More than 200 million years ago, dinosaurs began rapidly diversifying in body size to fill new ecological niches after a major extinction event. Over a period of 50 million years, the theropod ancestors of birds continuously shrank in size. Being little and light meant they these bird ancestors could explore new food niches and escape predators by climbing trees, gliding and flying. Their small size, efficient insulation provided by feathers and the ability to fly may have helped birds survive the catastrophic event that led to the extinction of their dinosaur cousins.

In addition to the Zoo's bird collection, the Sculpture Learning Plaza has a California condor, a horned puffin, a hoatzin, and a kiwi.

Birds are a specialized type of vertebrate. They are best understood when you remember that they are adapted for flying. Their adaptations for flight have shaped their anatomy, behavior, and ecology. Some birds such as penguins, ostriches, and cassowaries do not fly. But even birds that don't fly have ancestors that did, so they share many of the same adaptations.

What makes a bird a bird? Most people think it's the wings, but bats and some insects have wings too! The answer is feathers.

Birds are the only living animals with feathers. At one time, feathers were the characteristic defining birds; more recently, fossils of dinosaurs with feathers have been found. The primary function of early dinosaur feathers seems to have been for insulation. Like the hair of mammals, the simple feathers of dinosaurs would have kept out cold, external temperatures and held in body heat.

Feather and flight evolution occurred at the same time. Gradually feathers became more complex and began to serve other functions, like flight, camouflage, and mating displays. Although feathers did not evolve from scales, scales, feathers and hair are differentiated from similar tissues in its developing embryo. In birds, feathers evolved and have replaced scales as the primary skin covering. Birds also retained scales, some more than others. Note: modern reptiles, birds, and mammals all evolved from a common ancestor, a scaled reptile.

Though various species of birds have some truly amazing physical adaptations, the general body structure of a bird is the same in every species. In addition to feathers, wings are one of the most defining characteristics of birds but wings aren't restricted to just birds. Even flightless birds have retained adapted wings that they use for courtship dances, threat displays or swimming. The shape and size of wings varies between species based on how the bird flies. All birds have beaks, tails and relatively large eyes that help meet the demands of avoiding collisions in flight or for capturing fast-moving or camouflaged prey.

What other animals have wings? Bats are mammals with wings and most insects have wings too.

Birds that maintain a more vertical stance tend to be predators. Examples are egrets, and hawks. Birds with a more horizontal posture tend to eat seeds, plants, and insects off the ground. Examples are jays and finches.

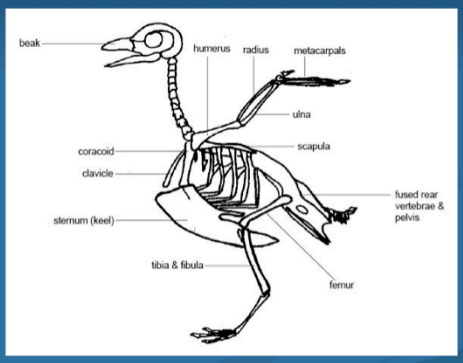
Birds' wings are modified forelimbs and they have two legs for locomotion; they are **bipedal**. Birds are **endothermic** and have fast metabolisms. To sustain their higher metabolism, endothermic animals typically require several times as much food as ectothermic animals. This gives birds the energy necessary for flight. One major advantage of high body temperatures is that activity is not constrained by the low ambient temperatures.

Another distinguishing characteristic of birds is that they lay eggs as do reptiles. While reptiles were the first to have eggs that could survive on land, birds gained an advantage when they developed eggs that had a **hard shell**. Bird eggs are stronger and can support the embryo inside through harsher conditions (i.e. like rolling out of a nest).

Bird bones are unique in that they are pneumatized (air pockets within the bones) to reduced weight and they have criss-crossing struts or trusses for structural strength. Birds that have lost their ability to fly have heavier bones than flighted birds but they are still comparatively lighter than a similar sized mammal bone. Ostriches and emus need the heavier bones to meet the demands of running. Penguins don't run on land, so why adapt heavier bones than flighted birds? Penguins need heavier bones to dive for food otherwise they would bob like corks near the surface.

Bones & Skeletal Structure

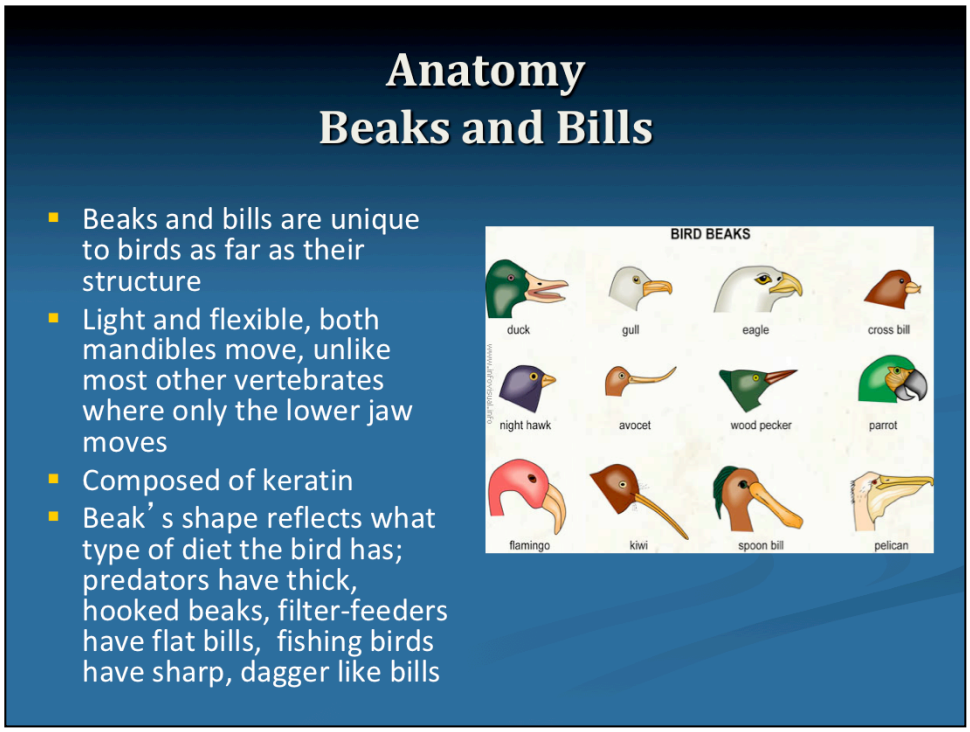
- Skeleton is light weight; it lacks heavy parts.
- Skeleton is strengthened or reinforced; there is a reduction in number of bones or they are fused to allow rigid, light frame.
- The keel-shaped sternum is where the powerful flight muscles attach.



Most major characteristics of birds can be directly related to their adaptations for flight; their skeleton is reduced in weight and strengthened; bones are reduced in number and weight; some bones are fused to increase skeletal strength.

The **keeled sternum** (breastbone) is where the powerful flight muscles attach to the body. Most non-flighted birds lack a sternum as they do not need such a large area for these same muscles. If you watch our Magellanic penguins in the water, they retained a keeled sternum because they "fly" through the water.

The ribs have boney extensions that go from rib to rib. These serve as attachment sites for the scapula muscles, and help to strengthen the rib cage overlapping with the rib behind them. They are also shown to have a role in respiration by increasing the effectiveness of muscles involved in inspiration. The "wishbone" (**furcula**), found only in birds, functions in strengthening the thoracic skeleton to withstand the rigors of flight and provides a flexible attachment site for the breast muscles.

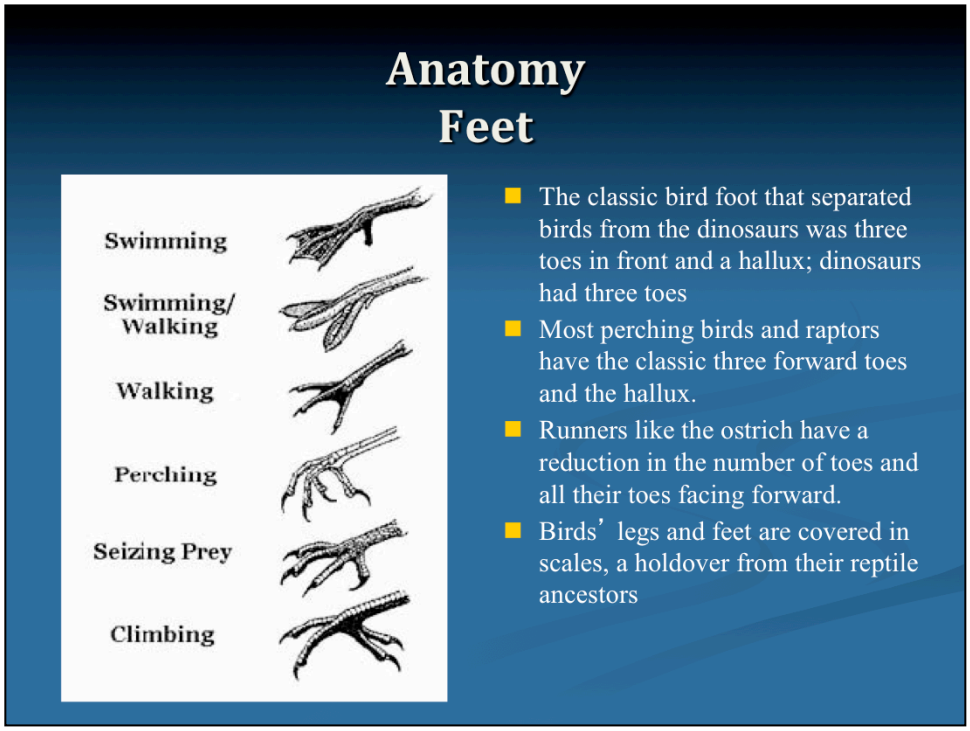


Beak's or bills? In Ornithology, beak is the general term applicable to all birds. In layman's terms, beak is always used for birds of prey and bill is used for humming-birds, pigeons, waders, and web-footed birds Birds beaks are an adaptation for flight as well as for foraging for food. Beaks are unique to birds and the shape of a bird's beak can tell you a lot about what it eats! Beaks are light and flexible and both mandibles move, unlike most other vertebrates where only the lower jaw moves. Beaks are covered in **keratin** which is light-weight, strong and flexible. **Note:** keratin is also a component of your hair and fingernails. Bird's lack teeth; this is another weight reduction strategy. Birds need a special digestive system to help break down their food.

The beak of a bird is an extension of its skull and is designed for feeding. Most birds rely entirely on their beaks to manipulate food. A duck has a wide, flattened bill used for eating aquatic plants and mosses. A hawk has a sharp, hooked beak used in tearing flesh from its prey or carrion. A hummingbird uses its long narrow bill to lap nectar from flowers and a sparrow has a small powerful beak used for picking berries and cracking seeds. A bird's beak can tell you a lot about not only the diet, but also their lifestyle.

The flamingo's bill is built for filter feeding. Flamingos feed with their heads down and their bills are adapted accordingly. They have big fleshy tongues to help push water through the bill's strainers/filters (**lamellae**). Why might feeding upside down be an advantage to the flamingo? As the flamingo swings its head back and forth, only the beak is getting wet, keeping its feathers dry.

Birds also have more neck (cervical) vertebrae than many other animals; most birds have 13 to 25 whereas most mammals have 7 cervical vertebrae. Their long necks act as extra hands to help them reach and gather food as well as to preen their feathers. Swans have the most vertebrae with 25; their long necks help them when foraging for food underwater. Flamingos have 19 cervical vertebrae; given the flamingo's long legs, it makes sense for it to have a long neck to better reach prey without having to wade too deeply into the water.



Although the classic bird foot that separated birds from the dinosaurs was three toes in front and a hallux behind, modern birds have a variety of foot and toe arrangements; dinosaurs had three toes and walked on these toes like birds. Like the bill, a bird's foot type can give an indication of its lifestyle. Bird's feet are covered in scales, and in some birds the scales go further up on the ankle. The scales are a holdover from their reptilian ancestors.

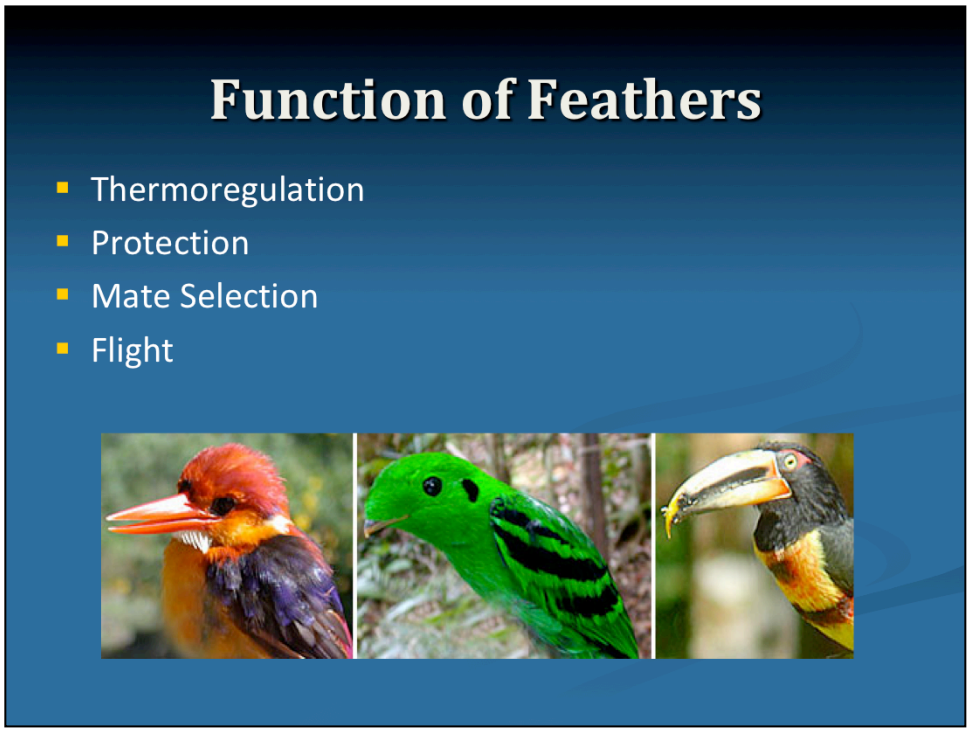
Modern birds have two to four toes on each foot. Most perching birds and raptors have the classic three forward toes and the rear hallux (**anisodactyl** foot).

Runners like the ostrich have all their toes facing forward. The ostrich is the only bird with two toes while the cassowary, rhea and emu all have three toes.

Woodpeckers and parrots have two toes forward and two rear facing (a **zygodactyl** foot). This arrangement is the second most common toe arrangement in perching birds. It is found in the osprey, most woodpeckers, and parrots. This arrangement is for clinging to and climbing through trees. The parrot can use its food like a hand and grip food.

Raptors (or **birds of prey**) have long, strong digits armed with heavy claws for catching, holding, and killing prey. **Raptorial** feet are found in owls, hawks, eagles, and falcons.

The palmate is the most common type of webbed foot and is found in ducks, geese, swans, gulls, and other aquatic birds. Webbing is useful for swimming and getting sure footing on wet ground. **Totipalmate** is having all four toes united by a web, as in the pelican & cormorant.

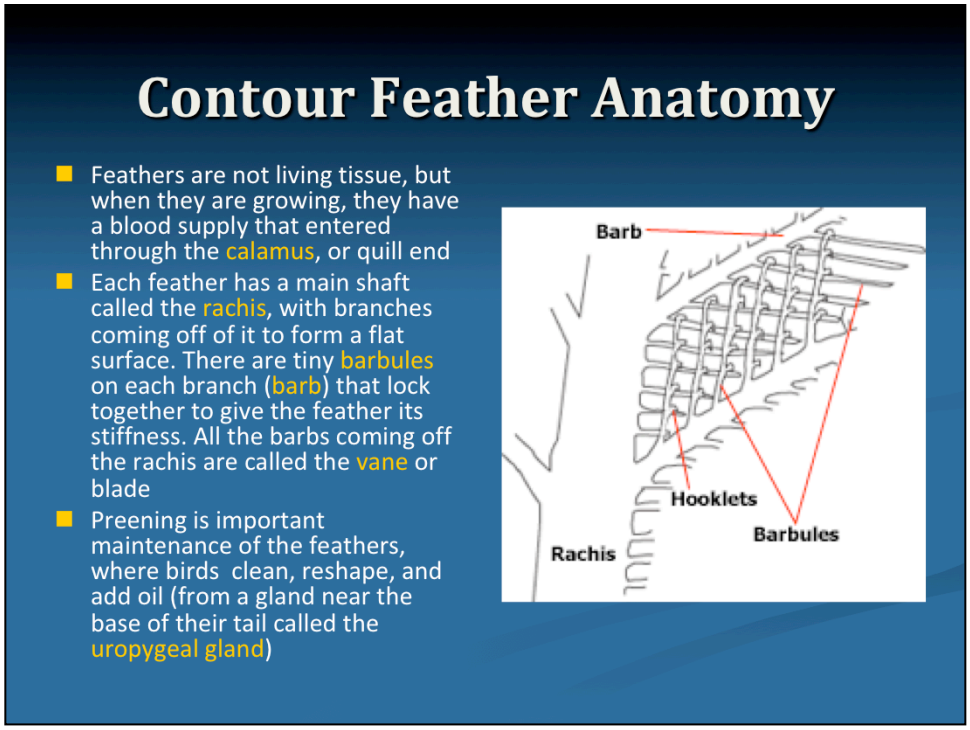


Feathers provide the capacity for flight but also provide thermal insulation, protection, waterproofing and are important in the incubation of their eggs. Feathers enhance a bird's ability to control its high body temperature by protecting them it the elements (wind, rain and sun) and thereby increasing the bird's activity and endurance levels. "As insulators, feathers are even more efficient than fur. Only a bird–the penguin–can survive on the Antarctic ice-cap in winter, the coldest place on earth." - David Attenborough

Feathers provide coloration, which is important in communication and camouflage. Feathers may also be ornamental for the purpose of courtship rituals and territorial display; in some species, the coloring and markings of the male can have a direct impact on how attractive he is to a female, and his mating success. The Zoo has many **sexual dimorphic** birds, where the male looks different from the female. The eclectus parrot is unusual in that both the male and the female display bright colors; there is extreme sexual dimorphism. The male is mostly green whereas the female is red. Why might this be the case? Both the male and female have multiple mating partners; they are both trying to attract the opposite sex.

Why are birds so much more colorful in the tropics than in the temperate areas? Outside of the tropics, bright colors would often make a bird too vulnerable to predators. Birds which fly in the trees in tropical areas are actually well-hidden because of their bright colors. Green feathers blend into the trees which are green all year-round in tropical climates. As the birds dart through the flashes of light in the forest, their colors actually make them harder to see.

Flighted birds have **asymmetrical** feathers that lead to powerful, graceful flight. Wings are curved convexly over the top edge, which creates a greater pressure underneath the wing and produces lift, just like an airplane. A bird's wing shape gives an indication of its lifestyle; fast flyers, like swifts and falcons, have long pointed wings. Soaring birds have broad, large wings to gain lift from thermal air pockets. Outside the ARC, you can have kids compare their arm size to some birds of prey wings. Ask them why long wings would be so helpful when the bird is looking for food. Would these long wings be helpful in a forested area? How do specialized feathers help the owl hunt? Owls are silent predators with a keen sense of hearing. Specialized feathers reduce noise of air rushing over the wing. With this adaptation, they are able to hear prey for which they are searching.



Feathers are not living tissue, but when they are growing, they have a blood supply that enters through the central shaft (calamus, or quill end). Feathers are composed of **keratin** (the same protein which makes up hair and fingernails) and light-reflecting pigments. In birds, keratin is a major component of feathers, bill and talons. Keratin is light-weight, strong and flexible.

The contour feathers cover most of the surface of the bird, providing a smooth appearance. The vane of the contour feather is the part of the feather that unzips and can be rezipped with preening. Individual barbs are hooked together, giving the feather its overall shape.

Preening is important maintenance of the feathers, where birds clean, reshape, and add oil from a gland near the base of their tail. However, over time, feathers suffer wear and tear as they are exposed to the elements. The quality of each feather slowly deteriorates and thus compromises their ability to provide insulation and the ability to fly. Therefore, feathers are shed in a seasonal molt that usually occurs once a year after breeding season. Although an adult bird will typically replace all of its feathers during a molt, the loss of feathers is staggered, often over several months, so the bird has enough feathers for flight and insulation. Some birds also have a partial molt in winter or spring.

In what type of habitat is the oil gland especially developed ? Those birds living in water environments have prominent oil glands to maintain their waterproof effect. The water just beads off the bird's back. Examples include our pelicans and penguins and the ducks in the tropical building. Oil glands are absent in doves, pigeons, Amazon parrots and Hyacinth macaws. Instead, these birds have specialized feathers that disintegrate into powder down, which serves the same purpose as preen oil. Birds that produce powder down are less likely to bathe or immerse themselves in water and do not require the stronger waterproofing that preen oil provides.

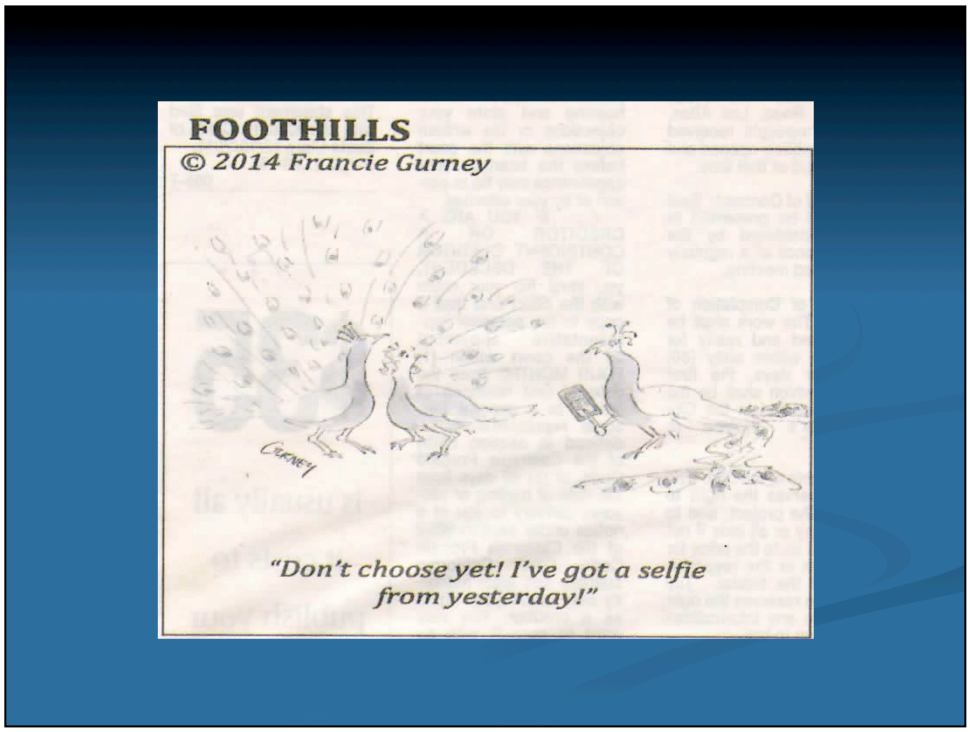
When a penguin goes into premolt, it puts on a lot of weight before it has a catastrophic molt and looses all of its feathers. Why does the bird put on weight for the molt? Since a penguin loses all of its feathers at once, the penguin would not be able to maintain its body temperature in the cold water and so the extra body weight, gets the bird through until the new feathers grow in.

Birds feathers are laid down in tracts to reduce weight, enabling them to be light enough to fly; there are portions of the bird's skin with no feathers. Penguins are unusual in that their feathers are not arranged in tracts. Why would having feathers evenly distributed be a good adaptation for the penguin? Penguins use their feathers to stay warm in extreme conditions. Feathers trap air to provide warmth and are very closely packed together in a penguin. How do the body feathers of penguins differ from the body feathers of flighted birds? All penguins have a high density of feathers with the Magellenic having around 70 feathers per square inch of skin. Their feathers are short and stiff and the shafts are flattened to enable the close packing of feathers. The shafts of flighted birds are rounded.

The feathers we first see when we look at birds are usually the **contour feathers**. These feathers form the outline of the bird and include body, tail, and large wing feathers. A typical flight feather consists of a stiff, central shaft that runs the entire length of feather, with vanes extending to each side. The leading edge of the feather during flight is the narrower vane. The flight feathers are **asymmetrical**, with the barbs on the front much shorter than on the trailing edge. The tail feathers are fairly uniform.

All birds have **down feathers**, which are small, fluffy and soft and they lack barbules. Down feathers are under the contour feathers and act as insulation by trapping air. An interesting form of down feathers is called **powder down**. These feathers are about the same size as down feathers but grow continuously and disintegrate at their tips into a fine keratin powder. Some birds use this powder to protect their feathers from parasites and feather-degrading bacteria. Not all birds have powder down feathers but many birds in which the preen gland is absent have them to help maintain their feathers. Powder down feathers are found in some parrots and cockatoos, herons and tinamous.

Other types of feathers include the seimiplumes, filoplumes and bristles but we will not be discussing them in any detail.



Note: During the springtime, watch the peacock as he turns his back to the peahen, displays his tail and then turns around to catch her attention. Since the peacocks elaborate tail is used for mate selection, in the fall and winter months notice that the peacock has shed most of his tail feathers as breeding season is over.

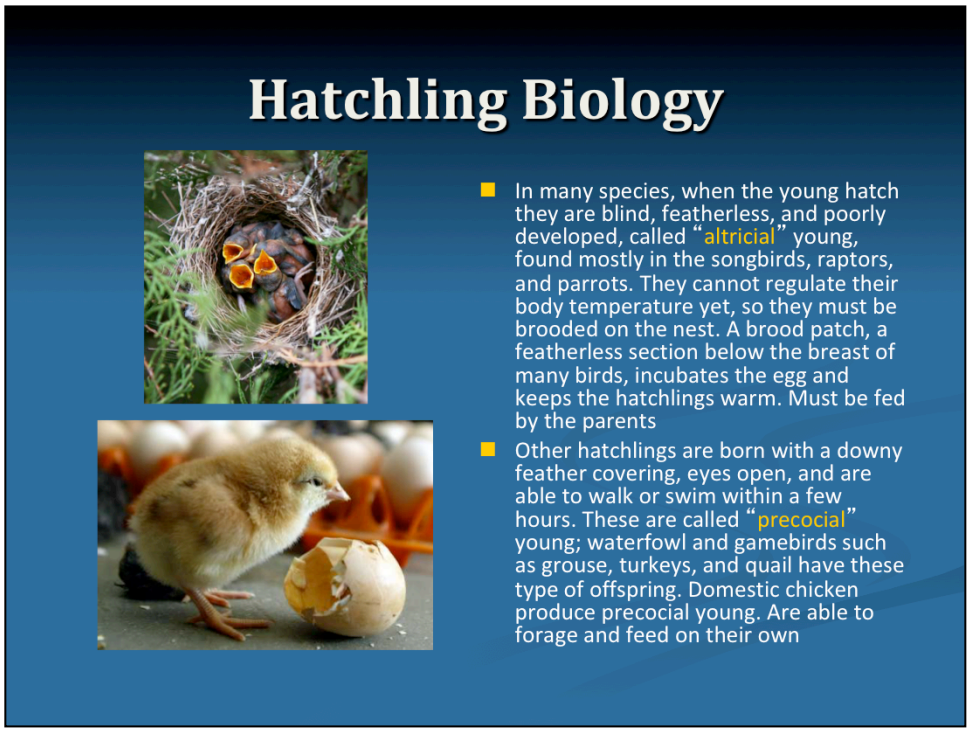
All birds lay amniotic eggs. The eggs have a hard shell and require incubation by using body heat to keep the eggs at an optimal temperature. Egg shape, size and markings, number of eggs laid, incubation time and condition of the chicks at hatching vary for each species. (see photo above)

Most birds lay their eggs in a nest that they construct from various materials such as wood, mud, grass, feathers, moss, or even spider silk. Nest structure and shape is species specific. Color to the hard, calcium carbonate egg is added as it moves through the genital tract. The color of the egg is also species specific. The coloring serves as camouflage as bird eggs serve as food for such animals as foxes, raccoons, and snakes.

Nurturing the growth of the embryos in the eggs and of the young after they hatch requires dedicated parental care. The parent who provides the care is species specific and can be done by one or both of the parents.

Look at an ostrich egg. Why is it much thicker than a chicken egg? Why is their shape so different? In a recent study published in *Science*, it was found that egg shape correlated with a bird's wing shape and their flying ability; the stronger fliers had long or pointy eggs.

Note: Because the large flightless birds are quite heavy, the shells of their eggs must be strong enough to support the weight of a brooding female. (a 200 lb. person can stand on an ostrich egg without breaking it)

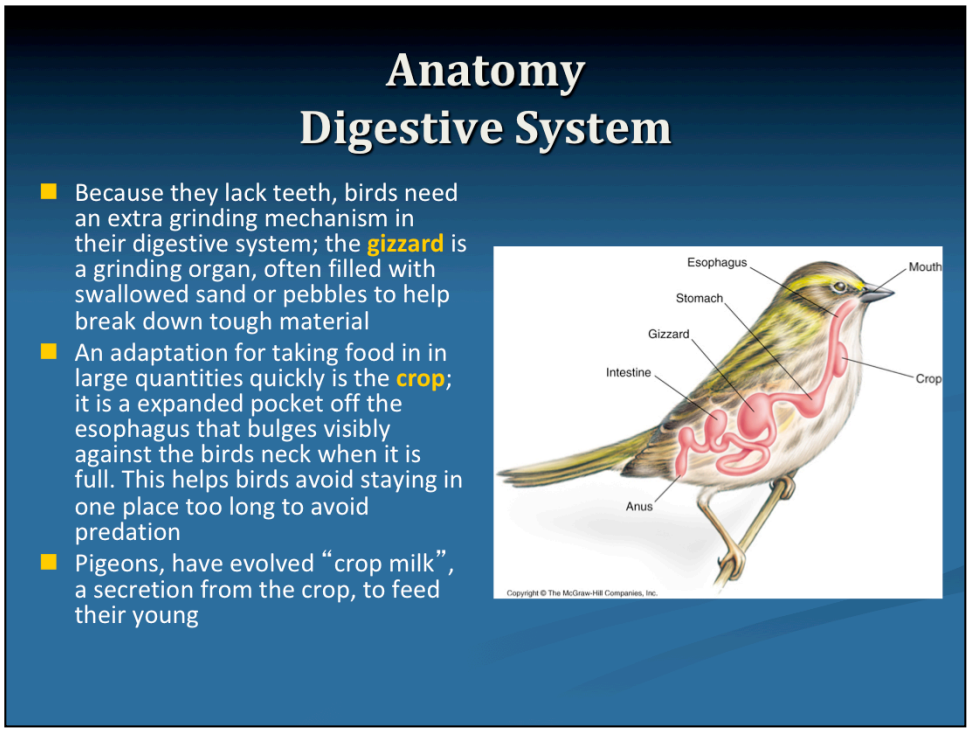


Altricial young are found mostly in the songbirds, raptors, and parrots. They cannot regulate their body temperature yet, so they must be brooded on the nest. The parent bird broods their young, keeping them warm by spreading the feathers out, umbrella-like, so the young can maintain contact with the skin of the adult through a **brood patch**, a featherless section below the breast of many birds. This brood patch helps incubates the egg and later, keeps the hatchlings warm. Altricial chicks must be fed by their parents.

Precocial young are able to walk or swim within a few hours. This type of offspring is found in waterfowl and gamebirds such as grouse, turkeys, quail and domestic chickens. Some precocial chicks are able to forage and feed on their own shortly after hatching.

Which is better, precocial or altricial development? A precocial chick can keep its body reasonably warm in the absence of heat from an incubating parent. Precocial chicks must be able to fend for themselves to some degree. However, the time before fledging takes a long time. That is a long time to avoid predators without the benefit of flying. Altricial chicks develop quite rapidly and the time before fledging is much less. Parents of altricial chicks have to work much harder but for shorter periods of time. Having precocial or altricial chicks is species specific and is an adaptation that works for the lifestyle of that species.

Note: birds that nest on the ground tend to produce precocial chicks. Birds that nest in trees or off the ground tend to produce altricial chicks.



Birds have physical digestive adaptations that help it consume food that is harder to digest such as insects, seeds and other plant material. Bird's don't have teeth (a weight reduction strategy), so they need an extra grinding mechanism in their digestive system. Birds evolved a two-chambered stomach; the first chamber has gastric juices and softens the food before heading into the gizzard; the **gizzard** is a thick-walled, muscular pouch in the lower stomach of birds that grinds food. Some birds often swallows sand or pebbles to assist the break down of cellulose in the plant material.

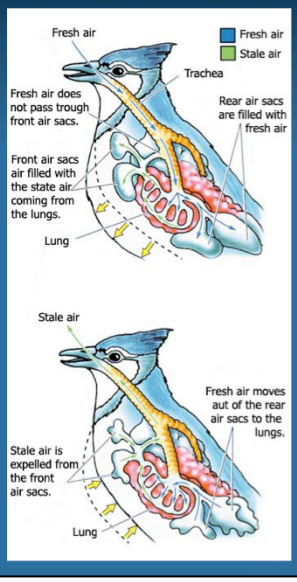
For many of the carnivorous birds, the gizzard is also a safety stop to prevent sharp bones and indigestible items from passing further. These birds, such as owls, then regurgitate a pellet including undigested bone, fur, and teeth.

In some birds, the esophagus has a large storage chamber or swelling called the **crop**. This is an adaptation for taking food in in large quantities quickly; it functions as a temporary storage area for excess food that can be digested later, reducing the time a bird is vulnerable to predation. The crops tend to be largest in birds that eat larger seeds.

Pigeons, have evolved "**crop milk**", a secretion from the crop, to feed their young. Young flamingos also feed on crop milk that is regurgitated by the parents and fed to their young as well as pigeons and emperor penguins.

The nitrogenous waste product of birds, **uric acid** requires less water than the excretion of urine by mammals. This is a weight reduction strategy and aids in flight. Uric acid eliminates 2x more nitrogenous waste than urea. Waste is excreted as guano; the white pasty material is urine mixed with fecal material. In the incubating eggs, the excretory products remain within the shell; they are crystalized from solution and stored harmlessly from the developing chick.

Anatomy
Respiratory System

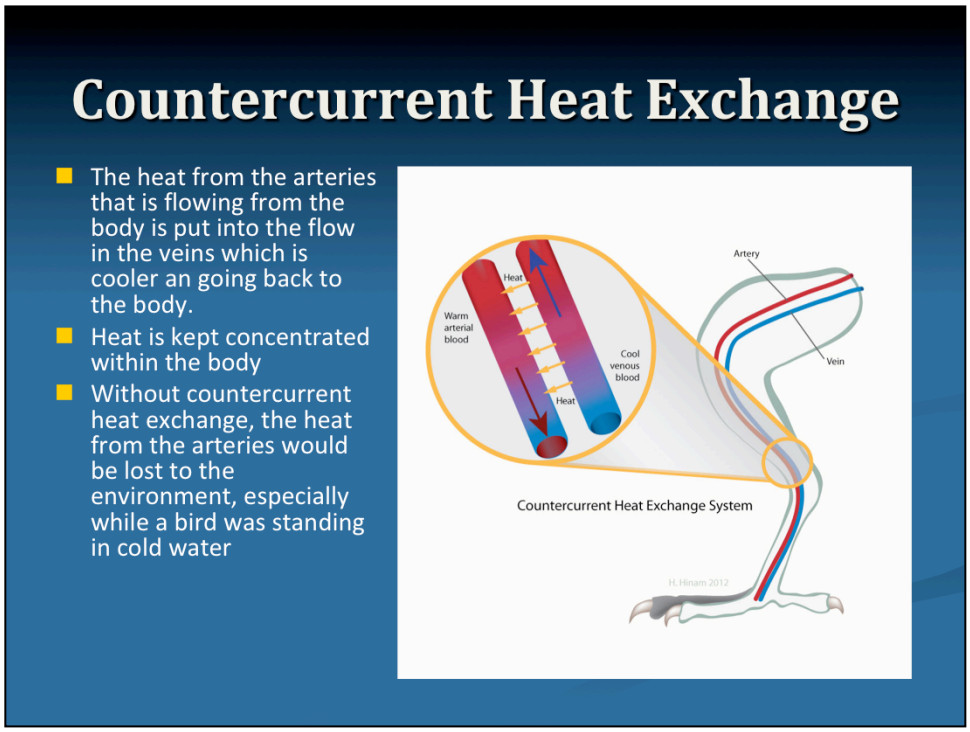


- Need an efficient system to extract oxygen from air at high altitudes that has little
- Lungs are fairly small but are connected to a system of nine air sacs, usually paired, one single, which act by negative pressure to move air to the lungs
- Air flows one way, not in and out like the mammals; takes two cycles of breathing in and out to get through the entire system
- Also have a large heart that pumps at a relatively high rate to move oxygen quickly around the body

Birds need an efficient respiratory system to extract oxygen from air at high altitudes, which has less oxygen. A highly efficient respiratory system with a four-chambered heart supplies the oxygen necessary for powered flight. A bird's large heart pumps at a relatively high rate to move oxygen quickly around the body.

Respiration is a one way system where air goes in and does not mix with the deoxygenated blood as it does in humans. Bird lungs are fairly small but are connected to a system of nine air sacs, which help move air to the lungs.

Inspired air passes first through the posterior air sacs, then into the lungs and finally through the anterior air sacs before leaving the bird. The air sacs act as a bellows, pushing a unidirectional flow of air through the lungs where the gas exchange of oxygen occurs. A bird needs two full respiratory cycles (inhalation & exhalation) to move air through its complete path. By transferring more air and air higher in oxygen content during each breath, birds achieve a more efficient rate of gas exchange than mammals do.



Along with feathers to keep them warm and insulated from cool temperatures, birds have other ways of maintaining their high body temperatures. For example, many wading birds have a special circulatory adaptation, a **countercurrent heat exchange** in their legs, which is an arrangement of blood vessels that allows peripheral cooling particularly of appendages and at the same time maintains an adequate blood supply without excessive heat loss; it enables arteries and veins flowing in opposite directions to exchange their heat content without mixing. An example of countercurrent heat exchange occurs in the feet of penguins, in which heat from blood in the arteries supplying the feet is transferred to blood returning to the body's core in veins that lie close to these arteries. This helps to maintain the core temperature in freezing conditions. What other birds might have this heat exchange system? Flamingos & ducks who spend a lot of time in the water, also have this system.

This concept of countercurrent heat exchange is also seen in mammals especially in extreme conditions. Desert animals use this in their respiratory system for management of their body temperature and water. As warm air has a higher capacity to carry water, breathing out warm air can cause substantial water loss to the animal. The countercurrent heat exchange occurs in the nasal **turbinate bones** (delicate bones inside the nose) Air can be cooled before it leaves the body and water conserved.

Birds have highly developed neural systems and acute senses. Most birds have excellent hearing; relying on their hearing to find mates and detect danger. Through songs and calls, they communicate with others. Their ears are located just below and in back of their eyes. They have no external pinnae, like mammals, but the ear openings are covered by specialized feathers to allow efficient sound transmission and protect against turbulence in flight. Owls have offset ear openings to be able to detect direction of the sound better. They are able to detect sounds in the leaf litter or sounds deep under the snow.

Predators like eagles have eyes that point forward, allowing for superb depth perception, and giving them an advantage when hunting. Prey animals have eyes placed on the sides of their head, giving them a much larger range of vision and allowing them to see a predator sneaking up from behind.

The vision of birds is their keenest sense and is essential for safe flight; bird eyes are the largest relative to their body size in the animal kingdom. To protect their eyes, birds have a lower and upper eyelid similar to mammals, but they also have a third eyelid called the **nictitating membrane**. The nictitating membrane serves the main role of lubricating and cleaning the cornea of debris. This clear membrane also protects the open eye from insects and debris while flying. Which other animals have a nictitating membrane? What type of habitats do these animals live in?

Bird eyes have almost no range of movement in their sockets; they compensate in some cases by having a greater range of neck rotation (i.e. owls) and in other cases by different eye placement and shape.

Unlike most mammals, birds have a poorly developed sense of smell. Most scientists think only turkey vultures (New World vulture), kiwis, albatrosses and a few other species use their sense of smell (as well as other senses) to find food. Old world vultures rely on their eyesight to find food not their sense of smell.

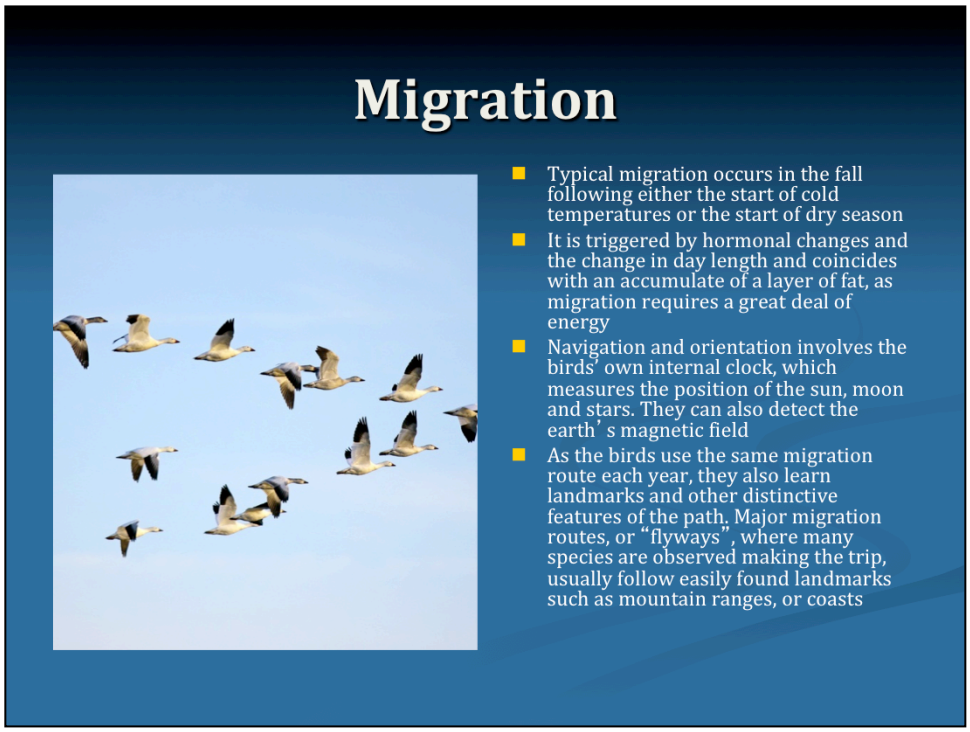
Birds are visual and typically see color if they are colorful themselves, as bright colors are for mate attraction only. Birds can see a wider range of wavelengths than humans, including many species that can see ultraviolet light (UV). Vision is also important for navigation and for finding food, especially in the raptors.

The passerines or songbirds are known for their songs produced by the bird's voicebox. Some birds do not have a voicebox and clatter their bills such as the stork. Birds can vary both the intensity (loudness) and frequency (pitch) of sounds with their syrinx. The attributes of song that characterize individual species appear to result mostly from differences in the learning process rather than from differences in the structure of the vocal apparatus.

Songs allow the bird to "speak" ; songs are perfect for communicating over long distances or among the trees where it is hard to see other birds. Calls are used for a variety of purposes, including mate attraction, evaluation of potential mates, bond formation, the claiming and maintenance of territories, the identification of other individuals (such as when parents look for chicks in colonies or when mates reunite at the start of breeding season), and the warning of other birds of potential predators, sometimes with specific information about the nature of the threat. Although it is generally the male that sings to attract mates or defend territories, in some species the female joins in too.

Colonial birds, like the Chilean flamingo and the Magellenic penguin have voices which differ greatly from one individual to another. When the chick has hatched, the parents recognize its call and are able to find their chick in a large group.

The intelligence of birds has been the focus of new research. Historically, birds have gotten a bum rap as a "bird brain" meaning someone was stupid, foolish or scatterbrained, but findings now show that some birds show remarkable forms of intelligence. Some birds, such as blue jays, green jays and woodpeckers, store seeds in the fall and at a later date are able to find them, which is critical for their survival as food becomes scarcer. Burrowing owls use dung as a decoy. They scatter clumps of animal feces near their nest and wait for the dung beetle arrive toward their trap. The palm cockatoo will use a stick as a drumstick to thrum a hollow tree for territorial display or to attract a female. The crow has even shown problem-solving skills by using traffic for cracking nuts.



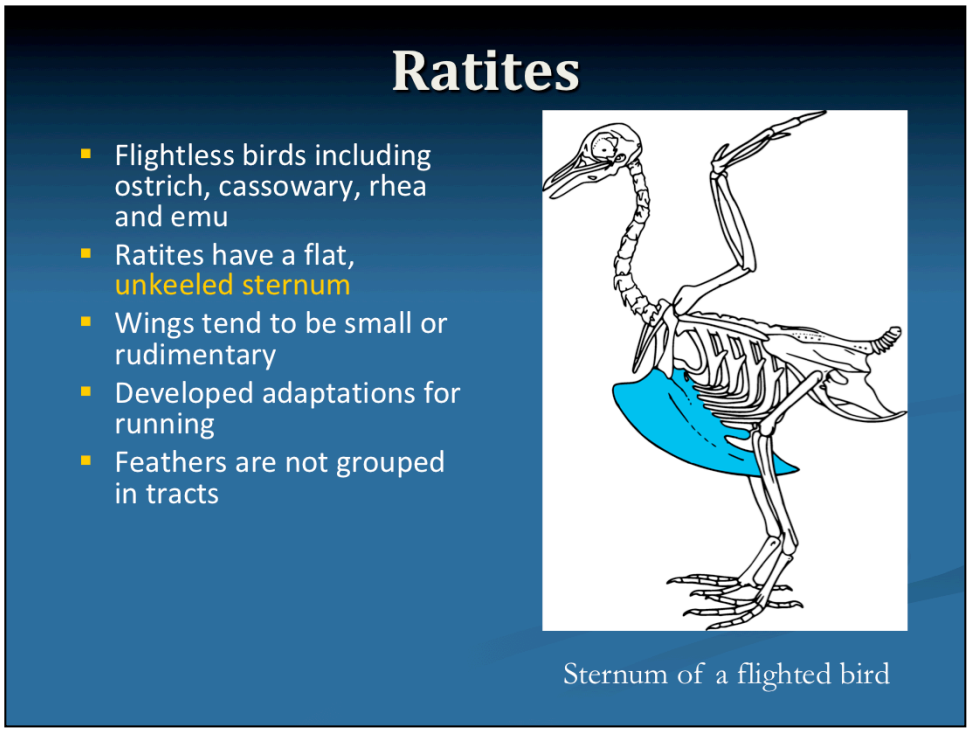
Many birds undertake seasonal migrations of thousands of miles including songbirds and waterfowl; this is a type of behavioral adaptation. Migration is the regular seasonal movement made in response to changes in food availability, habitat, or weather. Migration increases the amount of space available for breeding and reduces aggressive territorial behavior. It also takes advantage of the abundant food supply during the summer months and allows birds to avoid climatic extremes.

Migration is triggered by hormonal changes and the change in day length. Birds accumulate a layer of fat just before the migration period, as migration requires a great deal of energy Typical migration in the northern hemisphere occurs in fall from north to south, and in spring back north where the days are longer and food plentiful.

Navigation and orientation involves the birds' own internal clock, which measures the position of the sun, moon and stars. They can also detect the earth's magnetic field. Birds can navigate by using patterns of Earth's magnetism and celestial cues. This is especially important when migrating for the winter months.

As the birds use the same migration route each year, they also learn landmarks and other distinctive features of the path. Major migration routes, or "flyways", where many species are observed making the trip, usually follow easily found landmarks such as mountain ranges, or coasts. The San Francisco Bay is a major Pacific Flyway.

How can a behavioral trait like migration lead to differences in a bird's physical appearance and eventually result in speciation? When different populations of a species follow different migratory paths, it can open the door to creating a new species as they have different selection pressures.



Ratites are non-flying birds such as the ostrich, cassowary, emu, or rhea. Ratites have a flat, unkeeled sternum. A keel provides sites for muscle attachment, thereby providing adequate leverage for flight. Ratites lack this strong anchor for their wing muscles and tend to have have small or rudimentary wings with under-developed breast muscles.

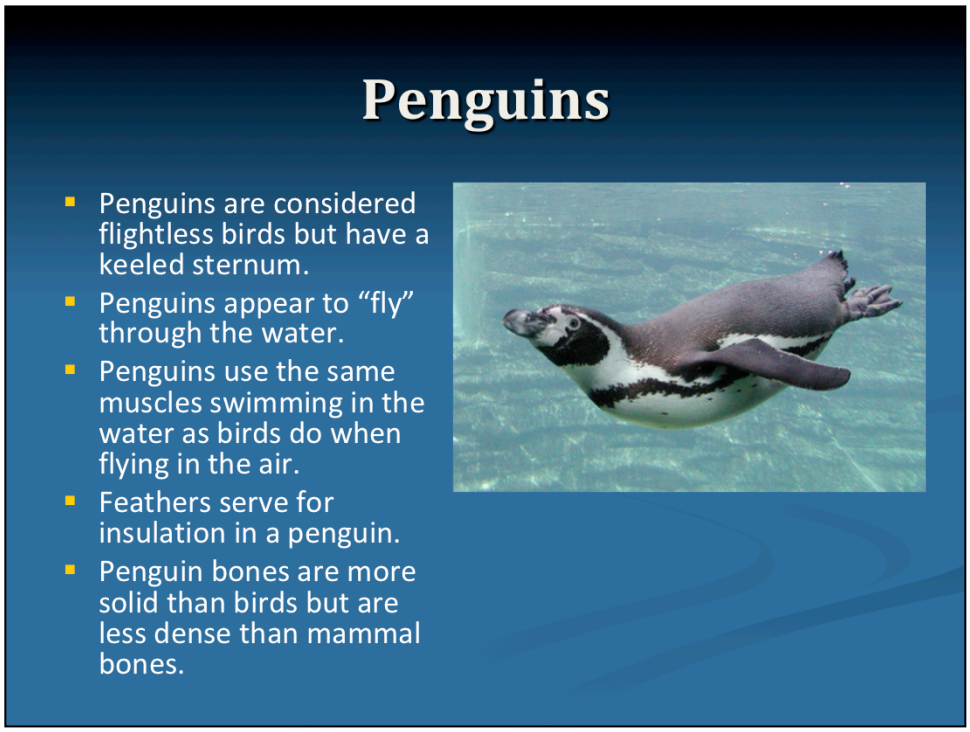
In general, ratites share many physical characteristics. Their feathers lack barbs and have no feather vanes, which means they do not have to oil them, hence they lack a preen gland. Their feathers are also evenly distributed across their body and are not grouped in distinct tracts; ratite feathers are for thermal regulation and display and weight is not an issue with non-flying birds. Notice the feathers on an ostrich, rhea, emu and cassowary. Their feathers hang loosely rather than locking, providing a very fluffy, downy appearance.

Without flight to flea danger, ratites have other adaptations of defense. Ratites have relatively stronger legs for running. Ratites tend to have a reduced number of toes; ostriches are the only bird with two toes, while the cassowary, rhea, and the emu have three. Cassowaries have developed long inner toenails, used defensively. (kiwis have four toes)

Ratites evolved features to protect their young. The thickness of their egg shells tends to be greater than flighted birds. Their young are hatched more developed than most and they can run or walk soon thereafter; they are **precocial**. Most ratites have communal nests, where they share the incubating duties with others. Ostriches are the only ratites where the female incubates; they share the duties, with the males incubating at night. With cassowaries and emus, males incubate the eggs and rear the chicks with no obvious contribution from females. Male rheas are responsible for building nests and incubating.

Recent studies have shown that tinamous are closely related to the ratites and are among the most ancient of birds. Although now considered among the ratites, tinamous have a keeled breastbone and can fly short distances on their short, rounded wings. Nonetheless, they spend most of their time on the ground, where strong legs help them get around and find food.

Penguins are also non-flighted birds but are not ratites; their sternum is keeled. Penguins are unable to fly in the air but their wing structures are evolved for swimming and “flying” in the water. Most birds have air-filled bones, making them lighter for flying. Penguins, however, have solid bones, making them heavier and making it easier to dive underwater for food. Their feathers are small and densely packed together for insulating against the cold water.



Penguins have a streamline body that helps reduce drag in the water and even though they are flightless bird they still have a keeled breastbone which is the sight of muscle attachment for the major muscles of flight. In penguins, these muscles are well developed. The motion of their flattened flipper-like wings resembles that of flying birds, giving penguins the appearance of flying through water.

Feathers in a penguin are symmetrical and overlap but function in thermoregulation and not in the ability to fly. Feathers are not arranged in tracts, as in other birds, but instead are evenly packed over their surface. Around 70 feathers per square inch cover Magellenic penguin bodies, keeping out the cold ocean water temperatures. The feathers are short and stiff relative to other birds, comprised of an outer vane region and a 'downy' inner 'after-feather’.

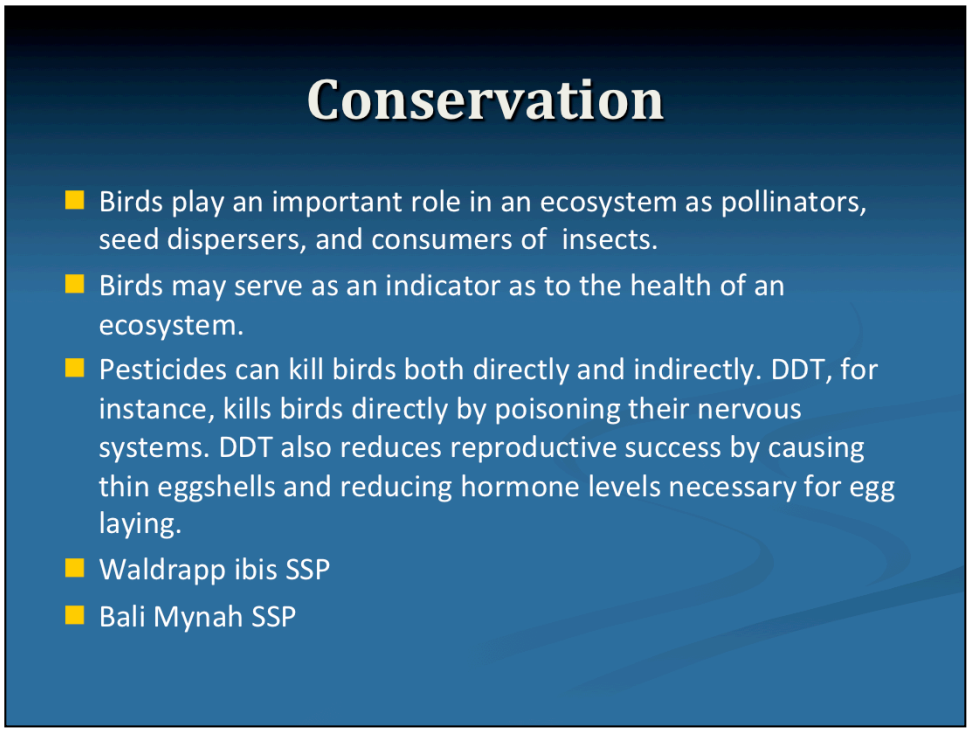
Penguins have solid, dense bones compared to other birds and are between a flightless and flighted bird in weight. This helps them overcome buoyancy in the water.

The word 'raptor' comes from the Latin word, "rapere", which means to seize or take by force. **Raptors** are considered birds of prey, who hunt and feed on other animals. These birds are characterized by keen vision that allows them to detect prey during flight and powerful, curved talons for capturing prey and hooked beaks for tearing apart meat from a carcass. This includes hawks, falcons, eagles and owls.

Males tend to be a third smaller than females. There are various theories but the prevailing is that raptors are aggressive because they kill active prey. With the formidable beak and talons, the male could pose a threat to the physical well-being of the female during mating. The size difference may have also been influenced by the female spending more time incubating and caring for the young and thus defending her nest. The male thus spends more time foraging and the smaller size makes him more agile in pursing prey.

Raptors cast regularly, which means they bring up the indigestible pieces of a meal. The casting is a round or oblong wad of feathers, fur, and bones which are left after the nutritious parts of a meal are digested.

Note: Turkey vultures really aren't birds of prey, because they are scavengers and therefore do not use their feet to hunt; turkey vultures are grouped in with birds of prey, but are more closely related to herons and storks.



Understanding the natural history of the species breeding and feeding needs is important for its conservation. Birds are important for maintaining healthy ecosystems so it is vital that they are protected and conserved; birds are consumers of insects, pollinators of flowers and seed dispersers. Birds also serve as barometers of the health of ecosystems; they are an **indicator species**. In the continental United States, hummingbirds are key in wildflower pollination, so their absence would have an impact on the wildflowers.

Long-distance migrants are particularly susceptible to global warming. They depend on precisely timed, once-a-year blooms of food to fuel breeding. If warming changes the traditional timing of food availability, chances are they'll suffer. If you want to participate in migratory bird conservation, you can increase your use of native plants in your garden. You can also reduce or eliminate any pesticide use.

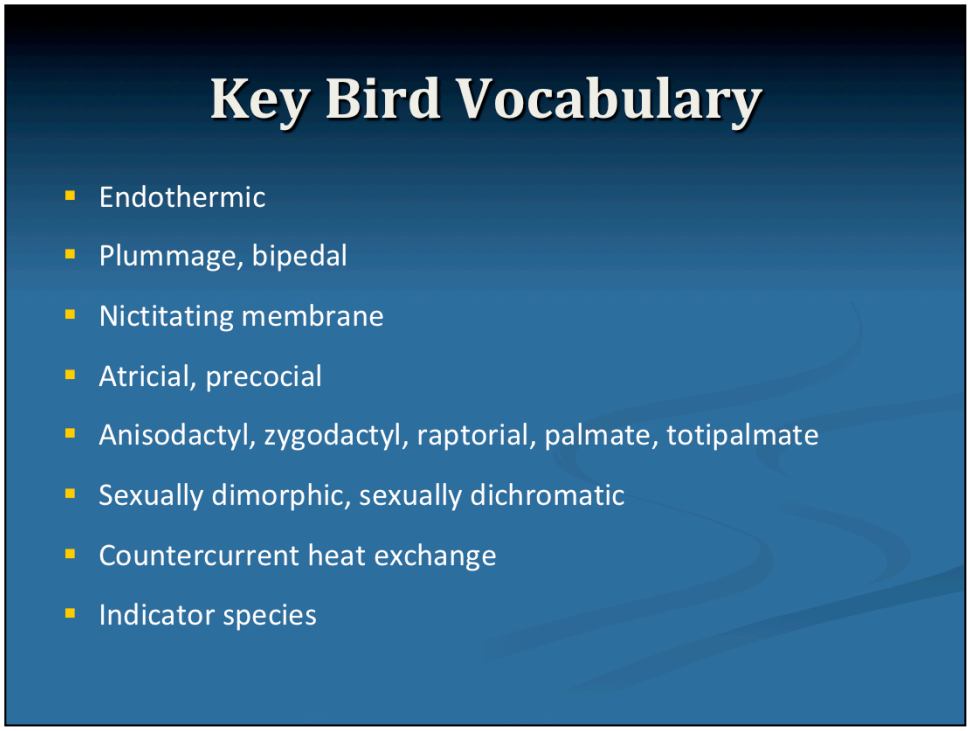
Bird conservation practices are increasingly necessary to address the impacts of human activities that have accelerated extinctions and continue to threaten bird populations worldwide. Habitat degradation needs to be addressed as well as the pet trade, which is also wiping out certain species. Although not a practice as much anymore, certain ornamental feathers were used to adorn ladies hats. In northeast India and Borneo, Indian hornbill feathers are used in traditional ceremonies. Many zoos, including the San Francisco Zoo, collect molted hornbill feathers and send them to these native lands.

Pesticides can kill birds both directly and indirectly. DDT, for instance, kills birds by poisoning their nervous systems. It also reduces reproductive success by causing thin eggshells and reducing hormone levels necessary for egg laying. Since birds of prey are top of the food chain, they are particularly susceptible as the toxins accumulate up the food chain. Ranchers have left poisoned animal carcasses out for wolves, a practice that also killed eagles and other bird scavengers that fed on the tainted carrion. Educating the public on the effect these poisons and pesticides have up the food chain is critical.

Waldrapp ibis are listed as Critically Endangered on the IUCN Red List; in fact, they are among the world's most endangered avian species. The San Francisco Zoo's colony has been produced offspring, contributing to the AZA Species Survival Plan for waldrapp ibis. With just over 100 waldrapp ibis in North American zoos, every young ibis is important to the success of the species!

Bali Mynahs are considered Critically Endangered on the IUCN Red list. They are extremely popular in the caged bird trade and a single bird can fetch thousands of dollars on the black market. In 2001 there were only 6 Bali mynahs left in the wild and populations were being maintained by the release of captive birds, however 39 captive birds slated for release into the wild were stolen, so problems still persist with the captive release program.

Corresponds to the Aves Study Guide in the Docent Notebook. For specifics on the Zoo's bird collection read the Aves Fact Sheets in the Docent Notebook or got to the SF Zoo's website (sfzoo.org)



Definitions:

Altricial: helpless at birth or hatching and requiring parental care for a period of time.

Anisodactyl: having the hallux behind and the other three toes are in front as in a thrush.

Bipedal: a form of terrestrial locomotion where an organism moves by means of its two rear limbs or legs.

Countercurrent heat exchange: an arrangement of blood vessels that allows peripheral cooling particularly of appendages and at the same time maintains an adequate blood supply without excessive heat loss; enables arteries and veins flowing in opposite directions to exchange their heat content without mixing.

Endothermic: any animal dependent on or capable of the internal generation of heat. The animal is able to maintain a relatively constant internal temperature, irrespective of the temperature of the surroundings.

Indicator species: an organism whose presence, absence or abundance reflects a specific environmental condition. Indicator species are used too monitor the health of an ecosystem.

Nictitating membrane: is a transparent or translucent third eyelid present in some animals that can be drawn across the eye for protection and to moisten it while maintaining visibility.

Palmate: webbed; the front toes are united as in ducks and gulls.

Plummage: the entire feathery covering of a bird; plumage refers both to the layer of feathers that cover a bird and the pattern, color, and arrangement of those feathers.

Precocial: refers to species in which the young are relatively mature and mobile from the moment of birth or hatching.

Raptorial: the toes are deeply cleft, with large, strong, sharply curved nails (talons), as in hawks & owls.

Sexually dichromatic: the difference in coloring or marking patterns between male and female members of the same species.

Sexually dimorphic: the difference in morphology between male and female members of the same species.

Totipalmate: fully webbed; all four toes are united by ample webs, as in a pelican or cormorant.

Zygodactyl: having the toes of each foot arranged in pairs, with two toes in front and two behind as in a woodpecker.