21 Birds: Feathers, Flight, and Endothermy

Lecture Outline

Birds are traditionally classified in the class Aves, due to unique adaptations for flight
Birds evolved from archosaurs; *Archaeopteryx* is a fossil giving evidence for the link between modern birds and reptiles; the fossils are approximately 150 million years old

Controversy surrounds the development of feathers and wings
Evidence from *Archaeopteryx* appears to suggest that they crawled up trees and glided and flew short distances
Other ideas describe early birds running or hopping along the ground, and grabbing their prey with wings
Both *Archaeopteryx*, and modern birds possess clavicles and feathers
Protoavis predates *Archaeopteryx* and is a controversial fossil; it is not certain whether it is a bird or not
Sinornis is another fossil bird, and is approximately 135 million years old, and appears to have characteristics associated with true flight
Eolulavis, 115 million years old has characteristics indicative of slow, hovering flight
Other fossil birds were terrestrial flightless birds, others were aquatic and it is not certain which, if any of these is the ancestor to today's birds
Today, over 9,000 species of extant birds are classified in about 27 orders

A myriad of adaptations of birds facilitate flight
Feathers allow flight; they also function in species recognition, endothermy, and waterproofing
Feathers evolved from epidermal scales of reptiles
Contour feathers cover the body, wings, and tail
Birds clean their feathers by preening; feathers are renewed by molting
The color of feathers may be due to pigments, reflected light, or iridescence

The skeleton of birds is lightweight; most large bones have air spaces, other bones are reduced in size
The keel on the sternum is enlarged for attachment of flight muscles
The pectoral muscles are the strongest and accomplish flight
The pectoral muscles are attached to the sternum, furcula, and humerus
Uncinate processes, also seen in reptiles, strengthen the rib cage
The rear appendages of birds are adapted for running, hopping, or perching
The synsacrum, a structure formed by fused vertebrae and pelvic bones, and the pygostyle support and steady the pelvic region while walking, hopping, and flying
Bird flight alternates between gliding and flapping flight

Flight in birds is a complex process
The airfoil design creates lift
Slotting of feathers and the alula decrease turbulence, which would decrease lift

The distal part of the wing provides most of the force of flight
The down stroke is the power stroke; the up stroke is the recovery stroke
The tail functions in balance, steering, braking, and increases lift
Differences in wing shape, length and aspect result in different flying patterns, speeds, etc

Other adaptations seen in birds
The bills and tongues of birds are adapted to their diet
The crop is a storage compartment in the esophagus; the stomach is modified into the proventriculus, which is involved in chemical digestion, and the ventriculus (gizzard), which is involved in mechanical digestion
In birds, the sinus venosus is reduced, and only remains as the pacemaker in the right atrium
A four-chambered heart, rapid heart rate, and a large heart characterize birds
The respiratory system of birds is unique; the connection of air sacs and the lungs, with a flow-through system allows maximal efficiency
Birds are endothermic, and maintain resting temperatures higher than most mammals
Some birds become torpid to save energy
The syrinx produces sound and is located at the bifurcation of the trachea

The nervous system of birds is adapted for a highly active life
The cerebrum is much enlarged, compared to reptiles
Vision in birds is also advanced; some have two foveae per eye; some have a 360° monocular field of vision, others have binocular vision
Many birds have well developed hearing

Birds excrete uric acid through the cloaca, which allows them to conserve water
Some birds have supraorbital salt glands for excretion of salt

All birds are oviparous; most are monogamous, although typically just monogamous for a single season
Some birds are polygynous, a small number are polyandrous
Many birds exhibit elaborate courtship behaviors
Nesting of birds varies from species to species; the number of eggs laid also varies, as well as the incubation period
Precocial birds are able to care for themselves soon after hatching, altricial birds are much more helpless
Migration by birds allow birds to exploit environments that are favorable at different seasons
Birds navigate by visual cues (by landmarks, the sun, moon and stars), as well as the earth's magnetic field

The respiratory system is unique in birds
Air flows from the bronchi to the posterior air sacs, and then with the exhalation, the air moves to the parabronchi
With the next inhalation, that bolus of air moves to the anterior air sacs, and with the next exhalation, out.

This is not an in and out form of respiration; it is a flow-through system
This is a very efficient system as there is almost no dead air space.

Research and Discussion Topics

• List at least 10 adaptations seen in birds that facilitate flight. Include adaptations seen in the digestive, excretory, reproductive, skeletal, and nervous systems.

• Discuss the different theories about the development of flight and feathers in birds. What purpose may the first feathers have served?

• Order Passeriformes is the most successful and speciose group of birds. What has led to this success?

• Many bird species are endangered, and a number are extinct due to human activities. What are the causes of this endangerment and extinction?

• What different life styles have resulted in birds being monogamous, polygynous, and polyandrous?

Teaching Suggestions

• I try to keep a theme of lightness and reduction of organ systems for flight throughout this unit. Even flightless birds evolved from ancestors that flew; some retain vestiges of this heritage. For example, penguins have a keeled sternum, which is useful when they swim ("fly") through the water.

Lecture Enrichment

• Birds and humans
Humans first domesticated *Gallus gallus*, the chicken in India around 3200 B.C., and chickens have been raised since then for meat and eggs. In the United States, the Tyson Chicken Company processes 30 million chickens per week! Annually, 2 billion chickens, 100 million turkeys and 11 million ducks are raised for food in the US. In Iceland, eider down collected from the nests of the eider ducks yields 4000 lb. (nearly 2 metric tons) of down for comforters and pillows. A cave swiftlet in Borneo and neighboring islands makes a nest that is collected for bird's nest soup. Between 20 and 30 tons (over 10 metric tons) of nests are collected annually!

Closer to home, an estimated one out of three adults in the United States bird-watch. About $5 billion is spent annually on this hobby, including $2 billion on birdseed and another $3 billion on travel, field gear, binoculars, guides etc. The number of jobs supported by bird-watching is about 200,000.

• Starlings

Starlings were introduced in the late 1800s to the United States because it was mentioned in Shakespeare's *Henry IV*. Now starlings are among the most common birds in the United States. Their success has unfortunately been to the detriment of many native birds.

• Hummingbirds

Hummingbirds are the smallest of the birds (the scintillant hummingbird weighs about 2 grams), and are terrific examples of the extreme in adaptation for flight. Their wings beat up to 75 times per second, and fly up to 90 km per hour. It consumes half of its weight in insects each day, and eight times its weight in liquid per day. I am often told that I "eat like a bird," to which I take offense, as I don't eat 8 times my weight per day! The heart of a hummingbird beats over 600 beats per minute. The brain of the hummingbird is 2 times as large as ours in proportion to our body weight, and the pectoral (primary flight) muscles make up 1/3 of their weight.

• Endangerment of birds

Birds' numbers have declined due to hunting, pollution, radio towers, farm equipment, and collisions with automobiles. In 1919, it was scientifically established that lead kills waterfowl. Nothing was done for decades. By the 1970s, over 3 million waterfowl died in the United States due to lead poisoning from lead shot, including the raptors that fed on poisoned ducks. There is now a national plan to ban lead shot in all states, as well as lead sinkers used by fishermen (lost sinkers kill loons).

Many species of animals are endangered in ways that we often are not familiar with. Conservation issues associated with birds include many areas that the general public is not aware of. An interesting article in *Audubon* magazine (Williams, T. "Killer fish farms." *Audubon*. March/April 1992. 14-21) points out that many fish farmers, including those that raise fish for bait are killing thousands of herons, egrets, and raptors per year, as they are perceived as a threat to bait fish.

One other peril to birds that is not commonly considered is both feral and pet cats. It is estimated that cats may kill 19 million songbirds and 140,000 game birds in Wisconsin alone. I read in a recent list of the top 10 environmentally friendly things you could do was to keep your cat indoors or put a bell on their collar. In a Wisconsin study, there were 57 cats per square mile in rural areas. In urban areas, the numbers are much greater: 1,295 cats per square mile in Madison, Wisconsin. In addition to birds, these felines are also killing many rodents, rabbits, bats, and other mammals. Interestingly, this study showed that well-fed cats killed the same number of birds and mammals as cats that were feral and had to hunt for their dinner. (Harrison, G. "Is there a killer in your house?" *National Wildlife.* October/November 1992. 10-13).

Suggested Readings

Konishi, M., S.T. Emlen, R.E. Ricklefs, and J.C. Wingfield. "Contributions of bird studies to biology." *Science*. 27 October 1989. 465-472. A discussion of bird studies in behavioral, developmental biology, physiological and evolutionary studies.

Taborsky, M. and B. Taborsky. "The kiwi's parental burden." *Natural History*. December 1993. 50-55. An interesting discussion, including X-rays of the kiwi and their amazingly large eggs.

Gould, S.J. "Of kiwi eggs and the Liberty Bell." *Natural History*. November 1986. 20-29.

Line, L. "Curse of the cowbird." *National Wildlife*. December/January 1994. 40-45. A description of the cowbird, which is a nest parasite of many other species of birds.

Morrell, V. "The origin of birds: the dinosaur debate." *Audubon*. March/April 1997. 36-45. A recent description of the ongoing debate.

Mann, C. and M. Plummer. "California vs. gnatcatcher." *Audubon*. January/February 1995. 39-48, contd. 100-104. A discussion of the bird that is stopping development in California; its protection may aid in conservation of the endangered chaparral habitat in coastal southern California.