravity. Requires the ability to obtain energetically rich food sources such as nectar.

The Archaeopteryx Story

The earliest known bird is represented by only six specimens on limestone slabs found in Bavaria, Germany. The quarry where they were discovered is part of the Solnhofen limestone formation, which is late Jurassic in age (152 million years old). The quarry operation is mainly for lithographic printing and building materials. Workmen often discover fossils while splitting the stone. Formed originally by marine deposits, fish and other sea life are most often discovered. However, many Pterodactyls, lizard-like reptiles, a tiny dinosaur and six fossil birds have been found throughout the years.

These earliest known birds are not considered to be on the main line of avian evolution, but on a specialized sideline.

The story began with the discovery of a single feather in 1861, proving birds existed during Jurassic times. Just a few months later, an entire skeleton was found, surprising scientists with a beak full of socketed teeth. It also had a long bony tail and three sharply clawed wing-fingers. If it had not come with feathers, it would have been identified as a small dinosaur!



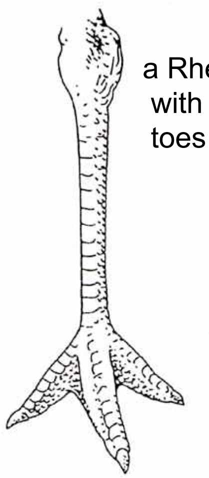
The first specimen found was purchased by the London Museum, which irritated the German people so much that when another one was discovered in 1877, it was purchased by a rich German industrialist and donated to the Humboldt University Museum in Berlin, where it resides today in a locked vault. Four others have been found, none with the beauty of the Berlin specimen. This robin-sized bird reclines in a natural position with open wings displaying feathers clearly on a 15x18” slab.

-- Prehistoric Products Co., Placerville, CA

BIRD FEET

Birds are constructed for essentially two modes of locomotion, flying with forelimbs and bipedal walking, running or swimming with their hindlimbs. Birds are bipedal but evolved from quadrapeds. Balance becomes an important issue with bipedal organisms. To help with balance, most birds have four toes, three of which point forward. The backward pointing toe is called the hallux.

a Secretary bird, with a typical avian foot



a Rhea foot, with three toes

Birds that scratch the ground in search of food often have heavy blunt claws, sometimes with a reduced number of toes.

Birds adapted to open, firm terrain have powerful legs with a reduced number of short toes. An ostrich, for example, has only two toes, similar to the hoofed mammals that occupy similar terrain.

an Ostrich foot, with only two toes

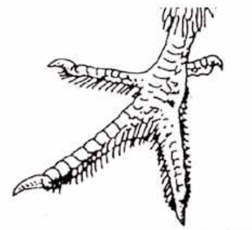
Some birds are very fast runners, such as road runners. Some of these fast runners have two forward-pointing and two backward-pointing toes. This condition is known as zygodactyly. Zygodactyly feet are also found in birds specialized for climbing, such as woodpeckers, cuckoos, and parrots.

a Roadrunner foot, with a zygodactyl foot

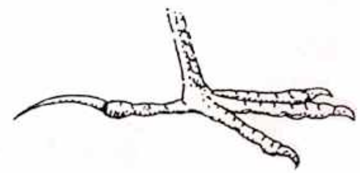
Some birds can barely walk, and instead hop. This is particularly noticeable in the perching birds, like sparrows and finches. Birds that spend more time on the ground tend to be walkers. These include larks, chickens, and jays.

BIRD FEET

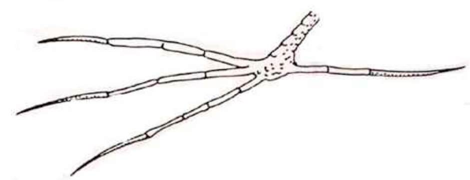
The feet of birds are strongly adapted to the behavior of the animal and the substrates of their habitat. Birds that walk on a soft substrate, such as marsh, sand or snow have special modifications to increase surface area. Note the elongation of the claw of the hallux is a frequent adaptation in sand and marsh.



Feet of a ruffed grouse and a ptarmigan (snow)



Foot of a lark

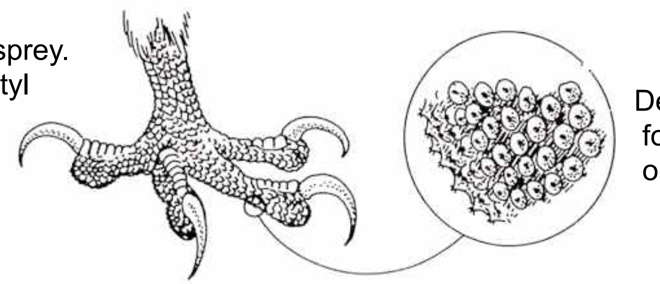


Foot of a jacaña (lily pads)

Osprey with fish in talons

Feet can be modified for catching and killing prey, like those of raptors. Feet of predators tend to be very large, powerful and equipped with long and sharp talons for holding and puncturing their prey.

Foot of a fish-catching osprey. It is a revesible zygodactyl foot.



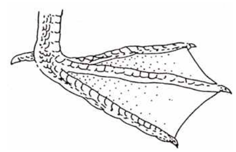
Detail of the spicules on foot pads for holding on to slippery fish.

BIRD FEET

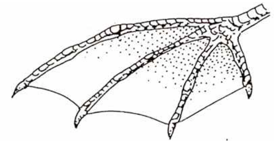
Feet can be also be modified for swimming. To increase "paddling" efficiency, the feet or either webbed or lobed.

Webbed feet

Webbing between the three forward toes is found in ducks, geese, flamingos, penguins, gulls and loons.



Webbed foot of a duck

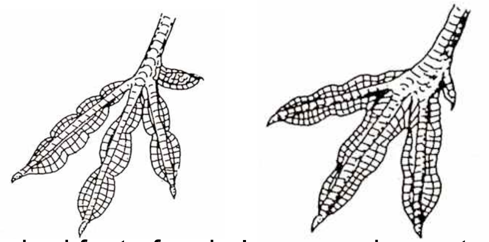


Webbed foot of a cormorant

Pelicans and cormorants (Pelecaniformes) have webbing between all 4 toes (totipalmate webbing).

Lobed feet

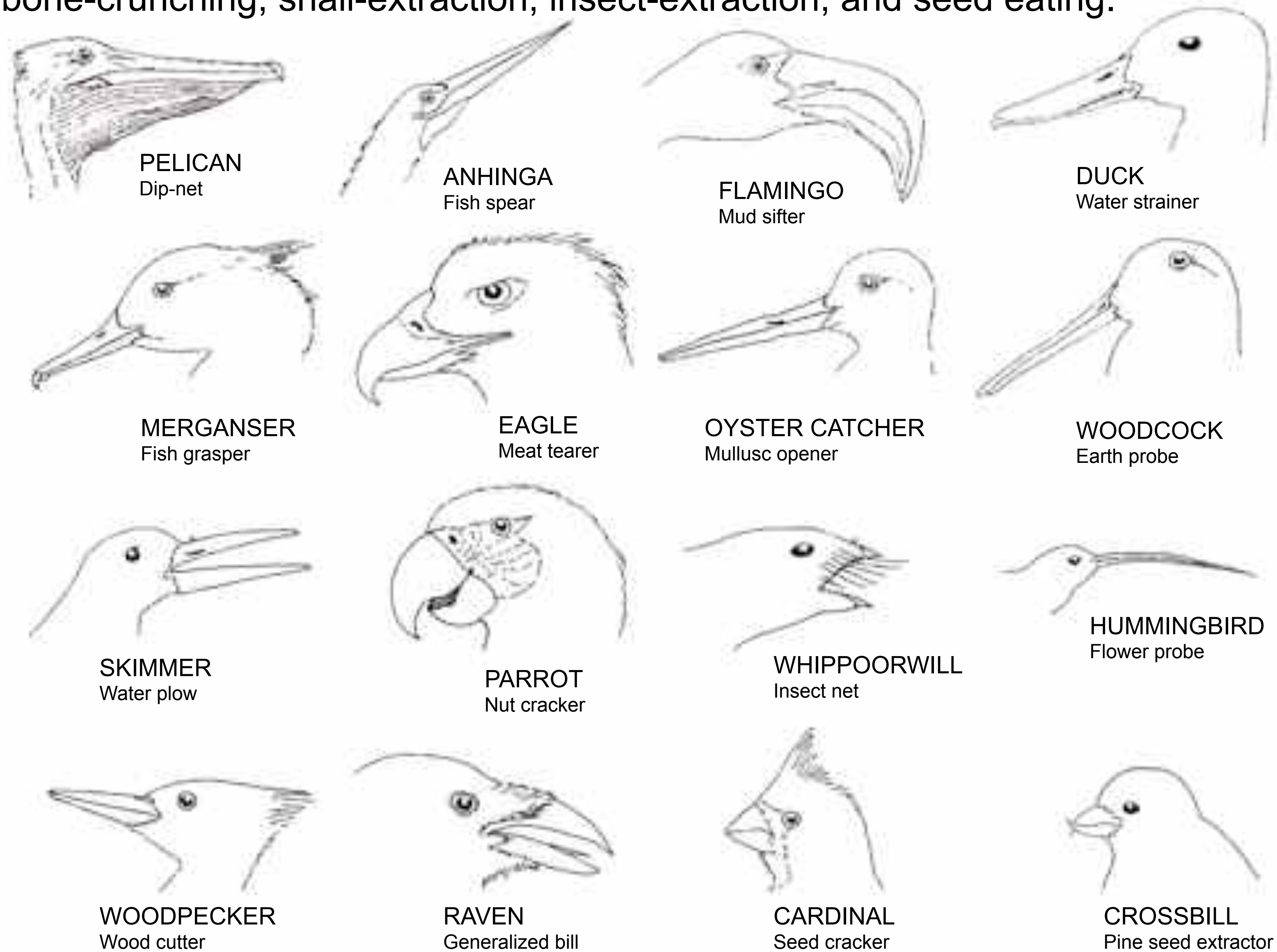
Lobe-footed swimmers, like coots and horned grebe, have flaps that fold back against the toe when the foot moves forward through the water to decreases drag. On the power stroke backwards, the lobes flare out to increase surface area.



Lobed feet of a phalarope and a coot

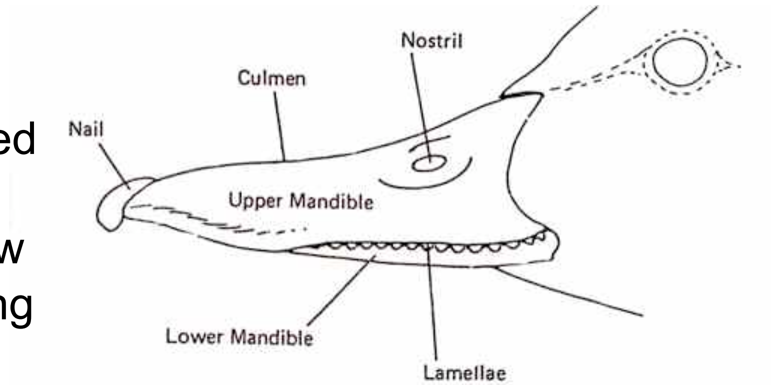
BILLS and BEAKS

Bird beaks are remarkably plastic, in an evolutionary sense, and have been modified in many different ways, depending on the feeding habits. Examine these examples of bills adapted to different kinds of feeding. These include: filter-feeding, nectar-feeding, shore-probing, neck-biting, bone-crunching, snail-extraction, insect-extraction, and seed eating.



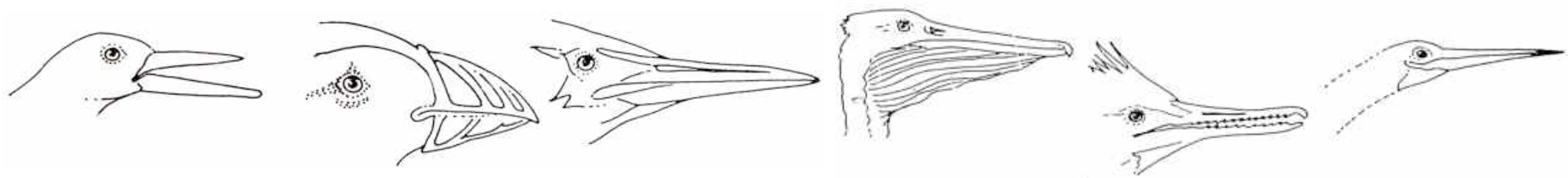
BILLS and BEAKS

Filter-feeding: This diagram of a duck bill clearly demonstrates some of the beak modifications associated with filtering food from water. The horny covering of the upper mandible extends down into lamellae, which allow filtering of the water. Avocets filter by sweeping their long bills in a semicircle across the water surface in front of them.



Snail-feeding: Note the adaptation of the beak for snail extraction in the snail kite.

Fish-feeding: There are several different strategies employed by birds for catching fish prey. Note some of the various types of adaptive modifications shown below.

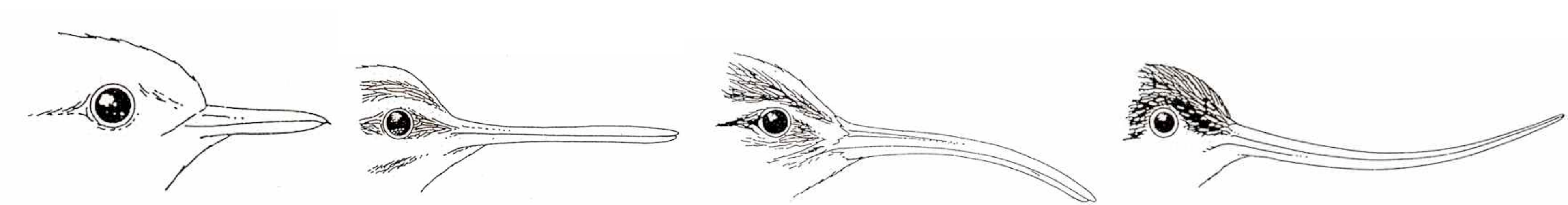


Skimmer (skimming) Puffin (grasping) Heron (grasping/spearing) Pelican (gulping) Merganser (grasping) Anhinga (spearing)

BILLS and BEAKS

Insect-gleaning: The bills of warblers and many other perching birds are made to rapidly peck at insects on leaves.

Shore-probing: You often see many different species of birds, with different-sized bills, along mudflats and sandy shores probing for invertebrate prey. It turns out that their bills not only reach different levels in the substrate but also work differently. Note the adaptation of the beak for probing in the sand and mud.

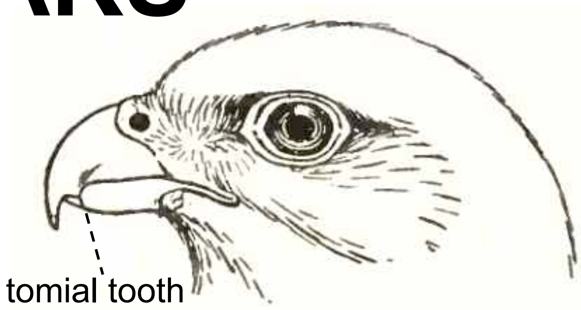


Plover Sandpiper Curlew Avocet




BILLS and BEAKS

Neck-biting: Falcons have a tomial tooth on each side of the upper bill with a notch in the lower mandible to match. This helps in disarticulating the cervical vertebra of the prey.

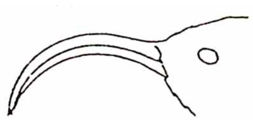


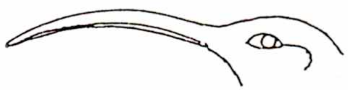
Bone-crunching: Note the bills of the owl and the hawk mounts, our local raptorial birds, and how well developed they are for cracking the bones of vertebrate prey (small birds, lizards, rodents).

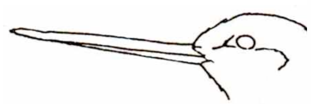

the bill of a Great Horned Owl

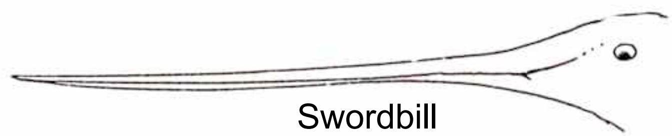
Nectar-feeding: Birds such as hummingbirds, sunbirds, honeyeaters, and honeycreepers are adapted for eating the nectar from flowers. These birds often have a long bill and a lengthened tongue. Below are some bill specializations of various types of hummingbirds that feed upon different flower types, along with the type of flower they prefer.

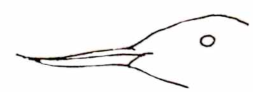

a Yellow Legged Honeycreeper


Sicklebill



Hermit



Lancebill



Swordbill



Awlbill


BIRD NESTS

The sexes play different roles in nest construction in different species. Six different labor allocation strategies are noted below.

1) Both sexes share nest construction fairly equally: kingfishers, woodpeckers, swallows
2) The female builds the nest, but both sexes gather nest materials: rooks
3) The female builds the nest, and the male gathers nest materials: doves and pigeons
4) The female does all of the work, both building and collecting: hummingbirds, manakins, red-eyed vireo
5) The male builds the nest, and the female gathers nest materials: frigatebird
6) The male does all of the work, both building and collecting: some shrikes, the Philippine weaverbird

Many numerous styles of nest building exist, only a few of which are displayed here. For most species, the beak and feet are the principal tools.

Some birds build no nests. These include tropical birds, auks, nightjars, and pratincoles.

A nighthawk incubating its eggs directly on the ground.

AMAZING BIRD NESTS

A nest of the colonial Social Weaver in sub-Saharan Africa. The underside of the nest has individual entrances.

Nests of Baya Weaverbirds of India. A male is working on the lower, half-built nest. When finished, their nests contain an enclosed lower chamber for the eggs and an upper chamber accessible from the outside only by a long, sleeve-like tube directed downward.

The enormous nest of a Mallee Fowl of Australia. This rare bird incubates its eggs in a large mound of earth and leaf litter, up to 35 feet across and 15 feet high! The male works tirelessly to keep the eggs at a constant 33˚C. When the hot summer sun blazes down, he adds a layer of sand or soil. When the mound composts more quickly,driving up the temperature, he removes some to expose the eggs to the air.

POLLUTION

Gyres are areas where oceanographic convergences and eddies cause debris fragments to accumulate naturally. In 2001, researchers studying plastic pollution in the Pacific Ocean discovered something shocking and outrageous: a floating mass of plastic junk stretching across an area of ocean the size of Texas. Rivers of soda and water bottles, spray can tops, candy wrappers, cigarette lighters, shopping bags, polypropylene fishing nets, buoys and unidentifiable, miscellaneous fragments collected in a huge rotating mass of plastic pollution. In samples taken from the gyre, the mass of plastic exceeded that of zooplankton (the dominant animal life in the area) by a factor of six. The floating particles are often mistaken as food by fish and marine birds and mammals, especially gulls. Being undigestible, the waste fills up their stomachs and they eventually starve to death.

Oil spills are another major source of pollution that kill marine life and destroys habitats. After a container ship ran into a support tower of the Oakland-San Francisco Bay Bridge in November 2007, 58,000 gallons of oil was released into our bay. More than 1,000 birds were brought to local officials for rescue and cleaning - but more than half of them died.

California gulls, characterized by greenish-yellow legs, a yellow bill with a red or black spot on the lower mandible, and black eyes, are scavengers of dead fish, garbage, and other waste products, and help control pollution of coastal waters beaches. However, they are also greatly affected by human pollution, oil spills or sludged-over harbors.

Spilled oil flows past Alcatraz Island in November 2007. The toxic pollution closed beaches and killed wildlife.