CHAPTER 42

BIRDS

Young birds, such as this owl, depend on their parents for food and protection.

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ORIGIN AND EVOLUTION OF BIRDS

Birds belong to the class Aves, which, with nearly 10,000 species, is the largest class of terrestrial vertebrates. Birds are also the most recently evolved group of vertebrates, having appeared only about 150 million years ago. Among living vertebrates, only birds and bats can fly. The bodies of most birds are well adapted to flight.

SECTION 1

OBJECTIVES

- **Identify** and describe seven major characteristics of birds.
- **List** three similarities between birds and dinosaurs.
- **Describe** the characteristics of *Archaeopteryx*.
- **Summarize** the two main hypotheses for the evolution of flight.

VOCABULARY

furcula

CHARACTERISTICS

Although there are many kinds of birds, birds are so distinctive that it is difficult to mistake one for any other kind of vertebrate. All birds—even those that cannot fly—share the seven important characteristics described below.

- **Feathers—**Feathers are unique to birds, and all birds have them. Like hair, feathers are composed mainly of the versatile protein keratin. Feathers are essential for flight, and they insulate a bird's body against heat loss.
- **Wings—**A bird's forelimbs are modified into a pair of wings. Feathers cover most of the surface area of the wing.
- **Lightweight, rigid skeleton—**The skeleton of a bird reflects the requirements of flight. Many of the bones are thin-walled and hollow, making them lighter than the bones of nonflying animals. Air sacs from the respiratory system penetrate some of the bones. Because many bones are fused, the skeleton is rigid and can resist the forces produced by the strong flight muscles.
- **Endothermic metabolism—**A bird's rapid metabolism supplies the energy needed for flight. Birds maintain a high body temperature of 40–41°C (104–106°F). The body temperature of humans, by contrast, is about 37°C, or 98.6°F.
- **Unique respiratory system—**A rapid metabolism requires an abundant supply of oxygen, and birds have the most efficient respiratory system of any terrestrial vertebrates. The lungs are connected to several sets of air sacs, an arrangement that ensures that oxygen-rich air is always in the lungs.
- **Beak—**No modern bird has teeth, but the jaws are covered by a tough, horny sheath called a *beak*.
- **Oviparity—**All birds lay amniotic eggs encased in a hard, calcium-containing shell. In most species, the eggs are incubated in a nest by one or both parents.

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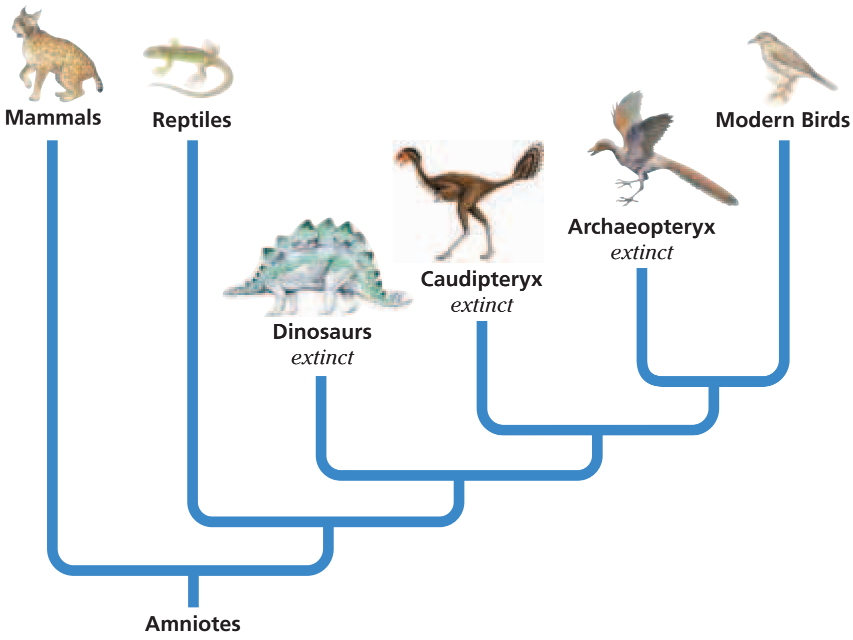
FIGURE 42-1

This phylogenetic diagram represents a hypothesis for the relationship among birds, reptiles, mammals, and some extinct relatives of birds. For updates on phylogenetic information, visit **go.hrw.com.** Enter the keyword **HM6 Phylo.**



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EVOLUTION

There are many similarities between birds and some dinosaurs, such as *Caudipteryx* show in Figure 42-1. Three of these similarities include a flexible S-shaped neck, a unique ankle joint, and hollow bones. Birds are thought to have evolved from small, fast-running carnivorous dinosaurs during the Jurassic period (200–146 million years ago). Figure 42-1 shows the likely relationships between birds and other terrestrial vertebrates.

The oldest known bird fossils are classified in the genus *Archaeopteryx* and date from the late Jurassic period, about 150 million years ago. In the fossil in Figure 42-2a, the shapes of feathers are clearly visible. Feathers covered *Archaeopteryx's* forelimbs, forming wings, and covered its body and tail as well. Like modern birds, *Archaeopteryx* had hollow bones and a **furcula** (FUHR-kyoo-luh), the fused pair of collarbones commonly called a *wishbone.* The furcula plays an important role in flight by helping to stabilize the shoulder joint. Based on such similarities with modern birds, scientists think that *Archaeopteryx* could fly. However, *Archaeopteryx* also had several characteristics of its dinosaur ancestors, including teeth, claws on its forelimbs, and a long, bony tail. Figure 42-2b shows an artist's conception of what an *Archaeopteryx* might have looked like.

Origin of Flight

The evolution of a flying animal from nonflying ancestors entails many changes in anatomy, physiology, and behavior. According to one hypothesis, the ancestors of birds were tree dwellers that ran along branches and occasionally jumped between branches and trees. Wings that allowed these animals to glide evolved. Once gliding was possible, the ability to fly by flapping the wings evolved.

Word Roots and Origins

archaeopteryx

from the Greek *archaios,* meaning "ancient," and *pteryx,* meaning "wing"

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(a)

(b) *Archaeopteryx*

(c) *Ichthyornis*

(d) *Hesperornis*

FIGURE 42-2

In this fossil of *Archaeopteryx* (a), one can find characteristics of both birds and dinosaurs. These artist's renderings of three extinct birds are based on fossil evidence. *Archaeopteryx* (b) is the oldest bird; it still had claws on its wings. *Ichthyornis* (c) had strongly developed wings and was about 21–26 cm (8–10 in.) in length. *Hesperornis* (d) was considered flightless, but its well-developed legs made it a strong swimmer.

Another hypothesis draws on the fact that the dinosaurs most closely related to birds were terrestrial and states that the evolution of birds must have occurred on the ground, not in the trees. Wings may have originally served to stabilize the animals as they leapt after prey. Or they may have been used for trapping or knocking down insect prey. Over generations, the wings became large enough to allow the animal to become airborne.

Evolution After *Archaeopteryx*

A number of recent discoveries show that by the early Cretaceous period (146–66 million years ago), birds had begun diversifying. *Sinornis,* a 140-million-year-old specimen discovered in China in 1987, had some key features of modern birds, including a shortened, fused tail and a wrist joint that allowed the wings to be folded against the body. The diversification of birds continued throughout the Cretaceous period. Figures 42-2c and 42-2d show two birds from the late Cretaceous period.

Only two of the modern orders of birds had appeared by the end of the Cretaceous period. Birds survived the global catastrophe that is thought to have wiped out the dinosaurs, and then underwent a dramatic and rapid evolutionary radiation. By about 40 million years ago, most of the modern orders of birds had originated.

SECTION 1 REVIEW

1. List two unique features of a bird's skeleton.
2. What are two functions of feathers?
3. Identify the characteristics that birds have in common with dinosaurs.
4. Describe two characteristics shared by *Archaeopteryx* and modern birds.
5. Name two differences between *Archaeopteryx* and modern birds.
6. Summarize the two major hypotheses for the evolution of flight.

CRITICAL THINKING

7. **Forming Hypotheses** Modern birds lack teeth. Form a hypothesis to explain how birds might have evolved to lack teeth.
8. **Evaluating Hypotheses** After studying the fossil of *Archaeopteryx,* evaluate the two hypotheses for the evolution of flight. Identify strengths and weaknesses of each.
9. **Applying Information** Identify three adaptations that help birds satisfy their high need for oxygen.

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SECTION 2

OBJECTIVES

- **Describe** the structure of a contour feather.
- **Identify** two modifications for flight seen in a bird's skeletal system.
- **Contrast** the function of the gizzard with that of the crop.
- **Trace** the movement of air through the respiratory system of a bird.
- **Explain** the differences between altricial and precocial young.

VOCABULARY

feather
follicle
shaft
vane
barb
barbule
preen gland
sternum
pygostyle
crop
proventriculus
gizzard
vas deferens
oviduct
brood patch
precocial
altricial
ornithologist

CHARACTERISTICS OF BIRDS

A number of unique anatomical, physiological, and behavioral adaptations enable birds to meet the aerodynamic requirements of flight. Natural selection has favored a lightweight body and powerful wing muscles that give birds their strength.

FEATHERS

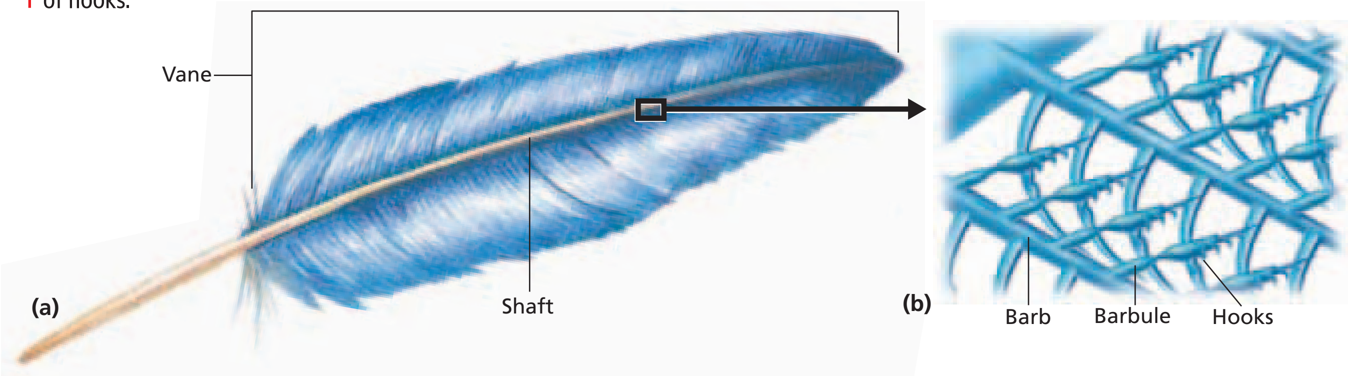
Feathers are modified scales that serve two primary functions: providing lift for flight and conserving body heat. Soft, fluffy *down feathers* cover the body of very young birds and provide an insulating undercoat in adults. *Contour feathers* give adult birds their streamlined shape and provide coloration and additional insulation. *Flight feathers* are specialized contour feathers on the wings and tail. Birds also have dust-filtering bristles near their nostrils.

The structure of a feather combines maximum strength with minimum weight. Feathers develop from tiny pits in the skin called **follicles.** A **shaft** emerges from the follicle, and two **vanes,** pictured in Figure 42-3a, develop on opposite sides of the shaft. At maturity, each vane has many branches, called **barbs.** The barbs, in turn, have many projections, called **barbules,** equipped with microscopic hooks, as shown in Figure 42-3b. The hooks interlock and give the feather its sturdy but flexible shape. Feathers are made of keratin, an insoluble protein that is highly resistant to decomposition. Keratin is also the protein that makes up fingernails, claws, hair, and scales in animals.

Feathers need care. In a process called *preening,* birds use their beaks to rub their feathers with oil secreted by a **preen gland,** located at the base of the tail. Birds periodically *molt,* or shed and regrow their feathers. Birds living in temperate climates usually replace their flight feathers during the late summer.

FIGURE 42-3

Bird feathers, such as this contour feather (a), usually have a shaft, with two vanes growing out either side of the shaft. The vanes (b) consist of barbs and barbules that interlock by means of hooks.



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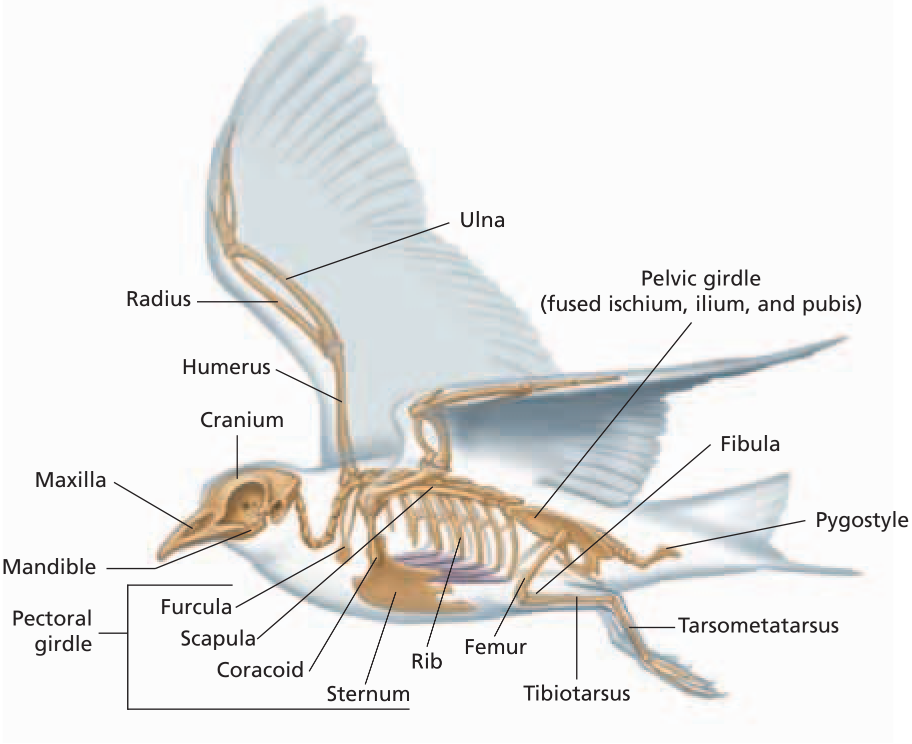

FIGURE 42-4

The avian skeleton is well adapted for flight. The bones are air filled, making them light but strong. The skeleton is arranged in such a way that it supports the large muscles necessary for flight.

SKELETON AND MUSCLES

The avian skeleton combines lightness with strength. The bones are thin and hollow. Many bones are fused, so the skeleton is more rigid than the skeleton of a reptile or mammal. The rigid skeleton provides stability during flight. Note in Figure 42-4 that the bones of the trunk and hip vertebrae and the pectoral and pelvic girdles are highly fused. Along with the furcula, the large, keel-shaped **sternum,** or breastbone, is an attachment point for flight muscles. The humerus, ulna, and radius, along with the pectoral girdle and the sternum, support the wing. The **pygostyle** (PIEG-uh-stiel), the fused terminal vertebrae of the spine, supports the tail feathers. The tail provides additional lift and aids in steering and braking.

Flight involves a series of complex wing movements, each one using a different set of muscles. On the downstroke, the wings cut forward and downward through the air. During upstroke, they move upward and backward. These movements are made possible by large, powerful flight muscles in the breast and wings. In some birds, flight muscles account for up to 50 percent of the body weight.

Quick Lab

Comparing Wing Structures

Materials pictures of different kinds of birds, ruler

Procedure Examine each sheet of birds and their wings. Compare the structure and shape of the wings. Measure the wingspan relative to the bird's body length. Record your observations.

Analysis Predict the type of habitat in which each bird lives. How does the shape of the wing relate to the bird's niche? Explain why the type of wings each bird has might make the bird unsuccessful if it were introduced into a much different environment.

METABOLISM

Birds are endothermic; that is, they generate heat to warm the body internally. Rapid breathing and digestion of large quantities of food support the high metabolic rate necessary to generate this heat. Birds, unlike reptiles, cannot go for long periods without eating. To help conserve body heat, birds may fluff out their feathers. Aquatic birds have a thin layer of fat that provides additional insulation.

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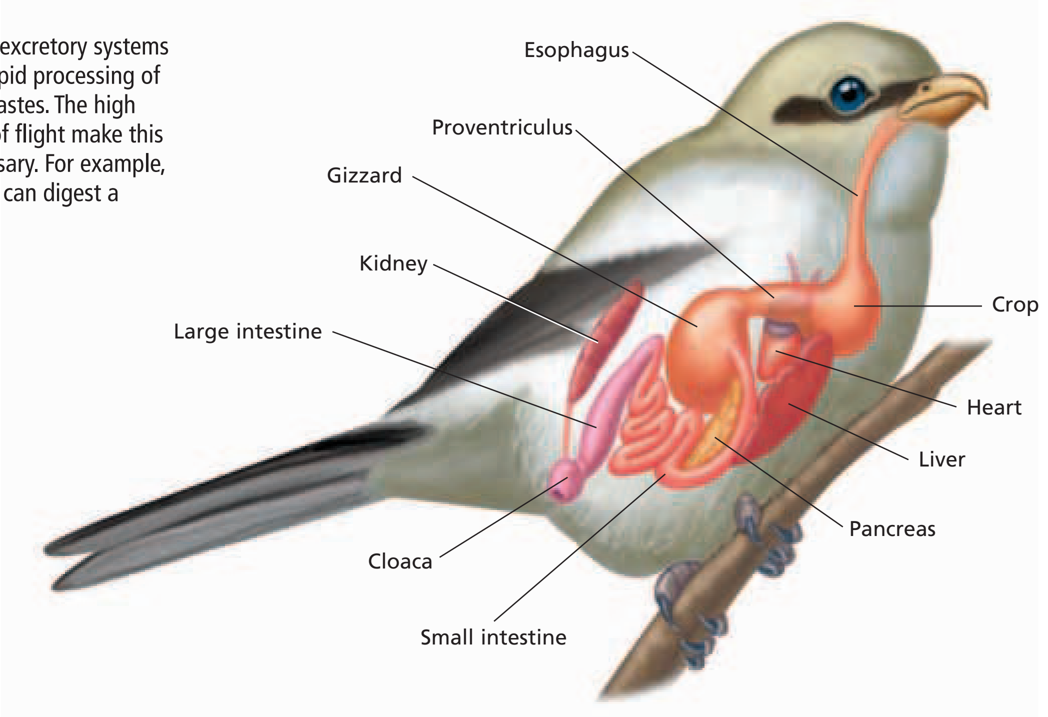
FIGURE 42-5

A bird's digestive and excretory systems are adapted for the rapid processing of food and metabolic wastes. The high energy requirements of flight make this efficient system necessary. For example, the carnivorous shrike can digest a mouse in three hours.



Word Roots and Origins

proventriculus

from the Greek *pro,* meaning "before," and the Latin *venter,* meaning "belly"

Digestive and Excretory Systems

The high amount of energy required to fly and regulate body heat is obtained by a quick and efficient digestive system, as illustrated in Figure 42-5. Because birds do not have teeth, they are not able to chew their food. Instead, food passes from the mouth cavity straight to the esophagus. An enlargement of the esophagus called the **crop** stores and moistens food. Food then passes to the two-part stomach. In the first chamber, the **proventriculus** (PROH-ven-TRIK-yoo-luhs), acid and digestive enzymes begin breaking down the food. Food then passes to the **gizzard,** the muscular portion of the stomach, which kneads and crushes the food. The gizzard often contains small stones that the bird has swallowed. These aid in the grinding process. Thus, the gizzard performs a function similar to that of teeth and jaws. Seed-eating birds usually have a larger crop and gizzard—relative to body size—than meat-eating birds do.

From the stomach, food passes into the small intestine. There, bile from the liver and enzymes from the pancreas and intestine further break down the food. The nutrients are then absorbed into the bird's bloodstream. Passage of food through the digestive system of a bird is usually very rapid. For instance, a thrush can eat blackberries, digest them, and excrete the seeds 45 minutes later.

The avian excretory system is efficient and lightweight. Unlike other vertebrates, most birds do not store liquid waste in a urinary bladder. The two kidneys filter a nitrogenous waste called *uric acid* from the blood. Concentrated uric acid travels through ducts called *ureters* to the cloaca, where it mixes with feces and is then excreted. This system is adaptive for flight because birds do not need to carry much water in their bodies.

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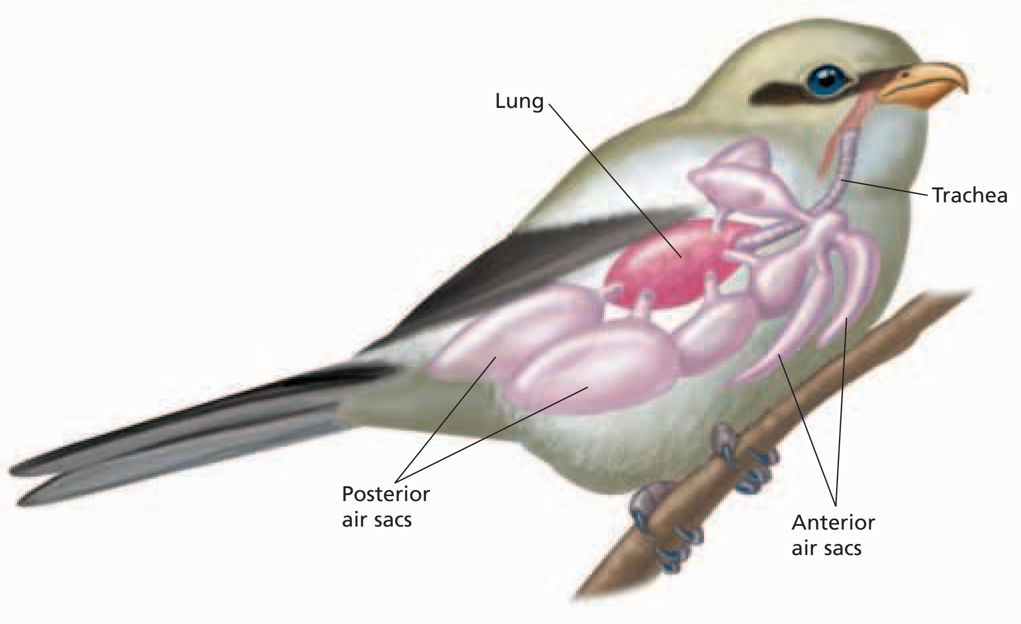

FIGURE 42-6
The unique architecture of the bird's respiratory system provides a constant flow of oxygenated air to the lungs. This highly efficient system allows birds to maintain the high metabolic rate necessary for flight. It also enables birds to function at high altitudes, where other animals would suffer from the low availability of oxygen.

Respiratory System

The high metabolic rate of birds requires large amounts of oxygen. Yet some birds migrate thousands of miles at altitudes as high as 7,000 m (23,000 ft), where air pressure is very low. So, birds have an elaborate and highly efficient respiratory system. Air enters the bird's body through paired nostrils located near the base of the beak. The air passes down the trachea and enters the two primary bronchi. From the bronchi, some of the air moves to the lungs. However, about 75 percent of the air bypasses the lungs and flows directly to posterior air sacs, shown in Figure 42-6. In most birds, nine sacs extend from the lungs and occupy a large portion of the bird's chest and abdominal cavity. These sacs also extend into some of the long bones. Thus, the air sacs not only function in respiration but also greatly reduce the bird's density.

Gas exchange does not occur in the air sacs. Their function is to store and redirect air. When the bird exhales, the oxygen-poor air from its lungs is forced into the anterior air sacs, and the oxygen-rich air in the posterior air sacs is forced into the lungs. This way, the bird has oxygenated air in its lungs during both inhalation and exhalation.

Circulatory System

The avian circulatory system has characteristics that are similar to those of either reptiles or mammals or both. Like crocodiles and mammals, birds have a four-chambered heart with two separate ventricles. Deoxygenated blood is always kept separate from oxygenated blood. In comparison with most other vertebrates, most birds have a rapid heartbeat. A hummingbird's heart beats about 600 times a minute. An active chickadee's heart beats 1,000 times a minute. In contrast, the heart of the larger, less active ostrich averages 70 beats per minute, or about the same rate as a human heart. Avian red blood cells have nuclei.

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Nervous System and Sense Organs

Relative to their body size, birds have large brains. The most highly developed areas of the bird's brain are those that control flight-related functions, such as the cerebellum, which coordinates movement. The cerebrum is also large. It controls complex behavior patterns, such as navigation, mating, nest building, and caring for the young. The large optic lobes receive and interpret visual stimuli.

Keen vision is necessary for taking off, landing, spotting landmarks, hunting, and feeding. Most birds have strong, color vision that aids them in finding food. In most species, the eyes are large and are located near the sides of the head, giving the bird a wide field of vision. Birds that have eyes located near the front of the head have better binocular vision, meaning they can perceive depth in the area where the visual fields of the two eyes overlap.

Hearing is important to songbirds and to nocturnal species, such as owls, which rely on sounds to help them locate their prey. Though birds lack external ears, owls have feathers around their ear openings that direct sound into the ear. The sense of smell is also strong in many birds.

REPRODUCTION

In the male bird, sperm is produced in two testes that lie anterior to the kidneys. Sperm passes through small tubes called **vasa deferentia** (singular, *vas deferens*) into the male's cloaca. During mating, the male presses his cloaca to the female's cloaca and releases sperm. Most females have a single ovary located on the left side of the body. The ovary releases eggs into a long funnel-shaped **oviduct,** where the eggs are fertilized by sperm. Fertilized eggs move down the oviduct, where they are encased in a protective covering and a shell. The egg passes out of the oviduct and into the cloaca. From the cloaca, it is expelled from the bird.

Nest Building and Parental Care

Birds usually lay their eggs in a nest. Nests hold the eggs, conceal young birds from predators, provide shelter from the elements, and sometimes serve to attract a mate. Most birds build nests in sheltered, well-hidden spots—ranging from holes in the ground to treetops. Woodpeckers, for example, nest in a hole they have drilled in a tree. Orioles suspend their nests from branches, well beyond the reach of predators. And barn swallows build a saucer of mud on the beam of a building. Birds construct their nests from almost any available material. Twigs, bark, grasses, feathers, and mud are common materials used.

One or both parents warm, or *incubate,* the eggs by sitting on them and covering them with a thickened, featherless patch of skin on the abdomen called a **brood patch.** Once the eggs hatch, the young usually receive extensive parental care.

Eco Connection

DDT and Bird Eggs

DDT is a pesticide that was widely used on crops until the 1970s. DDT was banned in several countries because of the harm it was causing to birds. DDT causes some birds to produce thin egg shells, decreasing survival rates of the birds' off-spring. The result was a significant drop in the populations of several species of raptors and pelicans. The thinning of the eggs was so significant that even the weight of an incubating parent could crush the eggs. With the banning of DDT in the United States, populations of the affected birds have increased.

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Birds have two general patterns of rearing young. Some birds lay many eggs and incubate them for long periods. These birds hatch **precocial** (pree-KOH-shuhl) young, which can walk, swim, and feed themselves as soon as they hatch. Ducks, quail, chickens, and other ground-nesting species produce precocial offspring. Other birds lay only a few eggs that hatch quickly and produce **altricial** (al-TRISH-uhl) young, which are blind, naked, and helpless, as shown in Figure 42-7. These young depend on both parents for several weeks. The young of woodpeckers, hawks, pigeons, parrots, warblers, and many aquatic birds are altricial.

FIGURE 42-7

This yellow warbler cares for its young by feeding and protecting them.

MIGRATION

Each year, thousands of bird species exploit the spring and summer food resources of temperate regions. Then, when temperatures drop and the food supply dwindles, they travel to warmer climates. The seasonal movement of animals from one habitat to another habitat is called *migration*. Many of the birds that nest in the United States and Canada during the spring and summer fly south in the fall to spend the winter in Mexico, Central America, the Caribbean, or South America.

How do birds manage to navigate thousands of kilometers across varied terrains and return to the same places each year? **Ornithologists**—biologists who study birds—have learned that birds rely on a variety of cues to help them navigate. Some species monitor the position of the stars or the sun. Others rely on topographical landmarks, such as mountains. The Earth's magnetic field, changes in air pressure due to altitude, and low-frequency sounds may also provide information to migrating birds.

Many species migrate thousands of kilometers and must rely on their fat reserves in order to complete the journey. To prepare for their migration, some birds, such as blackpoll warblers, eat so much food before their journey that their weight nearly doubles.

SECTION 2 REVIEW

1. Distinguish between vanes, barbs, and barbules.
2. What is the function of the keel-shaped sternum?
3. In what way does the gizzard compensate for the lack of teeth in birds?
4. What are the functions of the anterior and posterior air sacs?
5. Contrast altricial and precocial young.
6. Identify the cues birds use to help them navigate during a migration.

CRITICAL THINKING

7. **Analyzing Information** Why do you think the brood patch is featherless?
8. **Applying Information** Ground-nesting birds often produce precocial young. How might this improve the odds of survival for the young?
9. **Forming Reasoned Opinions** Some biologists have proposed that birds and reptiles should be grouped in the same class of vertebrates. Do you agree? Support your answer.

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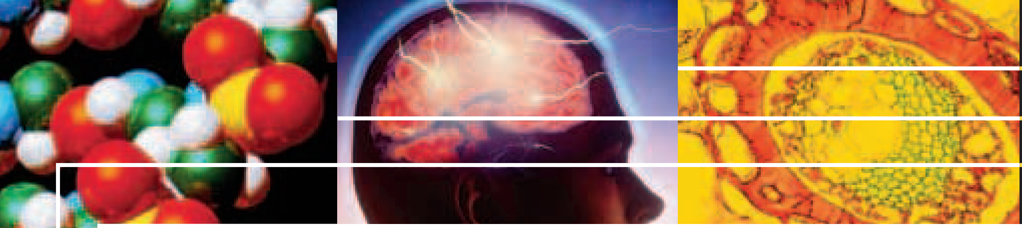

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MIGRATING BIRDS IN DANGER:
Conservation Issues and Strategies

Since Europeans first settled in the Americas, more than half of the Western hemisphere's wetlands have been destroyed. Today, in spite of regulations, wetland destruction continues.

Studies show that the numbers of shorebirds are declining worldwide. In order to preserve and protect these valuable species, researchers must first determine shorebird populations and map their migratory routes.

Crucial Roadside Park

More than 40 North American shorebird species—such as sandpipers, plovers, and curlews—breed in the Arctic and migrate to wintering sites in Central and South America. To complete these long-distance flights, shorebirds must accumulate large fuel reserves. The birds prepare for their journeys at a few food-rich staging areas, which are usually wetlands. In some cases, between 50 and 80 percent of the entire population of a species may visit a single site. The loss of such a staging area could devastate a population of shorebirds.

Technology to the Rescue

Today, the work of preserving shorebirds has been greatly advanced through the use of computer technology. One group that uses computers in this work is the International Shorebird Survey (ISS). The ISS was established in 1974 and consists of both volunteers and professional researchers. The volunteers record information on populations, habitat characteristics, weather conditions, and human activity. Researchers use computer programs to identify relationships among these variables. Complex methods of analysis have revealed much about the migratory habits of shorebirds—their velocity, altitude, flight path, and gathering sites, for example. Computer analyses have also helped researchers identify significant trends, such as a 70 to 80 percent drop in the population of sanderlings.

Delaware Bay, located between Delaware and New Jersey, is a staging site for shorebirds that migrate between South America and the Arctic. As much as 80 percent of the population of red knots (shown here) feeds and rests at this site.

Sanctuary Without Borders

Another organization that works to protect shorebirds is the Western Hemisphere Shorebird Reserve Network (WHSRN). The WHSRN has identified more than 90 sites where significant numbers of shorebirds breed, feed, and rest. The organization has proposed that these sites be recognized internationally as a single, vast wildlife reserve whose boundaries are, in effect, defined by the migrating birds.

Because most of the staging sites for shorebirds are wetlands, humans must develop a strategy for the conservation of these sites. The hemispheric wildlife reserve is one example of such a strategy.

REVIEW

1. What are some threats to shorebirds posed by humans?
2. How is technology aiding the conservation of shorebirds?
3. **Critical Thinking** How do the migration behaviors of shorebirds make them especially vulnerable to habitat loss?

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CLASSIFICATION

Birds are the most widespread terrestrial vertebrates. Their ability to navigate over long distances and their many adaptations for flight enable them to migrate to and inhabit virtually any environment. Their anatomical diversity reflects the diversity of places they inhabit.

OBJECTIVES

- **Describe** the relationship between beak shape and diet in birds.
- **List** 10 major orders of living birds, and name an example of each order.
- **Describe** the function of the syrinx.

VOCABULARY

syrinx
crop milk

DIVERSITY

By looking closely at a bird's beak and feet, you can infer many things about where it lives and how it feeds. Hawks and eagles have powerful beaks and clawed talons that help them capture and tear apart their prey. Swifts have a tiny beak that opens wide like a catcher's mitt and snares insects in midair. Because swifts spend most of their lives in flight, their feet are small and adapted for infrequent perching. The feet of flightless birds, on the other hand, are modified for walking and running. Some examples of the variety of bird beaks and feet are shown in Figure 42-8.

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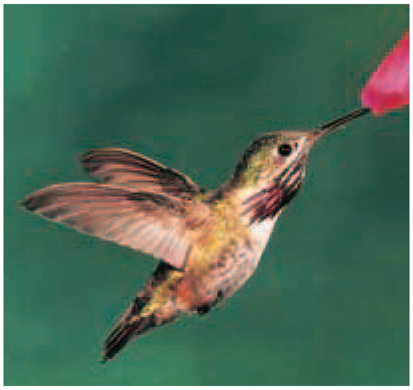

(c)

(d)

FIGURE 42-8

This cardinal (a), *Cardinalis cardinalis,* has a short, strong beak for cracking seeds and feet that enable it to perch on small tree branches. This kestrel (b), *Falco sparverius,* has a beak that enables it to tear flesh and talons that enable it to grip and kill prey. This calliope hummingbird (c), *Stellula calliope,* has a long, thin beak that enables it to extract nectar from flowers. This northern shoveler (d), *Anas clypeata,* has a flat beak that enables it to shovel mud while searching for food.

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FIGURE 42-9

This mute swan, *Cygnus olor,* is able to take off from water and fly at very high speeds despite its great weight. Weighing up to 23 kg (50 lb), mute swans are the heaviest flying birds. Swans are monogamous, meaning they mate for life. While the female incubates the eggs, the male helps guard the nest.

FIGURE 42-10

The parrot pictured below is a lesser sulfur-crested cockatoo, *Cacatua sulphurea.* Parrots range in length from 8 cm (3 in.) to over 91 cm (3 ft). The earliest fossils of parrots indicate that they have existed as a group for at least 20 million years. Like most parrots, these cockatoos nest in holes in trees, and they usually lay only two eggs per year. Because of human activities, many species have become extinct or endangered.

Most taxonomists divide about 10,000 species of living birds into 23 orders. Taxonomists have traditionally used morphological evidence from beaks, feet, plumage, bone structure, and musculature to classify birds. Technological advances in the analysis of blood proteins, chromosomes, and DNA have also been used more recently. Despite the introduction of these new methods, the relationships among the 23 orders of birds are still not well resolved. Ten of the most familiar orders of living birds are described below.

Order Anseriformes

Swans, geese, and ducks—commonly called *waterfowl*—belong to this order of 160 species. Found worldwide, members of this order are usually aquatic and have webbed feet for paddling and swimming. Waterfowl feed on a variety of aquatic and terrestrial foods, ranging from small invertebrates and fish to grass. The bill is typically flattened. The young are precocial, and parental care is usually provided by the female. A mute swan is shown in Figure 42-9.

Order Strigiformes

This order includes the owls, the nocturnal counterparts to the raptors. Owls are predators that have a sharp, curved beak and sharp talons or claws. As shown in the chapter opener photo, owls also have large, forward-facing eyes that provide improved vision at night. Owls rely on their keen sense of hearing to help locate prey in the dark. There are about 180 species of owls, and they are found throughout the world.

Order Apodiformes

Hummingbirds and swifts belong to this order. All of the roughly 430 species are small, fast-flying, nimble birds with tiny feet. Swifts pursue insects and capture them in flight. Hummingbirds eat some insects but also feed on nectar, which they lap up with a very long tongue. The long, narrow bill of a hummingbird can reach deep into a flower to locate nectar. Swifts have a worldwide distribution, but hummingbirds live only in the Western Hemisphere.

Order Psittaciformes

This order includes the parrots and their relatives, the parakeets, macaws, cockatoos, and cockatiels. Most of the roughly 360 species in this order live in the tropics. Parrots are characterized by a strong, hooked beak that is often used for opening seeds or slicing fruits. Their upper mandible is hinged on the skull and movable. Unlike most birds, parrots have two toes that point forward and two toes that point toward the rear, an adaptation for perching and climbing. They are vocal birds, and many species gather in large, noisy flocks. Parrots have long been prized as pets because of their colorful plumage and intelligence and because some species can be taught to mimic human speech. However, habitat destruction and excessive collecting for the pet trade now threaten many parrot species with extinction. Figure 42-10 shows a cockatoo.

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Order Piciformes

This diverse group of tree-dwelling birds contains woodpeckers, honeyguides, and toucans. All members of this order nest in tree cavities. Like parrots, they have two forward-pointing toes and two that point to the rear. There are about 350 species found throughout the world except in Australia. The diversity of foods consumed by these birds is reflected in the diversity of their bills. Woodpeckers, which drill holes into trees to capture insects, have strong, sharp, chisel-like bills. Toucans feed mainly on fruit, which they pluck with a long bill, as shown in Figure 42-11.

FIGURE 42-11

Toucans, such as this keel-billed toucan, *Ramphastos sulfuratus,* mate once per year, usually laying two to four eggs. The male and female toucans take turns sitting on the eggs. The eggs usually hatch after about 15 days of incubation.

Order Passeriformes

This large order contains about 5,900 species—more than half the total number of bird species—and includes most of the familiar North American birds. Robins, warblers, blue jays, and wrens are just some of the birds belonging to this group.

Passerines are sometimes called *perching birds.* In most birds, three toes point forward and one points backward. Passerines, too, have this arrangement of toes, but the rear toe is enlarged and particularly flexible to provide a better grip on branches. Passerines feed on a variety of foods, including nectar, seeds, fruit, and insects.

Many passerines are called *songbirds* because the males produce long, elaborate, and melodious songs. Male birds sing to warn away other males and to attract females. The song is produced in the structure known as the **syrinx** (SIR-ingks), which is located at the base of the bird's trachea. By regulating the flow of air through the syrinx, birds can generate songs of great range and complexity.

Order Columbiformes

This globally distributed group contains about 320 species of pigeons and doves. Figure 42-12 shows a mourning dove. These birds usually are plump-breasted and have relatively small heads; short necks, legs, and beaks; and short, slender bills. Most feed on fruit or grain.

The crop, which in most other birds is used to store food, secretes a nutritious milklike fluid called **crop milk.** Both sexes produce crop milk to feed their young. Columbiform birds usually lay a clutch of two eggs, which hatch after a two-week incubation period. The young usually leave the nest two weeks after hatching. Another member of this order is the now-extinct dodo of Mauritius, an island in the Indian Ocean.

FIGURE 42-12

The adult mourning dove, *Zenaida macroura,* stands about 30 cm (12 in.) tall and nests in trees or bushes. Mourning doves breed throughout North America. They winter as far south as Panama.

Order Ciconiiformes

The order Ciconiiformes is highly diverse, and has a worldwide distribution. This order includes about 1040 species of herons, storks, ibises, egrets, raptors, and penguins. Many have a long, flexible neck, long legs, and a long bill. Many are wading birds, and they feed on fish, frogs, and other small prey in shallow water. Many species of Ciconiiformes are diurnal (daytime) hunters with keen vision. Vultures, however, feed on dead animals and use their sense of smell to detect the odor of decomposing flesh.

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FIGURE 42-13

The great blue heron, *Ardea herodias,* uses its spearlike beak to stab fish, frogs, and other prey. Young herons must be taught how to hunt. Scientists have learned that young herons often miss their intended prey and must also learn what is and is not food.

Raptors have a sharp, curved beak and sharp talons and include ospreys, hawks, falcons, vultures, and eagles. About 310 species of raptors are distributed throughout the world. Some members of this order grow to be quite large. Figure 42-13 shows a great blue heron, a large species that is in North America. The marabou stork of Australia, for example, can be more than 1.5 m (59 in.) in height.

Penguins are a unique group of flightless marine birds. All 17 species live in the Southern Hemisphere. The penguin's wedge-shaped wings have been modified into flippers, and the feet are webbed. Underwater, penguins flap their flippers to propel themselves forward—they "fly" through the water. Most penguins have a thick coat of insulating feathers and a layer of fat beneath the skin, enabling them to live in polar conditions. They maintain this fat layer by consuming large quantities of fish and krill.

Order Galliformes

Members of this group, which includes turkeys, pheasants, chickens, grouse, and quails, are commonly called *fowl.* These terrestrial birds are usually plump-bodied and may have limited flying ability. Grains form a large part of the diet of many fowl, and all species have a large, strong gizzard. Some are also an important part of the human diet. The young are precocial. There are about 220 species distributed worldwide.

Order Struthioniformes

Some of the world's largest birds belong to this order. They include ostriches, rheas, emus, and cassowaries. Ostriches are native to Africa and can attain a height of nearly 3 m and weigh 150 kg. Ostriches cannot fly, but they are specialized as high-speed runners. Propelled by their long, strong legs, ostriches can reach speeds of 55 km per hour. Each large foot has only two toes. Reduction in the number of toes is common in running animals.

Rheas are a South American version of the ostrich. Emus are the second largest of the world's birds, originally found in Australia. Cassowaries, from New Guinea, are the most colorful of this order, with black bodies and blue heads.

Word Roots and Origins

syrinx

from the Greek *syrinx,* meaning "reed" or "pipe"

SECTION 3 REVIEW

1. Explain how a bird's beak and feet can provide information about the bird's lifestyle.
2. Identify the order to which each of the following birds belongs: dove, robin, goose, and penguin.
3. Identify similarities and differences between raptors and owls.
4. Identify the function of the syrinx.
5. Describe the source and function of crop milk.

CRITICAL THINKING

6. **Recognizing Relationships** Penguins have a large, keel-shaped sternum, but ostriches do not. Provide an explanation for this difference.
7. **Analyzing Information** Why can birds inhabit more diverse environments than reptiles can?
8. **Applying Information** Why might crops and gizzards be less common in carnivorous birds than in seed-eating birds?

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CHAPTER HIGHLIGHTS

SECTION 1 Origin and Evolution of Birds

- Seven major characteristics of birds are feathers; wings; a lightweight, rigid flight skeleton; a respiratory system involving air sacs; endothermy; a beak instead of teeth; and oviparity.
- Three similarities between birds and dinosaurs include an S-shaped neck, a unique ankle joint, and hollow bones.
- *Archaeopteryx* had feathers covering its body, tail, and forelimbs. It had hollow bones and a fused collar bone, called a furcula.
- There are two hypotheses for the origin of flight in birds. One hypothesis is that flight evolved in tree-dwellers. The second hypothesis is that flight evolved in ground-dwellers.

Vocabulary

furcula (p. 842)

SECTION 2 Characteristics of Birds

- Contour feathers are made of a central shaft composed of two vanes with branches, called barbs, that are connected by interlocking hooked barbules.
- Two modifications to the bird skeletal system include an enlarged sternum and hollow bones.
- The crop stores food. The two parts of the stomach are the proventriculus and the gizzard, which crushes food.
- The lungs of a bird are connected to several air sacs that store and move air but do not participate in gas exchange.
- Birds lack a urinary bladder and excrete their nitrogenous waste as uric acid mixed with feces.
- The cerebellum, cerebrum, and optic lobes of the bird brain are large.
- All birds lay hard-shelled eggs. Precocial young are active as soon as they hatch. Altricial young are born helpless and require parental care for several weeks.
- Many birds migrate using a variety of environmental cues to guide their migration.

Vocabulary

feather (p. 844)
follicle (p. 844)
shaft (p. 844)
vane (p. 844)
barb (p. 844)
barbule (p. 844)
preen gland (p. 844)
sternum (p. 845)
pygostyle (p. 845)
crop (p. 846)
proventriculus (p. 846)
gizzard (p. 846)
vas deferens (p. 848)
oviduct (p. 848)
brood patch (p. 848)
precocial (p. 849)
altricial (p. 849)
ornithologist (p. 849)

SECTION 3 Classification

- The feet and beak of a bird reflect its way of life.
- There are currently 23 commonly recognized orders of living birds, but technological advances add to our knowledge of relationships among animals, and taxonomy is subject to change with new information.
- Ducks, geese, and swans belong to the order Anseriformes.
- Owls are nocturnal hunters and belong to the order Strigiformes.
- Swifts and hummingbirds belong to the order Apodiformes.
- Parrots and relatives belong to the order Psittaciformes.
- Woodpeckers and toucans belong to the order Piciformes.
- Perching birds and songbirds belong to the order Passeriformes. Passeriformes have a structure called the syrinx, which they use to produce songs.
- Pigeons and doves belong to the order Columbiformes.
- Raptors, long-legged water birds, and penguins belong to the order Ciconiiformes.
- Chickens and turkeys belong to the order Galliformes.
- Large birds such as the ostrich belong to the order Struthioniformes.

Vocabulary

syrinx (p. 853)
crop milk (p. 853)

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CHAPTER REVIEW

USING VOCABULARY

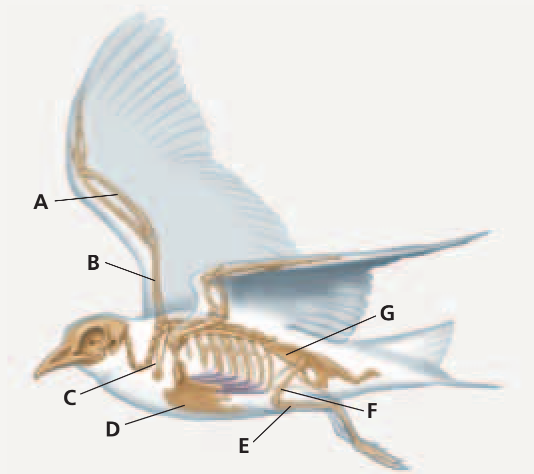
1. For each pair of terms, explain how the meanings of the terms differ.
   a. *furcula* and *sternum*
   b. *flight feathers* and *contour feathers*
   c. *crop* and *gizzard*
   d. *altricial* and *precocial*
2. Explain the relationship between vas deferentia, oviducts, and cloaca.
3. Use the following key terms in the same sentence: *shaft*, *follicle*, *vane*, *barb*, *barbule*, *preening*, and *preen gland*.
4. **Word Roots and Origins** The word *precocial* is derived from the Latin prefix *pre-,* which means "before," and the term *coquere,* which means "to mature." Using this information, explain why the term *precocial* is a good word for the type of young birds it describes.

UNDERSTANDING KEY CONCEPTS

5. **List** the seven defining characteristics of birds.
6. **Identify** characteristics that *Archaeopteryx* shared with its dinosaur ancestors.
7. **Summarize** the evidence indicating that *Archaeopteryx* could fly.
8. **Compare** two possible explanations for the evolution of flight.
9. **Contrast** the function of down feathers with that of contour feathers.
10. **Explain** how a bird's skeleton maximizes strength for flight while minimizing weight.
11. **Describe** the functions of two of the organs in a bird's digestive system.
12. **Name** the structure that grinds food, aided by stones that a bird swallows.
13. **Describe** the role that air sacs play in increasing respiratory efficiency in birds.
14. **Summarize** the differences between newly hatched ducks and newly hatched pigeons.
15. **List** several cues that birds might use to guide their movements when migrating long distances.
16. **Explain** the relationship between beak and feet shapes and the lifestyles of raptors, seed-eating birds, and flightless birds.
17. **Identify** the order to which each of the following birds belongs: ducks, owls, hummingbirds, parrots.
18. **Name** the characteristic that is unique to song-producing members of the order Passeriformes.
19. **Explain** how some members of the order Columbiformes are similar to mammals.
20. **CONCEPT MAPPING** Use the following terms to create a concept map that describes the adaptations of birds for flight: *contour feathers, flight feathers, sternum, keel, pygostyle, hollow, urinary bladder,* and *air sacs.*

CRITICAL THINKING

21. **Analyzing Concepts** The right and left sides of a bird's heart are completely separated. Thus, the oxygenated blood is never mixed with the deoxygenated blood. Why is this complete separation in the heart necessary?
22. **Interpreting Graphics** Look at the diagram below of a bird's skeleton. Identify the following structures: pelvic girdle, furcula, sternum, femur, humerus, ulna, and tibiotarsus.



23. **Applying Information** Why is binocular vision important to some birds?
24. **Inferring Relationships** Cowbirds lay their eggs in the nests of other birds. The young cowbirds hatch slightly earlier than the other birds do, and the cowbird hatchlings are slightly larger. Why might these characteristics be advantageous for the young cowbirds?
25. **Making Comparisons** Although many species of temperate-zone birds migrate to the tropics to escape winter, some species remain behind. What benefits might these birds gain from not migrating?
26. **Justifying Conclusions** In terms of evolutionary adaptations, explain why the young of some birds, such as ducks and quail, are precocial.

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Standardized Test Preparation

DIRECTIONS: Choose the letter of the answer choice that best answers the question.

1. Which of the following characteristics of *Archaeopteryx* is not shared by modern birds?
   A. tail
   B. teeth
   C. furcula
   D. feathers

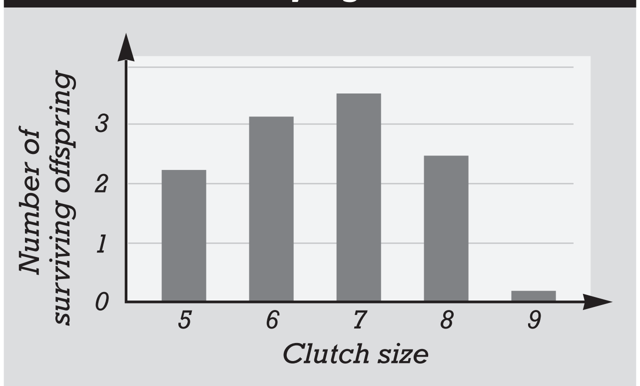
2. Which of the following characteristics do birds share with dinosaurs?
   F. crop
   G. lack of teeth
   H. presence of feathers
   J. structure of the ankle joint

3. What is the function of the preen gland?
   A. to produce digestive enzymes
   B. to control salt balance in the body
   C. to release scents that help attract mates
   D. to produce an oily substance used to condition the feathers

4. Which bone supports the tail feathers?
   F. ulna
   G. furcula
   H. pygostyle
   J. pelvic girdle

INTERPRETING GRAPHICS: The graph below shows the effect of varying clutch size on the number of surviving offspring in one bird species. Use the graph to answer the question that follows.

Effect of Varying Clutch Size

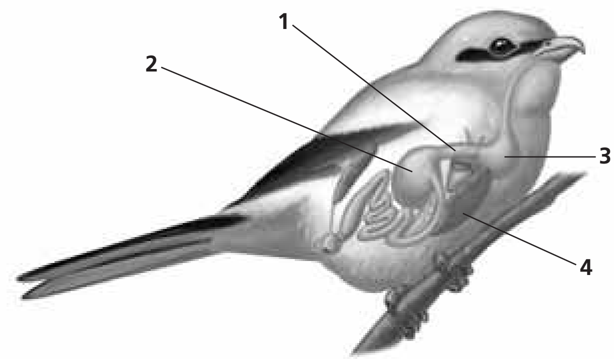


5. Based on these data, which of the following statements is true for this species?
   A. The optimal number of eggs in a clutch is seven.
   B. The greater the clutch size is, the greater the number of surviving offspring.
   C. Nests with five eggs produced the fewest number of surviving offspring.
   D. More offspring died in nests containing eight eggs than in nests containing nine eggs.

DIRECTIONS: Complete the following analogy.

6. crop milk : crop :: song :
   F. syrinx
   G. trachea
   H. proventriculus
   J. anterior air sacs

INTERPRETING GRAPHICS: The diagram below shows the digestive system of a bird. Use the diagram to answer the question that follows.



7. Which digestive structure grinds food, aided by stones swallowed by the bird?
   A. 1
   B. 2
   C. 3
   D. 4

SHORT RESPONSE

Each type of feather on a bird serves a specific purpose.

What are the functions of contour feathers and down feathers in birds?

EXTENDED RESPONSE

Imagine that a museum display of bird skeletons became mixed up, and all of the labels were lost.

Part A How could you separate the skeletons of flightless birds from those of birds that fly?

Part B How could you tell which birds flew rapidly and which birds could soar?

Test TIP When a question refers to a graph, study the data plotted on the graph to determine any trends before you try to answer the question.

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Comparing Feather Structure and Function

OBJECTIVES

- Observe a flight feather, a contour feather, and a down feather.
- Compare the structure and function of different kinds of feathers.

PROCESS SKILLS

- observing
- relating structure to function
- comparing and contrasting

MATERIALS

- 1 quill feather (large flight feather from wing or tail)
- 1 contour feather
- 1 down feather
- unlined paper
- prepared slide of a contour feather
- compound light microscope
- prepared slide of a down feather

Quill feather, a large flight feather

Background

1. List several distinguishing characteristics of birds.
2. How do birds differ from other vertebrates?
3. What are the functions of feathers?

Procedure

1. In your lab report, make a table like the one on the next page. Record your observations of each kind of feather in your data table.
2. Examine a quill feather. Hold the base of the central shaft with one hand, and gently bend the tip of the feather with your other hand. Be careful not to break the feather. Next, hold the shaft, and wave the feather in the air. Record your observations concerning the structure of the quill feather. Relate your observations to the feather's possible function. Describe the function of the feather under "Function of feather" in your data table.
3. Examine the vane of the feather. Does the vane appear to be a solid structure? Include a description of the quill feather's vane structure under "Structure of feather" in your data table.
4. Make a drawing of the quill feather. Label the shaft, vanes, and barbs. Compare your feather with the figure above.
5. Examine a contour feather. Make a sketch of the contour feather in your data table. Label the shaft, vanes, and barbs on your sketch. Does the feather resemble the one in the figure on the next page?
6. Describe the structure of the contour feather under "Structure of feather" in your data table.
7. Examine a prepared slide of a contour feather under low power. Note the smaller barbs, called *barbules,* extending from each of the barbs.
8. How might you observe the region between the barbs? Locate the tiny hooks at the end of each barbule. Note the arrangement of the hooks on adjacent barbs. Why do you think the hooks are so small? Make a separate, labeled drawing of the hooks in your lab report.
9. Examine the down feather, and sketch it in your data table. How does your down feather compare with the figure on the next page?
10. Describe the structure of the down feather in your data table. Do you notice a difference in the structure of the contour and down feathers?

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COMPARISON OF FEATHERS			
Type of feather	**Sketch of feather**	**Structure of feather**	**Function of feather**
Quill feather			
Contour feather			
Down feather			

Contour feather

Down feather

11. Examine the prepared slide of the down feather under low power. Locate the barbs and barbules. Switch your microscope to high power, and make a separate, labeled drawing of the down feather in your lab report. Does it resemble the one in the figure above?

12. Clean up your materials, and wash your hands before leaving the lab.

Analysis and Conclusions

1. What is the function of the shaft? What is the function of the vanes and barbs?
2. How do hooks increase the strength and air resistance of a feather?
3. How is the structure of the quill feather related to its function of aiding flight?
4. Based on your observations, why might down feathers be more effective at keeping a bird warm than the other two feather types you observed?
5. Based on your observations, how do you expect to see these feathers arranged on a bird? Explain how position of the feather affects the function of the feather.
6. What evolutionary pressure(s) would have caused the evolution of these different types of feathers?

Further Inquiry

Each of the feather types you have examined has a specific structure and function. Review your observations, and try to think of features that account for the efficiency of the three types of feathers.

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