Adapted from the National Wildlife Federation's NatureScope magazine "Birds, Birds, Birds" (Another example of how images can be used to teach.)

Flight of Fancy

You are going on a flight of fancy. You will travel to places you've never been before, moving high above the earth. But before you go, your body must change. Right now you are much too heavy to get off the ground.

Let's start the change with your feet. Think about your feet; notice how they feel. Wiggle your toes and bend your ankles. Now imagine that each foot is being squeezed together and stretched until it is long and skinny and extends upward like a leg. Your ankle looks like a knee, but it bends the wrong way. You must stand and walk on your toes, but there are only four of them. One has disappeared. Of the four that remain, three continue to face forward, but the other one moves around so it now sticks out the back. A sharp, curved toenail grows from the end of each toe. The skin on your feet and ankles changes from smooth skin to rough bumpy scales.

Now your legs become shorter and your knees pull up close to your body. You feel your body tip forward and grow shorter. All of your insides shrink so your body can become very slim and compact.

Suddenly your hands and arms start to change. Your fingers almost dissolve and your hands grow until they are long, flat and wide. Your hands and arms have become wings. Flap them a few times and feel how they move.

Now your head begins to change. Your teeth disappear and your nose and mouth grow together to form a hard, strong, sharp, hook-like beak. Your eyes slide around to the side of your head and become more difficult to turn in their sockets. You must turn your whole head to look around. Now your chin disappears and your outer ears fall off. Your ear holes move over beneath and a little behind your eyes.

More changes happen very quickly now. Each lung changes and air sacs appear in many places in your body. They are like balloons connected to your lungs. Air spaces invade your dense bones to make them much lighter than they were. The small hairs all over your body begin to change into feathers. Soft downy feathers grow close to your body, and longer, wider feathers cover them. Larger feathers give shape to your wings and form your broad tail.

Your body change is complete and you hop to the nearest open door. As you face outside, the outdoors calls to you and you jump, flapping your wings quickly and with great force. Up you go over the trees and buildings toward the sky. A warm gust of air pushes up under your wings and lifts you higher and higher until the trees look the size of buttons. However, when a mouse runs across a field far below, you can see its shape clearly even though you are high in the sky. As you look down, you see the colors of earth – green leaves and grass, brown soil and blue water.

As you circle on the warm rising winds, you see a puffy, white cloud ahead. With a few flaps of your wings and a tilt of your tail you glide into the whiteness. It is cool, damp and completely surrounds you. For a moment you feel lost, and then you come out on the other side. In the distance you see a range of mountains.

The mountains and sky are your new home, and as you fly high above the earth, you let out a long, loud cry. You are an eagle now.

"Young Naturalist" from
Texas Parks and Wildlife
magazine, January 1975

Bird Feet

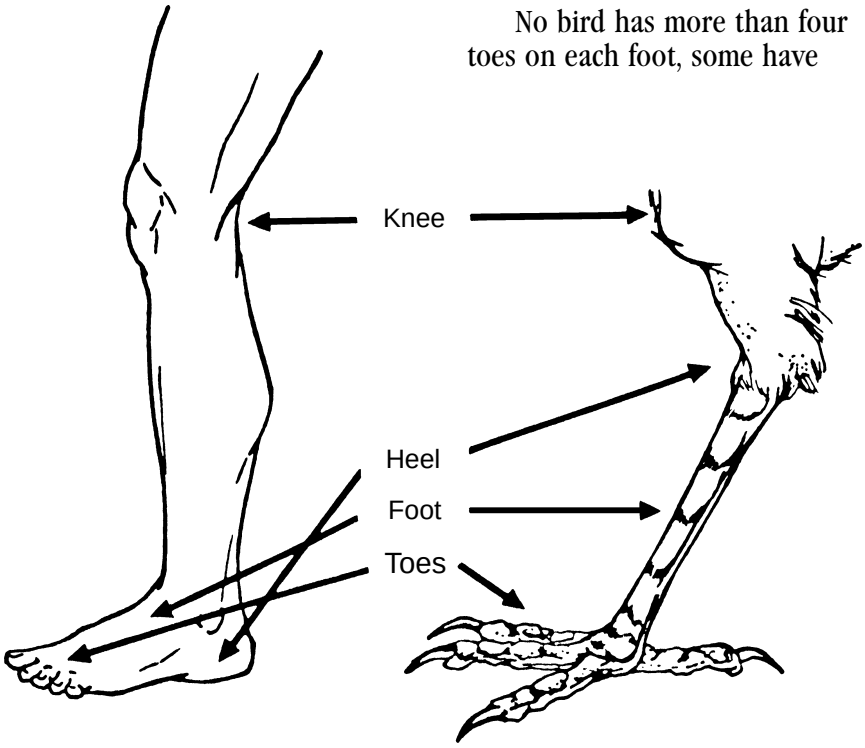
by Ilo Hiller

We humans all have feet, and they are basically alike. However, in the bird world, feet are uniquely different.

Birds walk on their toes, and what most people believe to be the leg is actually a long foot. People think the ankle joint is the knee although it bends in the wrong direction. The real knee is hidden in the bird's feathers.

Since birds are either scratchers, climbers, waders, swimmers, perchers, hunters, or a combination of these, the size and shape of their feet are different as are the number and location of their toes.

No bird has more than four toes on each foot, some have three and the ostrich has only two. To understand the location of these toes as we discuss them, imagine them as the thumb and first three fingers of your hand. We'll call the thumb the first toe, the index finger the second toe, the middle finger the third toe and the remaining finger the fourth toe. Pretend the little finger is missing.

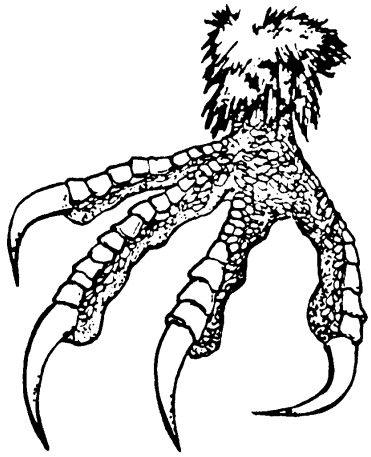


Some birds such as the swifts have all four of their toes pointing forward to help them climb vertically and cling to their nests, but most birds have three toes pointing forward (toes two, three and four) and one toe pointing backwards (toe one). This arrangement not only provides good balance for the bird, but it enables perching birds to firmly grasp a tree branch.

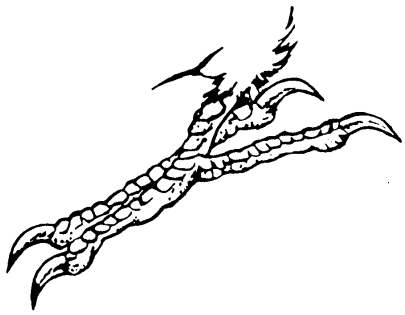
Owls and osprey have the basic arrangement of three toes forward and one toe backwards, but these birds are also able to turn the fourth toe backwards to give them two gripping toes on the back (toes one and four). Since they are both predatory birds, this reversible toe helps them grip their prey more easily. Nature has also provided the fish-eating osprey with spiny foot pads to help it hold the slippery fish it catches.

Cuckoos and woodpeckers are among those birds which have "yoke-toed" feet. Their toes are permanently paired with two in front (toes two and three) and two in back (toes one and four). This arrangement and their sharp claws enable them to climb without difficulty. The feet also brace the woodpecker as it hammers away with its beak.

Position and size of a bird's back toe (toe one) depend largely upon the importance of this toe for perching or seizing prey. Since this toe is of little importance to many running, walking and



Eagle (preying foot)

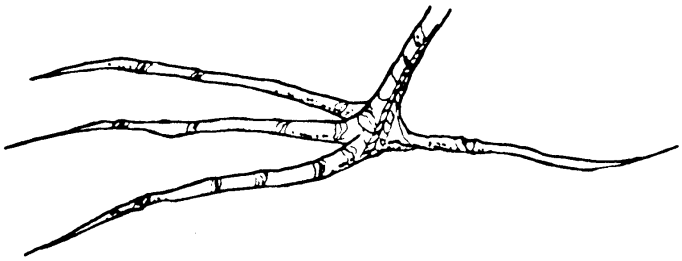


Woodpecker (yoke-toed climbing foot)

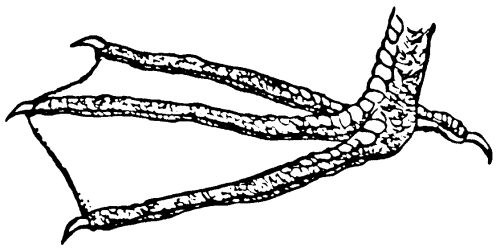
swimming birds, it is often quite small and may even be raised so that it doesn't touch the ground. In some species, such as the killdeer, the first toe has completely disappeared, leaving the bird with only three toes (toes two, three and four).

Length, shape and strength of the toes and claws depend upon where and how the feet are used. Perchers have highly developed, flexible toes to give them a firm grip on tree branches. Climbers not only have strong toes, but they also have sharp claws to grip the bark as they travel up and down tree trunks or hang upside down while exploring the undersides of branches.

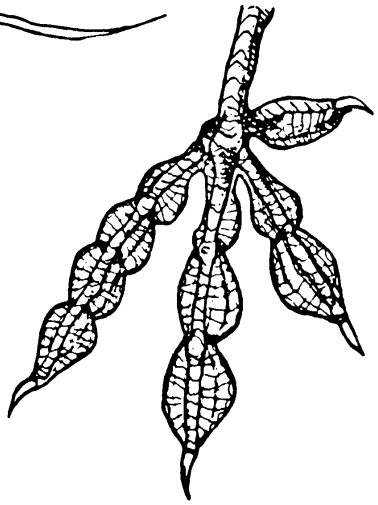
Turkeys, pheasants and quail use their feet to scratch among the leaves and dirt for food, so their strong toes have short, thick, blunt claws. Sharp claws would soon be dulled by scratching and long ones would quickly break, so these birds are properly equipped for scratching for food.



Jacana (wading foot)



Mallard (webbed swimming foot)



Coot (lobed swimming foot)

Birds of prey, such as the eagle, have very strong toes which are widely spread and equipped with long, sharp, curved claws. This type of foot has great grasping and holding power. Once the eagle's toes have grasped an object and clutched it tight, nothing short of cutting off the bird's leg will loosen the grip of these strong toes until the eagle wants to let go.

Vultures, which feed on dead animals, have a weaker type of foot more suitable for walking and perching. The muscles are weaker and the claws are shorter and more blunt. There is very little gripping power in the toes since the vulture doesn't need to seize and hold live prey.

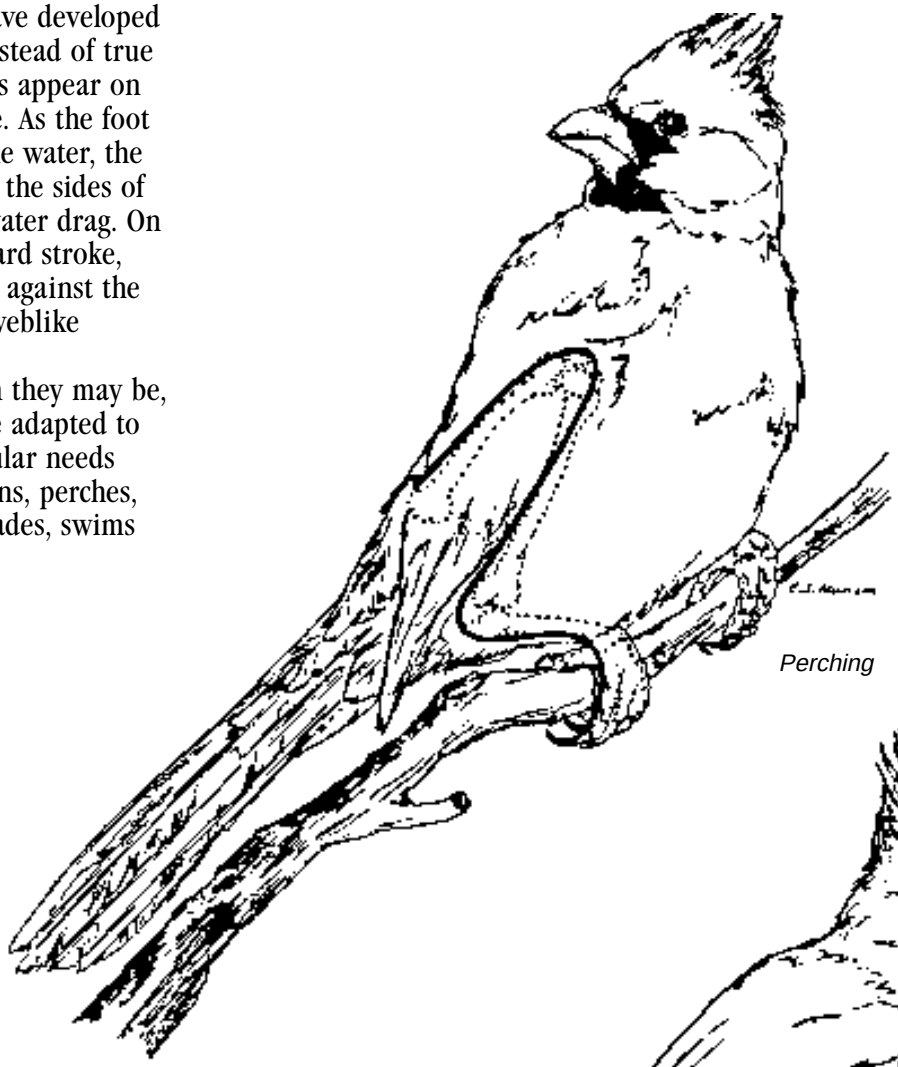
Wading birds must often walk on soft ground, so their feet are suitable for this. Some have long toes and claws to distribute their weight over a large surface area and keep them from sinking into the mud. The jacanas, also called lily-trotters, are an extreme example of this. They have very long, thin toes equipped with long claws, especially the back toe (toe one). With these feet, jacanas can walk on floating plants without sinking to get to feeding areas that are too deep for wading birds and too full of vegetation for swimming birds.

Some wading birds have extremely long foot and leg bones which make them look as if they are walking on stilts. These long bones enable the birds to wade in shallow water areas to feed without getting their bodies wet or being knocked down by incoming waves.

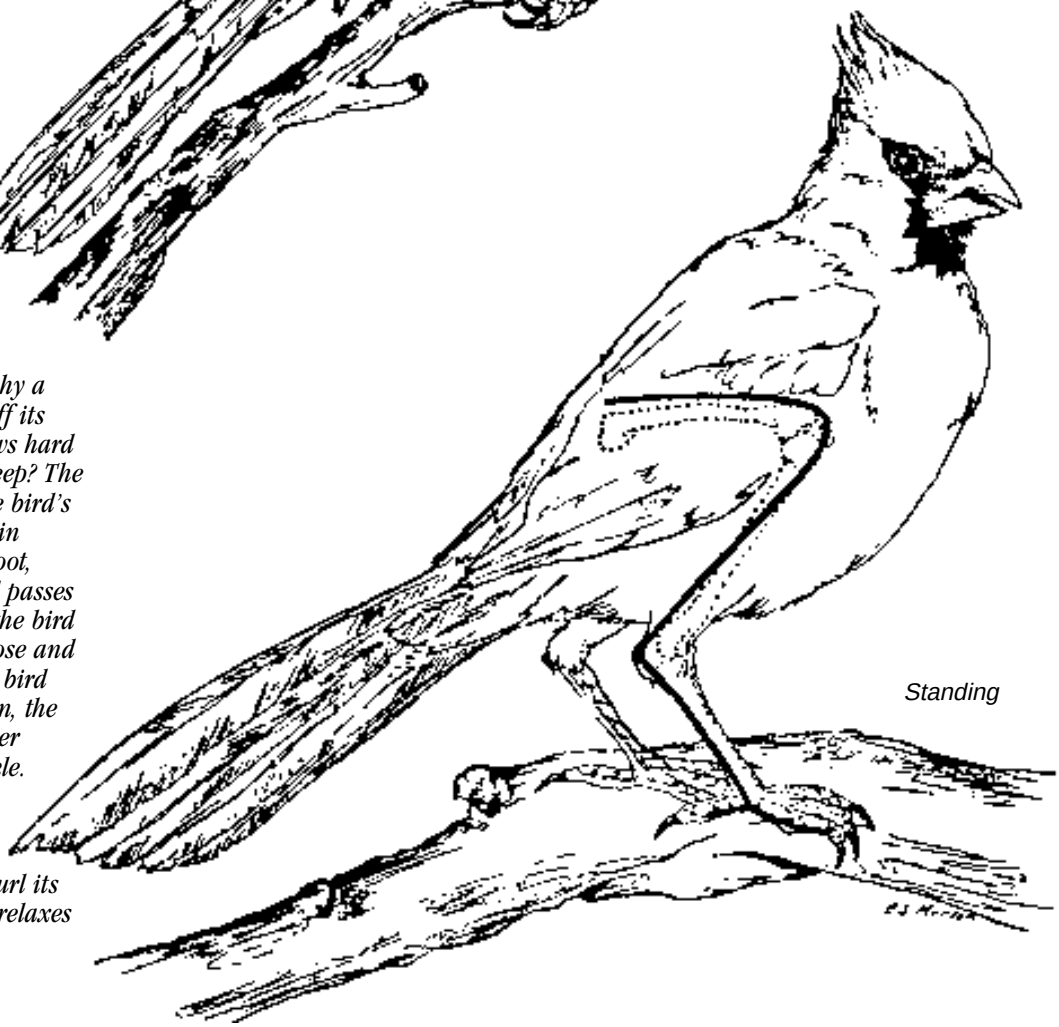
Ducks, geese, gulls and many other swimming birds have webbing between their toes. Usually only the three forward toes are webbed (toes two, three and four), and the rear toe (toe one) is quite small and poorly developed.

Some swimmers, such as the coots and grebes, have developed toe flaps or lobes instead of true webbing. These flaps appear on the sides of each toe. As the foot moves forward in the water, the flaps fold in against the sides of the toes to reduce water drag. On the powerful backward stroke, the flaps flatten out against the water to provide a weblike surface.

Different though they may be, each bird's feet have adapted to meet its own particular needs whether it walks, runs, perches, scratches, climbs, wades, swims or hunts.



Perching



Standing

Have you ever wondered why a perching bird doesn't fall off its branch when the wind blows hard or when the bird goes to sleep? The reason is, it can't. All of the bird's toes are connected to a main tendon which runs up its foot, bends behind its ankle and passes in front of its knee. When the bird stands up, the tendon is loose and the toes are relaxed. As the bird settles into a sitting position, the tendon is stretched tight over its knee and behind its ankle. This pulls the bird's toes into a curled position and they tightly grip the branch. The bird can't uncurl its toes until it stands up and relaxes the tendon's pull on them.

"Young Naturalist" from
Texas Parks and Wildlife
magazine, November 1988

Winging It

by Ilo Hiller

The human body was never designed to fly. Although our desire to be airborne has led us to invent machines that can take us faster and higher than any flying creature, we will never be able to get off the ground on our own. Our bodies are too heavy and unstreamlined, and the muscles that control the bones of our hands and arms cannot lift us into the air.

Flying animals and nonflying animals have muscles in different places. Since walking is our primary means of locomotion, our largest muscles are in our legs. If we develop our arm and shoulder muscles we can grip an overhead object, such as a chinning bar, and lift our bodies from the ground. However, this takes a lot of effort and, depending on the strength of the individual, can be done only a few times. Doing push-ups will lift most of your body away from the ground, but to do push-ups you must position your hands and arms close to your body. If your arms were extended during a push-up the way a bird's are for lift-off, you probably couldn't lift your body at all, and you certainly couldn't fly.

In a bird, large outside breast muscles are attached to the underside of the upper arm bones. These large muscles pull the wings down. An inner set of breast muscles is attached to the top side of the upper arm bones to pull the wings up. The other ends of both sets of breast muscles are attached to the breastbone. The depth (keel) of this breastbone varies with the bird species and is a good indicator of the flying power of the bird. The deeper the keel, the more wing muscles the bird probably has.

Nonflying birds normally do not have large keels or greatly developed breast muscles. The ostrich, which walks rather than flies, has its main muscles in its legs as humans do. And speaking of humans, it is estimated that a person weighing 150 pounds would need to have a breastbone keel projecting outward six feet to accommodate muscles large enough to operate wings and fly.

Let's take a look inside the wings of three very different flyers – a reptile, a mammal and a bird – and compare the bone structure of their wings with our arms and hands.

Going back more than 65 million years to the time of

The bones of this roseate spoonbill's wings are almost visible through the bird's skin. Muscles attached to the breastbone move the wings up and down.

the dinosaurs, we discover one of the first flyers – a large winged reptile called the pterodactyl (tair-ah-DACK-til).

For years, scientists have disagreed over whether pterodactyls could actually flap their huge wings up and down in flight or whether they used their wings primarily for soaring and gliding. Since humans weren't around when pterodactyls lived on the earth, this argument can never be settled. You will just have to decide for yourself whether you believe these creatures were able to take a little hop and, by using a strong wing stroke, become airborne; or whether they had to climb to a high spot, take off in a glide and catch rising air currents to stay in the air.

Paleontologists (those who study fossils) tell us that pterodactyls had no feathers. They were true members of the reptile family, but their bodies were covered with a furlike substance and they flew on leathery, batlike wings. Most of the fossilized pterodactyl bones that have been found by paleontologists came from specimens with wingspans of 20 to 25 feet; however, during the 1970s a 21-inch pterodactyl upper arm bone was discovered in Big Bend National Park. It is estimated that this giant reptile had a wingspan of about 51 feet.

In the illustration you can see that the pterodactyl's "hand" is attached to its upper and lower arm bones. Its "thumb" and three of its "fingers" are not enclosed in the wing. The top edge of the wing is attached to the long bones of its fourth "finger." Fossilized tracks indicate that when pterodactyls were on the ground they walked on their feet and used their wing hands as front feet, probably scuttling along the way bats do today. The tips of the wings were probably folded back over the body out of the way. The clawlike hands on each wing also may have been used batlike when climbing and possibly could have been used for hanging when resting or sleeping.

Flying reptiles disappeared about the time flying mammals (bats) appeared on the scene. Fossil records show that bats have changed very little during the last 50 million years. In fact, one 40-million-year-old fossil belongs to the same genus as the European horseshoe bat.

There are several distinct species of bats in the world today, but their wings all follow the same general plan of construction. Unlike the "hand" of the pterodactyl, only the "thumb" of the bat is not enclosed in the wing. The bat uses this clawlike thumb for clinging to branches or the rocky walls of caves, and for grooming. Bats also scuttle around on the ground by using their "wrists" as front feet.

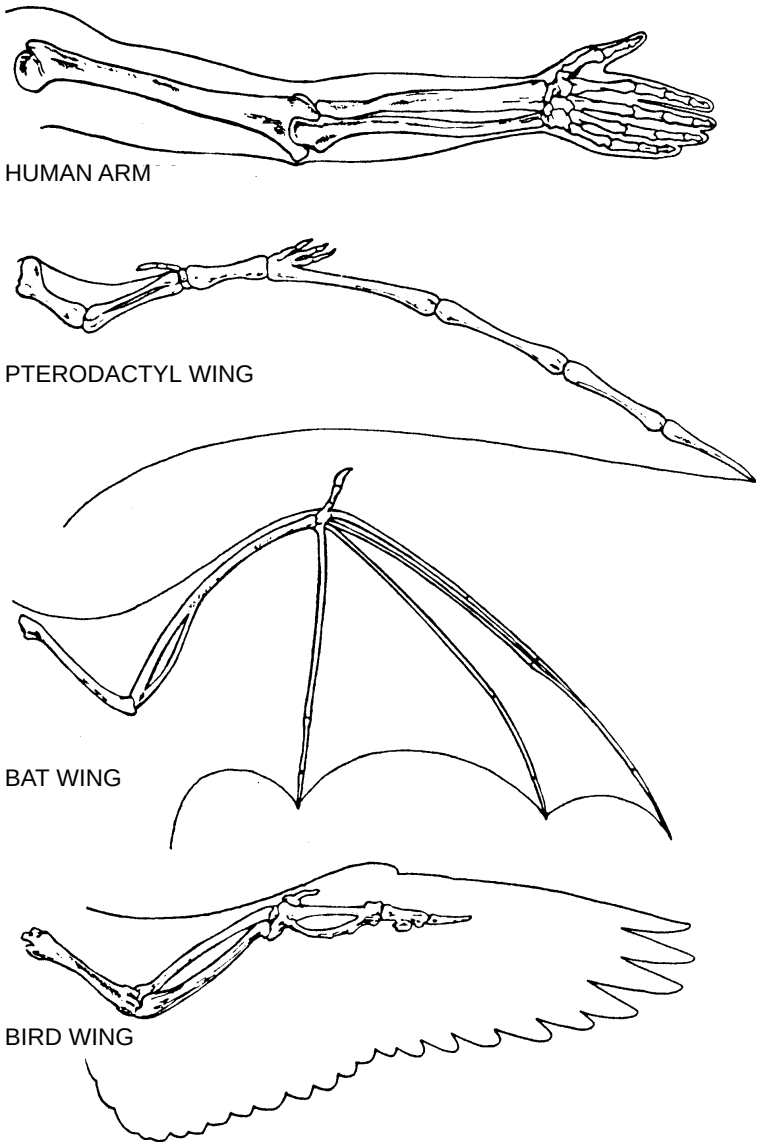


Illustration by Patrick Stark

The thumb and three fingers of the pterodactyl are outside the wing. However, everything but the bat's "thumb" is enclosed in the wing membrane. The structure of the bird's wing and the human arm are similar except in the hand area.

The bat's long "finger" bones are enclosed in the thin layer of skin that forms the wing membrane, and they give it support by extending from the front edge to the back. The wing membrane has about ten times the surface area of the bat's head and body, and it contains a network of small blood vessels and nerves. The wing is attached to the hind leg for additional support, and some species of bats also have another membrane stretched between their hind legs.

The real work of flying is handled by large muscles attached to the upper arm bone and shoulder blade. With the exception of the small ones that extend to the fingers and are used to spread and fold the wings, muscles are not found in the bat's wing. The wing is merely skin and bone held together by ligaments and tendons. Fine hairs grow on the upper and lower surfaces of the skin.

Unlike the rigid wings of an airplane, the living wing of the bat must provide both lift and forward thrust, and be able to handle turns in all directions. It must be able to change shape for landings, takeoffs and different species, and fold out of the way when not being used for flying.

When the bat's wing is folded close to its body, the membrane does not form large flaps or pleats, as a piece of cloth would do. Instead, the wing's surface is composed of hundreds of tiny, crescent-shaped pockets that fold individually like the petals of a flower. The wing seems to shrink as it is folded and it takes up very little space.

At the time prehistoric bats appeared, prehistoric birds had been around for millions of years. From its fossil remains scientists recognize the Archaeopteryx (ar-kee-OP-te-ricks) as being the first bird – a possible link between reptiles and the many different kinds of birds that would follow. This prehistoric bird, which lived about 140 million years ago, was no larger than a crow or pigeon, had heavy bones that looked like those of a reptile, a long beaklike face (no horny bill) with sharp, conical, lizardlike teeth. Scientists believe it was more of a glider than a flyer, climbing trees to get altitude and relying on air currents to stay aloft.

There are only two known skeletons of the Archaeopteryx and these bones and feather impressions are preserved in limestone. From them, we have discovered that this prehistoric bird had short wings with primary and secondary feathers arranged much as they are in modern birds. However, the hand bones were separate and the digits free. It had three fingers equipped with claws. Its long lizardlike tail was composed of 23 separate vertebrae with a pair of feathers springing from each one. (Modern birds' tail feathers spring from a triangular bony plate at the end of their short rudimentary tails.)

As birds evolved from the Archaeopteryx, many of them developed incredible flying ability. Some can fly more than 2,000 miles nonstop across the ocean while others can glide for hours on air currents without flapping their wings. Birds can glide, soar, dive, brake, turn and bank. Some not only fly forward, but also stop, hover and fly backwards.

When we compare the structure of the bird's wing to the human arm and hand, we find they are very similar except in the hand area. The human hand with its dexterous fingers evolved into a structure that can make and use complicated tools and accomplish intricate tasks. A bird's hand is less complicated. Many of the bones have disap-

Large soaring birds such as this turkey vulture have long, broad wings. Turkey vultures can glide for hours on air currents without flapping their wings.

Bill Reaves

peared and others have lengthened and fused together. Fewer bones makes the wing "hand" less flexible than our hand, but the fused bones are more rigid and stronger. This added strength is needed since the outer section of the wing is where the greatest strains occur during flight. The section of wing between the shoulder and wrist moves very little during flight.

Wing joints in the bird are designed to help withstand the strain of flight. The "wrist" is joined together so the hand section is in proper alignment with the rest of the wing, and it does not rotate as ours does. Since the "elbow" cannot bend in the direction that receives the greatest stress during flight, there is no need for special muscles to hold the wing stiff. The "shoulder joint" also is shaped to hold the wing at the proper angle for the most effective lift for flight. These three joints also fold the wing sections into a tight "Z" against the side of the bird's body.

Although all wings are basically the same, they do have different shapes and flight characteristics, and a bird's life style is tied in with its wings. Ground birds, such as quails and pheasants, have short, rounded wings that allow them to make almost vertical takeoffs and quick escapes. Open-country speedsters, such as swallows and swifts, dart about on narrow swept-back wings. Eagles and other large soaring birds have long, broad wings.

If humans had understood in the beginning that a bird does not fly merely by flapping its wings up and down, the secret of flight might have been discovered long before it was. The first attempts with wax and feather wings, paddles and various other contraptions strapped on the arms were failures. Inventors also could have skipped the first flying machines with mechanical wings that flapped up and down and were powered by human muscle. Real flight became possible when humans learned the principals of aerodynamics – a moving stream of air passing over the wing produces lift, and changing the angle of the wing increases lift.

A plane can change the angle of its wing by lowering flaps along the trailing edge of the wings. A bird does it by changing the angle of its entire wing.

Skin and feathers cover the wings. Small feathers called coverts streamline the wing and serve as protection. Primary and secondary flight feathers make up the sail area needed to stay airborne. On the first powerful stroke of the wing, the broadside of the primary feathers (those attached to the "hand") bite the air at an angle, driving it forward. On the upstroke, the wings bend and the primaries open like louvers to lessen air resistance while the rearward flip of the wings add another forward thrust. With several such strokes, the bird is on its way.

Once airborne, the effort is diminished since most of the lift is provided by the shape of the wing. Air flowing over the curved upper surface travels faster than air passing beneath the flat undersurface. This creates an area of low pressure above the wing forcing it upward. The primary tips add their own airfoil effect. A bird can move each feather independently by contracting muscles near the base. This allows the bird to adjust feather positions to take advantage of air currents in the best possible way. When rising air currents, called thermals, provide additional lift, the bird may travel without flapping its wings.

The wings and the muscles that control them are fascinating to study, but even more amazing is the way the bird's whole body system is synchronized for flight. The bones are hollow to make them lightweight, but are reinforced with internal struts for strength. Diets are high in energy-rich foods, and the digestive systems are geared to rapid processing. Birds have extremely efficient lungs and circulatory systems and can fly great distances before getting tired. The muscles that power the wings also contract and expand the rib cage, filling and emptying the lungs with each wing beat. As the bird breathes, some air passes directly to the lungs and into the tiny tubules where oxygen reaches the blood. However, much of the air bypasses the lungs and goes into a series of air sacs located in other parts of the body. This air, which retains its oxygen, passes back through the breathing tubules of the lungs when the bird exhales. This allows the bird to obtain oxygen as it inhales and exhales.

Much more could be said about these amazing flyers and the principles of flight, but perhaps this glimpse into the fascinating world of wings will stimulate you to do some research on your own.

PWD LF C2000–139M (6/94)
Dispersal of this publication conforms with Texas State Documents Depository Law, and it is available at Texas State Publications Clearinghouse and/or Texas Depository Libraries.