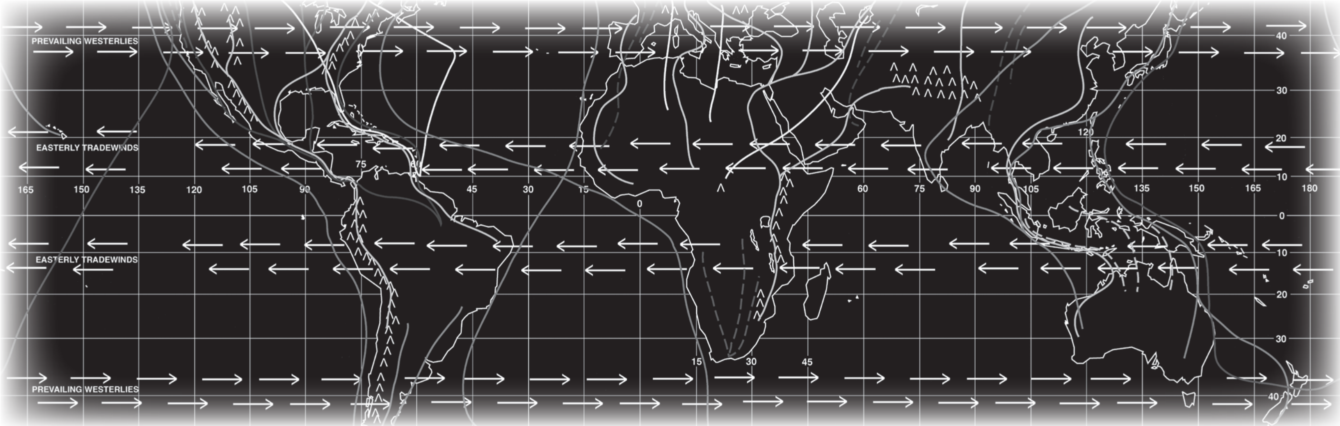
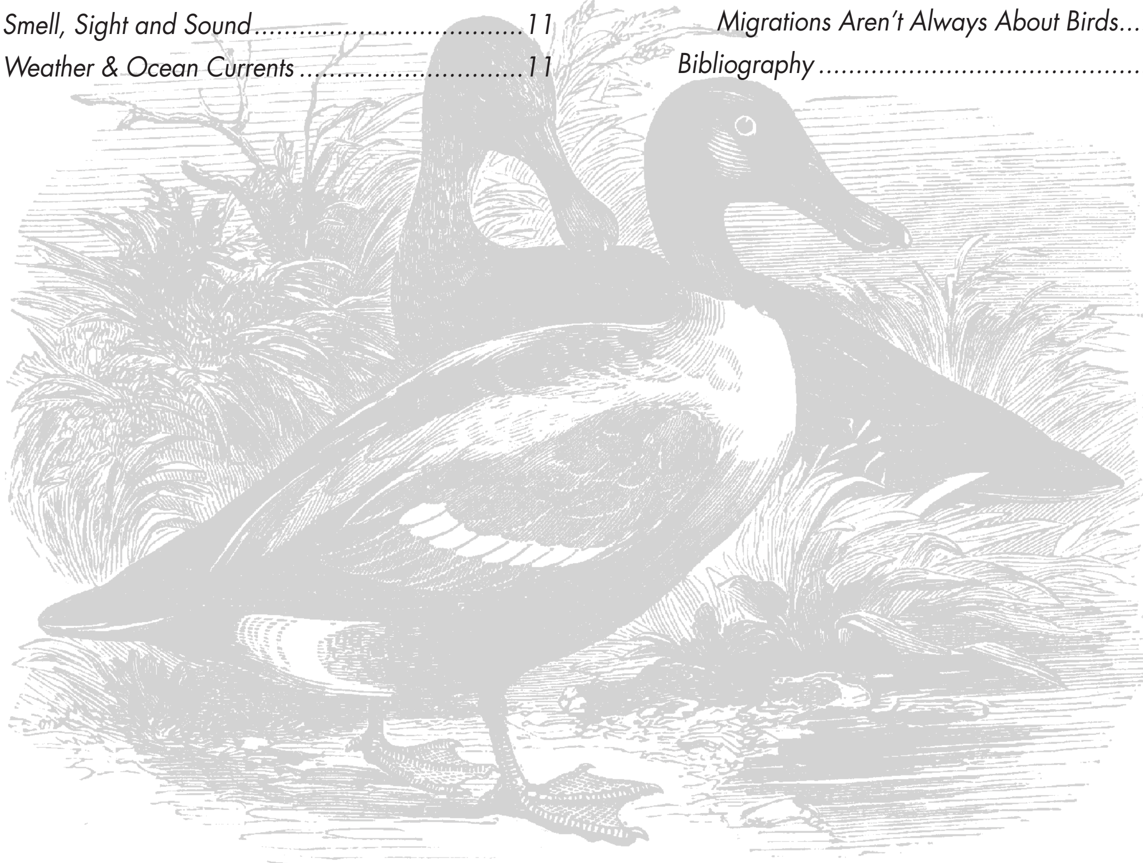


A Collection of Curricula for the STARLAB® Bird Migration Cylinder

Including:

The Bird Migration Cylinder Curriculum Guide by John T. Meader of Northern Stars Planetarium

Curriculum Guide Contents



The Bird Migration Cylinder Curriculum Guide

Contributed by John T. Meader, Northern Stars Planetarium

Introduction

Bird Migration is a worldwide phenomenon that happens for many varied reasons. Temperature changes, seasonal fluctuations in food supplies, breeding needs, and territorial considerations all play a role in the why of migration. Routes vary from species to species, as well as from bird to bird. How routes are found and followed is a fascinating aspect of this yearly pilgrimage that scientists are exploring.

In this guide you will find information to help your students address all these areas. The Bird Migration Cylinder features the general routes of only fourteen specific species of the hundreds of bird species that migrate. However, the cylinder is designed to give you an overview of several different types of migrations that are typical of many species.

You will also note that prevailing winds, mountain ranges, and magnetic poles are shown on the cylinder. Using these features, students will be able, with assistance, to begin to uncover how birds use prevailing air currents, land formations (such as mountains, rivers, islands, and seas), Earth's magnetic field, and the location of already established bird communities to assist (or sometimes hinder) them on reaching their seasonal destination.

The major features to be noted on the cylinder are:

- General migration routes for fourteen specific bird species.
- The four major waterfowl flyways unique to North America.
- Generalized routes used by many birds of prey.
- Prevailing winds.
- Major mountain ranges.
- "Staging and congregating areas" marked by dots.
- The magnetic North & South Poles, which some birds use to help them with navigation.

Note

Throughout this guide, whenever bird species or terms that are featured on the cylinder are discussed, their names will be in **bold type**.

The Birds & Features Found on the Cylinder

Bird Species

African Paradise Flycatchers	Africa
Albatross	South Seas
Arctic Terns	Arctic & Antarctic, Atlantic & Pacific
Blackpoll Warblers	North & South America
Fox Sparrows	North America
Hawks & Vultures	Americas, Eurasia & Africa
Pacific Golden Plovers	Pacific, North America, Asia
Redwing Thrushes	Eurasia
Redshanks	Eurasia & Africa
Sacred Kingfishers	Australia & South Pacific
Short-Tailed Shearwaters	Pacific
Snowy Owls	North America & Eurasia
Swift Parrots	Australia & Tasmania
Two Banded Plovers	South America
Willow Warblers	Eurasia & Africa

Waterfowl Flyways of North America

- Atlantic Flyway
- Central Flyway
- Mississippi Flyway
- Pacific Flyway

Staging Spots

Areas where birds congregate during migration.

Prevailing Winds

- North Polar Easterlies
- North Easterly Trade Winds
- South Prevailing Westerlies
- North Prevailing Westerlies
- South Easterly Trade Winds
- South Polar Easterlies

Physical Features

- Magnetic North and South Poles
- Major Mountain Ranges

Coordinates

- Equator
- Tropic of Capricorn
- Antartic Circle
- Tropic of Cancer
- Arctic Circle

Facts About the Featured Birds

Species	Weight	Wingspan	Migration Length
African Paradise Flycatchers	15 g 0.5 oz	24-28 cm 9.5-11 in	500-1,800 km 300-1,100 miles
Albatross	6-11 kg 13-25 lbs	2.5-3.5 m 8-11 ft	5,000-20,000 km 3,000-12,500 miles
Arctic Terns	80-120 g 3-4 oz	75-85 cm 29-33 in	15,000-20,000 km 9,300-12,500 miles
Blackpoll Warblers	11 g 0.33 oz	20-24 cm 8-9 in	4,000-8,000 km 2,500-5,000 miles
Fox Sparrows (Pacific Populations)	42-45 g 1.5 oz	27 cm 10.6 in	950-5,600 km 600-3,500 miles
Pacific Golden Plovers	90-150 g 3.25-5.25 oz	60-67 cm 24-26 in	5,000-13,000 km 3,000-8,000 miles
Redwing Thrushes	35-75 g 1.25-2.5 oz	33-35 cm 13-14 in	1,000-6,500 km 600-4,000 miles
Redshanks	90-150 g 3-5 oz	59-66 cm 23-26 in	500-6,500 km 300-4,000 miles
Sacred Kingfishers	30-60 g 1-2 oz	29-33 cm 11-13.5 in	0-3,900 km 0-2,400 miles
Short-tailed Shearwaters	480-800 g 1 lb-1 lb 12 oz	97 cm 38 in	11,000-13,500 km 6,800-8,500 miles
Snowy Owls	1.2-2.95 kg 2 lbs 10 oz-6 lbs 8 oz	1.4-1.66 m 4 ft 8 in-5 ft 5 in	500-5,000 km 300-3,000 miles
Swift Parrots	50-75 g 1.75-2.66 oz	33-36 cm 13-14.5 in	350-2,500 km 200-1,550 miles
Two Banded Plovers	40-60 g 1.5-2 oz	45-55 cm 18-22 in	0-3,600 km 0-2,250 miles
Willow Warblers	8-12 g 0.3-0.4 oz	20 cm 8 in	4,000-14,000 km 2,500-8,700 miles

The three following species are not plotted specifically on the cylinder, but generally follow the North American Flyways to winter in Central America. They are frequent subjects of discussions within the enclosed lessons.

Species	Weight	Wingspan	Migration Length
Ruby Throated Hummingbird	3-3.5 g 0.01-0.02 oz	10-12 cm 4-4.75 in	0-6,000 km 0-3,500 miles
Indigo Bunting	14-30 g 0.5-1 oz	15.25-24 cm 6-9 in	760-5,600 km 470-3,750 miles
American Robin	77 g 2.75 oz	37-42 cm 14.5-16.5 in	0-6,400 km 0-4,000 miles

Why Do Birds Migrate?

Temperature

When asked why birds fly south every fall, the average middle school student will tell you that birds leave because of the cold. There is some truth in that, but it is far from the whole story. It's important to point out that not all birds migrate. Chickadees, jays, woodpeckers, redpolls, and nuthatches are among the many species that generally stay put through the winters of North America. Some of these birds are quite small—surely if the cold were the sole reason for leaving, these tiny birds would leave too.

Food

While there are certainly many birds that would have a difficult time with the cold temperatures of a northern winter, perhaps the largest single factor for migrating is food. Consider the many warblers that visit central and northern regions of the northern continents. These birds eat primarily insects, which are very prolific throughout the summer months. In autumn, the number of insects decreases steadily. With this decline, warblers must leave to warmer climes where their food supply is still available.

Waterfowl (ducks, geese, loons, and waders such as egrets and herons) feed on fish, frogs, crustaceans, and aquatic plants. Thousands of lakes, ponds, bogs, rivers, and coastal estuaries provide an abundance of food for these birds. In winter, when many of these areas freeze over, it forces these birds to move in search of open water. Many waterfowl will fly hundreds—even thousands—of miles to a wintering ground, however, many will only go as far as the nearest open water. Even deep in the heart of a northern continent in the middle of January, it is not uncommon to find dozens of ducks huddled around an open lead of gently moving water along a river. Perhaps their migration might take them from an inland lake to the ocean—a journey that might be as great as 2000 miles (3200 km) or as short as 10 miles (16 km). Migratory journeys vary greatly from species to species, and from individual to individual.

Snowy Owls and some **hawks** only migrate south when their food supply of small rodents (mainly lemmings and voles) is scarce. For unknown reasons, the lemmings, for instance, have drastically fluctuating populations, peaking about every four years then crashing almost to extinction. When food supplies are abundant, these birds of prey stay north all winter.

Territorial Considerations

Territory can be a defining factor in how far a bird migrates. A good example of this is a phenomenon known as "Leap-frog Migration." Leap-frog Migration is what happens when a bird species has an extended north/south range. The birds who live in the central part of the range migrate only a short part of the range, but when the birds at the extreme northern edge of the summer range migrate, they must over fly their southern neighbors because the territories are all taken, forcing them to fly further south to find open territory.

Two examples of this behavior can be seen on the cylinder with the **Fox Sparrows** of the American Northwest and the **Redshanks** of Eurasia. Populations of **Fox Sparrows** who summer in British Columbia move to Washington State and Oregon for the winter. When the Alaskan populations travel south, they find the Oregon territories already taken by the more southerly British Columbia summer populations. They then must keep going—thus "leap-frogging" the British Columbia **Fox Sparrows**—until they reach open wintering grounds in California.

The same type of behavior is found throughout Eurasia with **Redshanks**, a common wading bird. **Redshanks** that live in Central Europe migrate to the Mediterranean Coast, while **Redshanks** that live in Scandinavia must leap frog the Central European populations further south into Africa where they can establish their own territories.

How Do Birds Find Their Way?

Birds use many different methods to navigate between their summer and winter grounds. Following are some of the best known methods.

Landforms and Flyways

Landforms both help and hinder migration. A landform that helps one bird may be a major hindrance to another.

In 1952, waterfowl biologist Frederick Lincoln noticed how North America's distinct landforms provided waterfowl with four main pathways of migration. He coined the idea of "flyways," though today, we know that the flyways concept must be used in only the broadest terms. Lincoln recognized that many birds seemed to follow both the east and west coasts during their migrations, providing them with both distinct paths to follow north or south and ample supplies of food along the way. Also, both flyways were bordered inland by mountains: the Appalachians in the east, the Sierras, the Cascades, and the Western Rockies along the Pacific. These two great pathways he named the **Atlantic** and **Pacific Flyways**.

Lincoln then distinguished two interior routes through North America: the **Mississippi Flyway** and the **Central Flyway**. The **Mississippi Flyway** is the longest flyway originating in the Mackenzie delta on the Arctic Ocean. It moves south through central Canada, through the Great Lakes, and then down the Mississippi River system. For more than 3,000 miles (4,800 km), it runs without any intervening mountain ranges. The **Central Flyway** follows the eastern ranges of the Rocky Mountains and the western Great Plains. Since water and food are important to waterfowl and many other migratory species, these four basic pathways amply meet that need. Also all four flyways provide strong visual clues in the form of a landform roadmap to help the birds navigate. Coastlines, mountain ranges, rivers and lakes all provide key landmarks to assist the birds along their way.

Today, however, it is widely recognized that birds do not necessarily fall into a specific "flyway" and follow it to their destination. While some individuals and some species seem to follow the flyway guidelines fairly precisely, many do not, hopping from one flyway to another and perhaps back again. Many birds make their own way regardless of the flyways we perceive.

It is also important to remember that what is an obstruction to one species may present a free ride to another. Mountains present a major obstacle for many songbirds that often must fly hundred of miles around them; while, to many **hawks**, the updrafts found along mountain ranges provide a free lift that carries them along their way. On the other hand, when small songbirds reach the Gulf of Mexico in North America or the Mediterranean Sea in Europe, these large bodies of water are not major obstacles. They simply fly across them. When a hawk reaches such a large expanse of water, their forward direction stops and they must fly around the water, as no updrafts are present over open water.

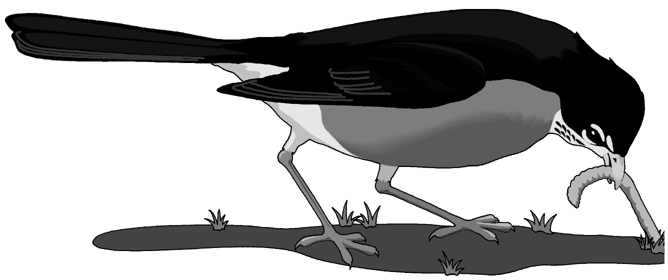
Sun Compass

Experiments have proven that many daytime migrants use the Sun to help with a sense of direction. Birds held in special enclosures where the apparent direction of the Sun was altered, reoriented their migratory direction with the new location of the Sun.

Note

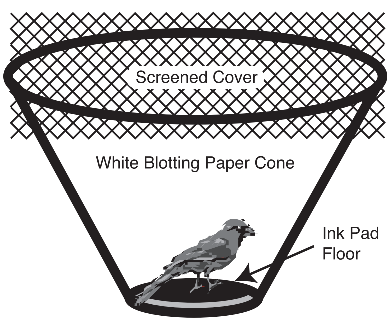
The birds in this experiment did not actually fly in these enclosures, they simply hopped in the direction they tried to go. The phenomenon of caged birds becoming restless and trying to escape in the direction they would migrate is known as "Zugunruhe" or "migratory restlessness." This phenomenon is utilized in many of the experiments, such as this one, testing migratory birds.

Of course the Sun's position in the sky changes from easterly in the morning, to westerly in the afternoon. Sun navigating birds all orient to the proper angle from the Sun to head south (during a fall migration) for the time of day. They continually adjust their angle to the Sun accordingly as the day progresses. It seems they have a rather accurate internal clock mechanism that aids them in knowing where the Sun should be at any given time of day.



Magnetic Field Detection

It has long been thought that many birds may use the natural magnetic field of the Earth to help them navigate during migration. But how does it work? Does a bird really work like a compass? Yes! An experiment with robins in a cage surrounded by magnetic coils—so that the magnetic field within the cage could be changed—helped to prove the point. During spring migration, the birds naturally aligned northward with Earth's magnetic field. When the field was artificially changed so that magnetic north seemed to come from the southeast, the birds gradually started to change to the new perception of north as indicated by the artificial magnetic field. Within three days the birds were all aligned to the artificial north of the experiment and were trying to fly toward the southeast. It is believed that the birds can detect the magnetic field through small magnetite crystals that are situated near the bird's nostrils.



Star Compass Testing Cage

Star Compass

Many species of birds migrate after dark. How do they find their way when the ground landforms are less evident? Some may use magnetic field detection, or smells and sound. Some may use stars.

In 1967, Stephan Emlin, a Cornell University ornithologist, did an experiment to test whether Indigo Buntings used stars to find their direction of migratory travel. He built special cages that were cone shaped with a small inkpad floor. The cones were made of blotting paper to record the birds' movement within the cage. The cones opened to a wide top with a wire mesh screen cover. Each cage held one bird. Utilizing the bird's restlessness to migrate, the birds were placed within individual cages in a planetarium. When the night sky was simulated, the buntings paced nervously within the cages, occasionally jumping up on the cone in attempts to escape. The blotting paper recorded their footprints as they slid back down the cone onto the inkpad in the bottom. When the night was over, each paper cone recorded the motions of each bird. They showed that the majority of hops to escape were in the direction of south in relation to the stars projected overhead. To see if the birds were really using the stars, the star field was reversed so that the North Star was located in the south rather than in the north. When the experiment was done again, the birds changed their orientation. In a control group where no stars were shown, the birds hopping activities were random. The Indigo Buntings were clearly utilizing the stars for navigation.

Further investigation showed that it was not so much the star patterns that the birds were watching as it was the stars' motions. Stars rise and set just as the Sun does. This is, of course, due to Earth's rotation on its axis. Because Polaris, the North

Star, lies nearly directly above the north polar axis of Earth, it never moves. It turns out that it is the continuous apparent motion of stars around Polaris that the Indigo Buntings are aware of when they migrate. When young Buntings were raised in an artificial sky environment so that the stars all revolved around Betelgeuse, a star in the constellation of Orion, they yearned to fly towards this fake pole star in the spring and away from it in the fall.

Smell, Sight and Sound

Birds also use smell and sound to help them migrate. These senses may play a larger role when the bird arrives at the basic area it is headed for, where it uses sight, hearing and smell to find a specific location. Sounds such as the call of other birds, frogs, highways, surf, and wind can be important signals when a bird is searching for its nesting area. Smells of salt marshes, certain plants, or the strong smell of guano from a bird colony can be unmistakable. The sight of landmarks such as tall trees, cliffs, large buildings, steeples, highways, headlands, and beaches are also strong local clues to finding a specific spot.

Weather & Ocean Currents

Weather plays a huge role in bird migration. Not only do storms bring accidental bird visitors to foreign shores where they never intended to go, but birds also use prevailing winds and rising thermals as migratory aids.

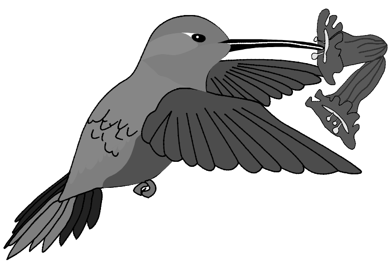
The **Blackpoll Warbler**, which summers in northwestern Canada, seems to fly a rather strange migratory path at first glance. Leaving the Yukon, for example, it heads southeast to New England and continues southeasterly right out to sea for several hundred miles before turning abruptly southwest to its wintering grounds in northeastern South America. In the spring, it does not reverse its course, instead it flies northwest through the West Indies, Cuba, and Florida. Then it continues northwest across the heart of North America until it reaches its summer breeding grounds in northwestern Canada.

Why this strange off-shore path each fall for such a tiny land bird? Study the prevailing wind patterns and you will see that in the mid-latitudes, we have a prevailing westerly wind that carries our tiny-feathered friend to sea. The point where it makes its abrupt turn to the southwest is when it reaches the easterly trade winds of the sub-tropics, which in turn carry it to shore. The **Blackpoll Warbler** lets the wind do much of the work while it moves itself southward. It doesn't waste time fighting that ever-present wind; instead it puts the wind to work. Of course on the return trip, the easterly trade winds will help carry it northwest through the Indies into the southern United States. The only time it must fight the wind is for the final leg of the migratory journey northwest across the heart of North America.

Albatross. Courtesy U.S. Fish & Wildlife Service.

Hawks use the rising thermals off mountains and islands to lift themselves high into the sky. Then, they soar downward in their migratory direction in search of another thermal that will carry them up again. Repeating this process carries them great distances with hardly a wing-beat.

Albatross ride the small updrafts off waves as they glide for days riding the winds that follow the ocean currents of the South Seas.



Amazing Migration Facts

- There are always birds migrating somewhere on Earth at any given moment, day or night; spring, summer, winter or fall.
- The **Arctic Tern** is the long distance migration champ. These birds migrate from the Arctic to the Antarctic every fall, and then they return back to the Arctic again in the spring. That's a 25,000 mile (40,300 kilometer) round trip each year! Each migration takes approximately 3 months.
- In a single night, as many as 12 million songbirds have been detected by radar flying over Cape Cod during autumn migration.
- Ruby Throated Hummingbirds fly non-stop for 600 miles (970 km) across the Gulf of Mexico in just over one day as part of each migration. Considering that Ruby Throated Hummingbirds beat their wings an average of 70 times per second, flying constantly for more than 24 hours amounts to more than 6 million wing beats in one day without a break. And, these birds weigh in at only 0.1-0.3 ounces (2.5-8 g).
- The **Wandering Albatross** has the longest wingspan of any bird, often exceeding 11 feet (3.5m). It soars for days at a time just feet off the ocean's surface, receiving small updrafts off the waves themselves. They breed only once every two years because it takes nearly a year to raise their young. During that time they will migrate continuously with the prevailing ocean currents and prevailing winds of the southern oceans and circumnavigate the globe.
- Most songbirds migrate at night. Many use the stars as navigational aids. Birds that migrate at night include: warblers, hummingbirds, Indigo Buntings, robins, and many more.
- Some migrating birds such as robins can detect Earth's magnetic field like an internal compass. They are believed to use this ability to aid them in navigation during migration.
- 5 billion North American land birds (500 species) migrate south annually to Central and South America.
- Caged migratory birds experience something called "migratory restlessness" or "Zugunruhe" in which they become uneasy during the time when they should be migrating. During the fall southern migration, the birds tend to move to the south side of their cages and try to get out. The opposite is true during the spring northward season. This phenomenon is utilized in many experiments with migratory birds such as those testing stellar navigation and magnetic field detection.
- Not all birds fly when they migrate. When the snows arrive, the Blue Grouse leave—on foot—from the foothills of the Rocky Mountains where they summer, and walk to the bitterly cold wind-driven high country in search of conifers. That's a migration to a harsher climate—but one with food!
- During peak **hawk** migration in Veracruz, Mexico, nearly a million **hawks** have been counted flying by in a single day!
- **Arctic Terns** spend the summer in the Arctic and the winter in the Antarctic—both are regions of nearly continuous sunlight. In this way, they experience more hours of daylight in a lifetime than any other living thing.
- **Pacific Golden Plovers** fly non-stop for 35 hours from Alaska to Hawaii. To accomplish this amazing flight, they maintain an average speed of nearly 60 miles per hour (100 kph).

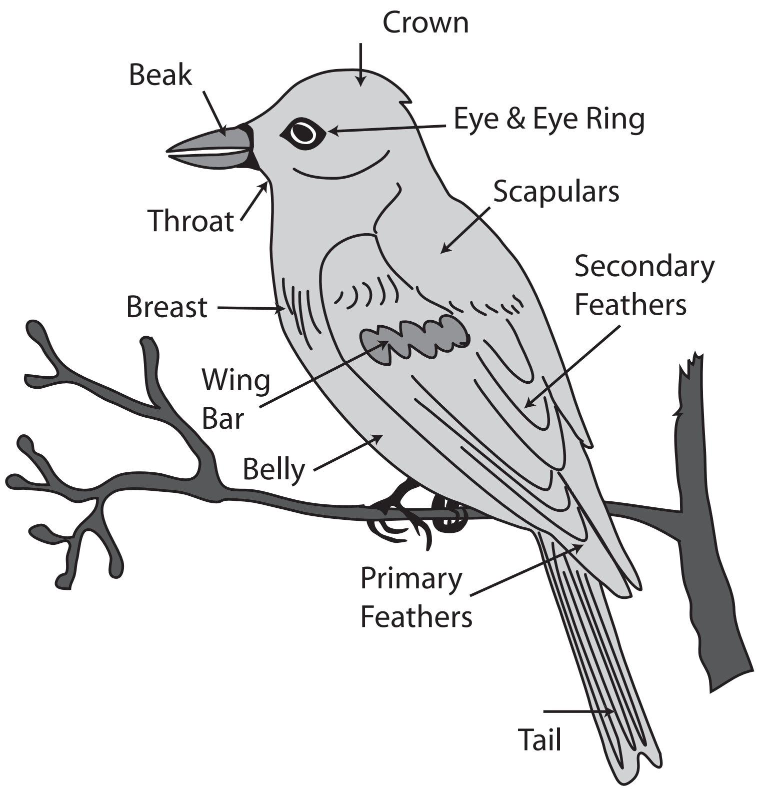
- Penguins migrate long distances by swimming!
- Many birds migrate at great altitude. Bar-headed geese fly over the Himalayan Mountains at altitudes of nearly 30,000 feet (9,000 meters)! Whooper Swans have been seen by pilots as high as 27,000 feet (8,230 meters). Even the common Mallard Duck has been seen as high as 21,000 feet (6,400 meters).
- Flying in V-Formation has always been thought to provide lift for the trailing birds, thus saving valuable energy. However, recent studies suggest that most geese, for example, do not fly close enough together to get any lift from the bird ahead of it. The reason for the V-formation is still a mystery.

Blue Jay. Courtesy of U.S. Fish & Wildlife Services.

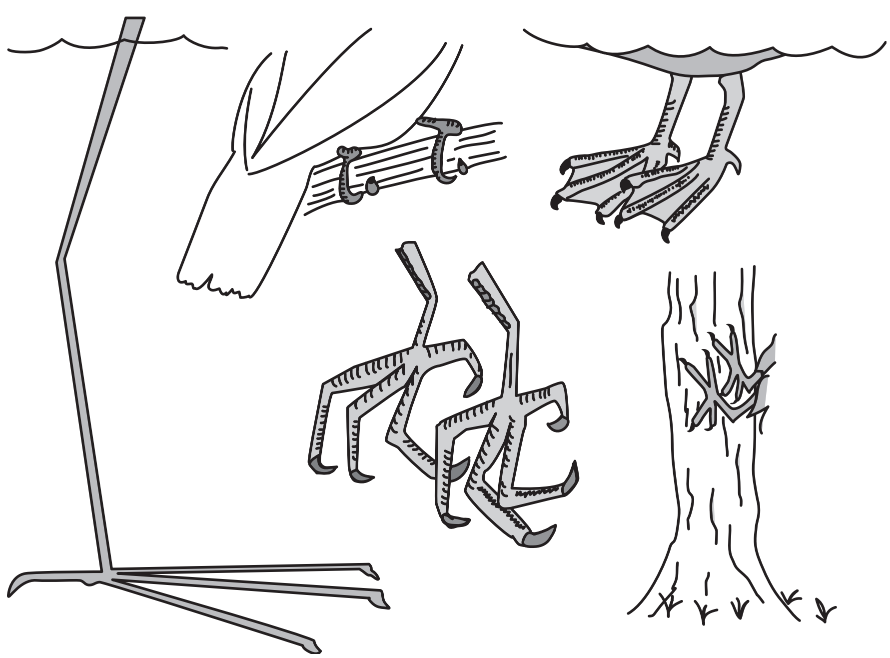
Amazing Bird Facts

- The fastest flying birds are Swifts that have been clocked at over 200 miles per hour (320 km/hr).
- The fastest swimming birds are Penguins. They can swim more than 25 miles per hour (40 kph).
- The tallest and heaviest bird is the Ostrich, which is over 8 feet (2.4m) high and can weigh over 300 pounds (136 kg).
- An Ostrich's eye is larger than its brain.
- Ostriches can run 40 miles per hour (65 kilometers per hour)!
- Passenger Pigeons were once the most abundant bird on the Earth. Alexander Wilson estimated a single flock he saw as having two billion birds! John James Audubon watched one flock take three days to pass overhead. He estimated that 300 million birds flew by him each hour! Yet, their abundance could not withstand 19th century hunting practices when people would shoot them by the thousands. The very last Passenger Pigeon was a female named Martha at the Cincinnati Zoo; she died in 1914.
- There is no blue pigment in a Blue Jay's feathers. Feathers (in any bird) that are either blue or iridescent produce those colors by refracting and scattering light.
- Brown Headed Cowbirds never build nests or raise their own young. Instead, they lay their eggs in another bird's nest, which fools this species into raising their chicks.
- Ruby Throated Hummingbirds beat their wings 70+ times per second. They can fly in any direction—even backwards—and eat 50% of their body weight each day.
- The smallest bird is the Bee Hummingbird of Cuba which is only 2.24 inches (5.7 cm) long and weighs 0.056 ounces (1.6 g).
- Birds are so closely related to dinosaurs that some scientists believe birds are dinosaurs!
- There are more than 9,700 species of birds worldwide, divided up into 23 orders, 142 families and 2,057 genera.
- The Sooty Tern remains continually aloft for 3 to 10 years before returning to land to breed. It seems to almost never land. It does its eating, drinking and even sleeping while it flies!
- The Pitohuie of New Guinea is the world's only poisonous bird. It's skin and feathers contain a toxic alkaloid similar to that of poison arrow frogs.
- The highest flying bird recorded was a Ruppell's Vulture which collided with a commercial aircraft over the Ivory Coast at an altitude of 37,000 feet (11,278 meters)! The plane was damaged but landed safely. The vulture wasn't so lucky.
- The greatest age ever recorded for a bird was a Sulfur-Crested Cockatoo at the London Zoo that lived for 80 years.
- The heaviest flying bird is the Kori Bustard of Africa, which have been recorded weighing 42 pounds (19 kg). The Mute Swan comes in a close second at 40 pounds (18 kg).

Bird Parts



Bird parts vary considerably from species to species. Examine the following feet and consider how each is developed to its own habitat. Where does it live? What might it eat?



Materials

- STARLAB Portable Planetarium
- Bird Migration Cylinder

STARLAB Activity 1: Investigating Migration Routes

Objectives

To have the students gain an understanding of why different birds travel the migratory routes that they do. Discover the forces and influences that lead to the migrations we see.

Suggested Grade Levels

With proper modifications, this activity can be either simplified or expanded upon for grade levels three and up.

Integrated Subjects

Science • Geography • Weather • Seasons • Biology • Ecology

Processing Skills

Listening • Observing • Interpreting • Discovering • Reasoning • Making Hypothesis and Conclusions

Preparation

Read the support material regarding the Bird Migration Cylinder. Pay special attention to why certain species follow the routes that they do.

Using the Bird Migration Cylinder, tilt the projector to approximately 45° so that you can see about half way down the southern hemisphere.

Procedure

Make sure that the students are seated around the edge of the dome and are comfortable.

Explain to the students that today's visit to the STARLAB will help them understand bird migration in several different ways. First, they will see a selection of migratory pathways. Second, they will learn how seasons provide the core reason for migration. Third, they will gain a perspective of why birds use the various pathways they do, and why different species use different pathways to get to where they are going.

Dim the lights and bring up the projector to full brightness. You may later choose to dim it slightly after the students become more dark-adapted, but initially use full brightness to bring out the various colors used to code the different flyways on the Bird Migration Cylinder.

Ask the students what they see. Be sure they can recognize the continents, oceans, and major landforms. It is often a good first step to locate the position of their home on the map.

Point out other features that are visible on the cylinder (but skip over the flyways for the moment) such as:

- Prevailing winds
- Major mountain ranges
- Magnetic north and south poles

- Equator
- Tropics of Cancer and Capricorn
- Arctic and Antarctic Circles
- Staging Spots

Discuss why they think these features are relevant to bird migration.

Many birds use the **prevailing winds** to help them along, riding the currents, but note that not all birds do so.

Discuss how **mountain ranges** can be obstacles for some birds (such as many songbirds) or aides along the journey for others (many birds of prey ride the thermals that come off mountains).

Point out that the same is true for general landforms such as **peninsulas**, **isthmuses**, **lakes**, **seas**, and **oceans**. Water is a necessity for all birds, so most birds prefer to fly routes that have access to shorelines, lakes, rivers, and marshes. These places are great sources of food and shelter. Point out that many small birds migrate directly across great expanses of open ocean, while soaring birds of prey avoid them as open expanses of water create no thermals to soar upon.

Magnetic poles. "Do birds carry compasses?" you might ask. Sort of. Some birds (such as robins) have been proven to be able to detect the Earth's magnetic field and seem to use it to navigate.

Point out that migration is generally (but not always) a north/south movement. The **equator** divides the north and the south. However, have your students notice that many birds do not travel south of the **equator** when they fly south. Why?

Tropics of Cancer and **Capricorn**, and the **Arctic** and **Antarctic Circles** relate to positions of the Sun at different times of the year. Explain that on the first day of summer the Sun is directly above the **Tropic of Cancer** and never sets above the **Arctic Circle**. On the first day of winter, the Sun is directly above the **Tropic of Capricorn** and never sets below the **Antarctic Circle** (and never rises above the **Arctic Circle**). Discuss how this relates to seasonal changes of climate and therefore, migration.

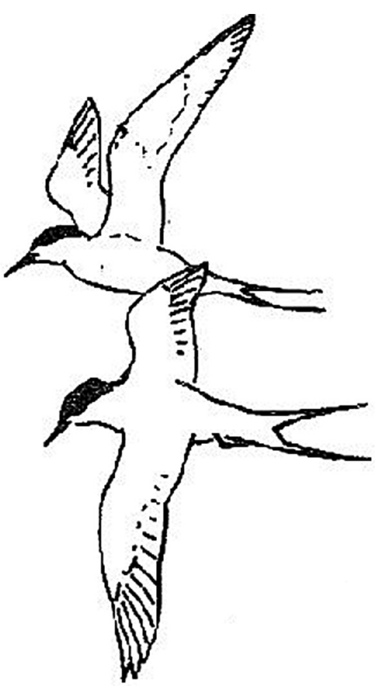
Ask why seasonal changes make birds migrate to a different wintering ground. The common answer is the cold. While it is true some birds do not like the cold, the real reason most birds leave is diminishing food supplies. Note that not all birds fly south. Chickadees are small birds that stay put all winter. Why don't they leave? Bluebirds are small birds that fly south. Why don't they stay? The answer is that chickadees eat seeds, which can be found all winter, while bluebirds prefer insects that can be difficult to find during winter months.

Staging spots that appear on the map as dots are locations along migratory routes where birds tend to gather just prior to large migratory transits. These are often places that provide good food, shelter and water. Many **staging spots** are used only during fall migrations while others are used only during spring migrations. This is because while food might be abundant at one place in the fall, come spring it might not have much to offer until after a summer's growth.

At this point tell the students to look over the migratory routes on the map. Tell them that you are going to cover them systematically so that it all makes sense, perhaps comparing just one route to another.

- Have them begin by pointing out how the **hawks** and **vultures** follow landforms. What landforms do they seem to like to follow? (They like mountains, scattered fields, coastlines, peninsulas and islands. These features tend to create thermal updrafts that they can ride.) Which land forms do they avoid? (They tend to avoid large open expanses of water or large forests. These features do not

Blackpoll Warbler. Courtesy of the U.S. Fish & Wildlife Service



Arctic Terns. Courtesy of the U.S. Fish & Wildlife Service

produce updrafts.)

- Now have them examine the warblers on the map, of which there are two species featured: the **Blackpoll Warbler** and the **Willow Warbler**. Discuss the size and type of these birds. If you have slides of the featured birds, it helps your students to visualize the species that you are discussing. Note that warblers such as these do not hesitate to fly over open water. Explain that warblers do not soar, so they do not search out thermals. They do, however, make use of air currents. Ask your students to try to determine why the **Blackpoll Warbler** flies east in the fall across North America, then flies hundreds of miles southeast directly out over the open Atlantic Ocean, then abruptly turns southwest to end up on South America. Also have them note that it does not return by the same pathway in the spring. What physical feature on the map might play a role in this route? (Prevailing Winds.)
- Examine the four **North American Waterfowl Flyways**. Tell your students that these routes are used by many species of birds, especially waterfowl. Also explain that these routes are very generalized. Many species jump flyways or use only part of a flyway. Ask them to try to determine why these four routes seem to attrack so many birds? Are there ground features that they seem to follow? (Coastlines, rivers, prairies, mountains)
- Point out the **Fox Sparrow** route along the west coast of North America and/or the **Redshank** routes of Europe and Asia. Have the students notice that there are some short routes and some long routes. Point out the birds that live further north travel further south, while the birds that live at mid-latitudes don't travel so far. Why should this be? (As migration begins, the populations at the north-end of the mid-latitude range don't have to go far south to find a good wintering home; however, by the time the more northerly population gets to the same area, the territory is already taken and they must keep moving further south to find free territory.) This is known as "Leap- frog Migration." The same thing happens again in the opposite direction in the spring.
- Have your students notice that some species of birds live nearly their entire lives at sea. These types of birds are called "pelagic birds". The **Arctic Tern** is the prizewinner for the longest yearly migration: 40,300 kilometers (25,000 miles)! They travel from the Arctic in summer to the Antarctic in the winter. Tip the Bird Migration Cylinder to 0° latitude (horizontal) to see the entire route from north to south. Point out that their route is not straight north to south. It is, instead, much like a large irregular figure-eight. Challenge your students to determine why **Arctic Terns** follow this strange route. (Prevailing winds and seasonal changes.)

Examine the route of the **Short-Tailed Shearwater** in the Pacific. It too is pelagic (over the open sea). How do the winds affect its route?

Now that your cylinder is positioned so that you can see the southern hemisphere, help your students to observe that there are far fewer migration paths for land birds south of the **equator**. Notice that few of them fly even as far north as the **equator**. See the examples of the **Two Banded Plover** in South America, the **African Paradise Flycatcher**, and the **Sacred Kingfishers** and **Swift Parrots** in Australia. Why are there fewer routes in the south? (Where there is less land, there are fewer species of birds.)

Point out the route for the **Albatross** in the far southern seas. Rotate the cylinder to see where it goes. What forces of nature does it make use of? (Prevailing winds.) Tell your students that this bird migrates east/west, not north/south. It soars within a foot or two off the surface of the water, catching small updrafts off the waves, eating what it finds in the water as it goes. It breeds only once every two years on remote islands. Stop the cylinder rotation so that Eurasia is overhead.

Now slowly move the cylinder northward and have them notice that the **Redwing Thrush** is an east/west migrant in Eurasia. It leaves the tundra of Siberia and heads toward Europe and seas that surround it. There are east/west land migrants just as there are east/west pelagic migrants.

Finally, have them look at the **Snowy Owl** routes of the far north. This gives you a chance to explain that "south" is a relative term. Many students, when they think of the term "south," conjure up images of palm trees and sandy beaches. While there are many places like that in the world, when many birds fly south for the winter, their "south" may very well be north of where you live. Notice where the **Snowy Owl** stops for the winter: in southern Canada, the northern United States, Scandinavia, and Russia. These are not exactly tropical places, but **Snowy Owls** are not looking for Sun and fun, just food. They don't even come south every year, only when the local food supply is depleted, as happens occasionally in the Arctic.

At this point you might want to review some major themes.

- Why do many birds fly south for the winter?
- How do land-forms affect the routes that different birds travel?
- What do seasonal changes have to do with migration?
- How do birds use natural air motions such as prevailing winds and rising thermals?
- What is a "Leap-frog Migration?"
- Why are there more northern hemisphere migrants than southern hemisphere migrants?
- Is "south" the same place for all birds?

Snowy Owl. Courtesy of the U.S. Fish & Wildlife Service

STARLAB Activity 2: Finding Your Way After Dark

MATERIALS

- STARLAB Portable Planetarium
- Bird Migration Cylinder
- Northern Starfield Cylinder

Objectives

To have the students gain an understanding of how many bird species navigate their migratory paths after dark.

Suggested Grade Levels

Grades 3 and up.

Integrated Subjects

Science • Geography • Astronomy • Biology • Ecology

Processing Skills

Listening • Observing • Interpreting • Discovering • Reasoning • Making Hypothesis and Conclusions

Preparation

Read the support material regarding the Bird Migration Cylinder, especially the section entitled: "How Do Birds Find Their Way?" (Page 9.)

Set the Bird Migration Cylinder on the projector. Do not tilt it. Instead, leave it so that the North Pole is directly overhead.

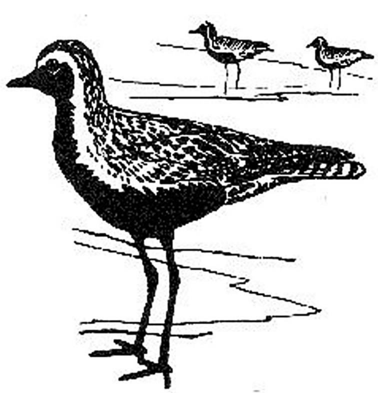
Have the Northern Starfield Cylinder nearby, ready to use.

Procedure

- Make sure that the students are seated around the edge of the dome and are comfortable.
- Explain to the students that today's visit to the STARLAB will help them to understand how birds find their way while migrating.
- Dim the lights and turn up the projector to full brightness. You may later choose to dim it slightly after the students become more dark-adapted, but initially use full brightness to bring out the various colors used to code the different flyways on the Bird Migration Cylinder.
- Ask the students what they see. Be sure they can recognize the continents, oceans, and major landforms. It is often a good first step to locate the position of their home on the map.
- Point out the following features and explain briefly what they represent:
    - Flyways
    - Prevailing winds
    - Major mountain ranges
    - Magnetic north pole
    - Staging Spots

Dead Reckoning

Ask your students to start by examining some of the birds routes and see what they can infer from them. Have them observe how many routes relate to land structures such as coastlines, islands, lakes, and mountains. This style of finding your way is



Golden Plover. Courtesy of the U.S. Fish & Wildlife Service known as “dead reckoning.” Point out some examples of this such as the four **North American Waterfowl Flyways**, the routes of **hawks** and **vultures**, the **Pacific Golden Plover**, and **Redshanks**.

Fox Sparrow. Courtesy of the U.S. Fish & Wildlife Service

Wind Navigation

Now have your students look for routes that might be affected by prevailing winds. (**Arctic Tern**, **Blackpoll Warbler**, **Short-Tailed Shearwater**, and the **Albatross** in the far south). Do these birds use winds to help them find their way, or are they simply being pushed about? Can the students find birds that seem to not use the prevailing winds or seem to be unaffected by them? (**Fox Sparrow**, **Redshank**, **Snowy Owl**, and the **Willow Warbler**.) Do **hawks** and **vultures** use wind? (Yes, but a different kind of wind, updrafts and thermals, which are used for soaring.)

Magnetism

Point out the **Magnetic North Pole**. Ask how people make use of Earth’s magnetism to navigate. Briefly explain magnetic fields if necessary. Could it be possible for birds to detect this? Explain that experiments have been done showing that some birds can detect Earth’s magnetic field and use it to determine direction. Robins do this, and it is believed that they use small magnetite crystals found near their nostrils to detect the magnetism.

An interesting side point: A study using students was done that suggests that even people can detect the Earth’s magnetism without a compass. In the experiment, students wore a coil around their heads that, in some students, cancelled out Earth’s magnetic field. In other students the coils had no effect. The students took a long bus ride with many turns; when the ride was over, the students who had the active coils had completely lost their sense of direction, while the others were still able to point the direction home.

Sun Navigation

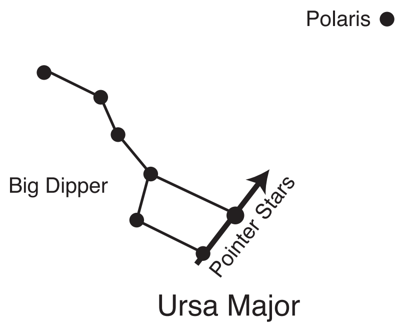
Explain that many birds use the Sun to aid them along their way. This is complicated because the Sun changes position in the sky throughout each day. Scientists believe Sun navigation is correlated with the bird’s own internal sense of time. You might point out that many household pets seem to “know” when it’s suppertime, or bed time or time to go out.

Star Navigation

Explain that many birds, especially songbirds, migrate at night. Can they easily see landforms to help them find their way? (Maybe a little, but not as easily as during daylight hours.) Can they use the Sun as an aid? (Clearly, no.) Can they use magnetism? (Yes.) Can they use prevailing winds? (Sometimes, but winds tend to diminish after dark, and this might be an added motivation for many small birds to prefer night flying.) What else might help them on their way? (Stars.) Explain that we are now to going to examine how some birds use the stars to navigate.

(At this point you need to lower the light on the star projector, bring up house lights if it seems necessary, and change the cylinder to the Starfield Cylinder. Set the projector for a September or October sky. Tilt it to your latitude. Dim the house lights and bring up the stars.)

Before discussing what birds know about the sky, it is best for your students to become oriented with it themselves. Point out the cardinal directions. Begin by pointing out where to find east, have them guess west, then see if they can decide where north and south are. Ask them if there are any stars that are easy for them to find. Perhaps the Big Dipper and Orion will be mentioned. Explain that Orion is best seen in the winter sky, but overhead right now is an autumn sky, so it is not visible. The Big Dipper (Ursa Major) is visible year round because it’s in the northern skies.



Indigo Bunting. Courtesy of the U.S. Fish & Wildlife Service

Explain that constellations seen to the south tend to be seasonal (for viewers from the northern hemisphere), while those constellations in the north are seen year round.

(You can take time to explain why this is, but it is not requisite.)

Tell your students that you will get back to the Big Dipper soon, but first find a couple of Autumn constellations in the southern sky. About due south you should find Aquila the Eagle and above it, near the zenith, will be Cygnus the Swan. Yes, there are constellations of birds! Note that the Swan is flying roughly south, as many birds do every fall.

Point out the Big Dipper (Ursa Major) and show how to find the Little Dipper (Ursa Minor) using the pointer stars of the Big Dipper. Show them how the pointer stars point to the end of the Little Dipper's handle. Tell them that this is probably the most famous star in the night sky. What is it? (Polaris, the North Star.) Why is it famous? (It is famous because it is directly above the North Pole of the Earth and therefore it never moves. The other stars will all slowly draw circles around it as the Earth rotates under our feet. Polaris is not the brightest star. It is actually the 48th brightest star—nothing special in that regard.)

It is under this sky that birds make their fall migrations. Do you suppose that nighttime migrants recognize these same star patterns? Tell them that in 1967 an ornithologist did an experiment to test the idea. He chose Indigo Buntings for the experiment as they migrate after dark.

(If you have a slide of an Indigo Bunting, show it now.)

He built special cages that were cone shaped with a small inkpad floor. The cones were made of blotting paper to record the birds' movement within the cage. The cones opened to a wide top, with a wire mesh screen top. Each cage held one bird. The birds, in individual cages, were placed in a planetarium. When the night sky was simulated the buntings paced nervously within the cages, occasionally jumping up on the cone in attempts to escape. The blotting paper recording their footprints as they slid back down the cone onto the inkpad in the bottom. When the night was over, each paper cone recorded the motions of each bird. What direction did the birds all hop the most? (South.)

Did that prove the birds were looking at the stars? (Not necessarily, perhaps they were detecting south using Earth's magnetism.) To see if the birds were really using the stars, the star field was reversed so that the North Star was located in the south rather than in the north.

(At this point slowly rotate the cylinder platform 180° so that it is facing exactly opposite as was done in the experiment.)

When the experiment was done again, which direction do you think the birds hopped the most now? (Towards the new "south".) In a control group where no stars were shown the birds hopping activities were random. The Indigo Buntings were clearly stargazing.

Further investigation showed that it was not the star patterns that the birds were watching, but the stars' motions. Stars rise and set just as the Sun does. This is, of course, due to Earth's rotation on its axis. As we said earlier, because Polaris, the North Star, lies nearly directly above the north polar axis of Earth, it never moves. All the other stars simply trace out circles around it each day. If we speed up Earth's rotation we can see this motion, and the lack of motion in the North Star.

(Move Diurnal motion and have them notice the star motions and the lack of motion in Polaris. Stop the motion when Orion is clearly visible in the southeastern sky.)

It is the slow continuous motion of stars around Polaris that the Indigo Buntings are aware of as they migrate. When young Buntings were raised in an artificial sky environment where the stars revolved around Betelgeuse (point out Betelgeuse), a star in the constellation of Orion, they tried to fly towards this fake pole star in the spring and away from it in the fall. Notice that by speeding up Earth's rotation a moment ago, we now see Orion in the sky. (In the fall, Orion becomes visible late at night.)

Ask for questions.

Classroom Activities

Create a Nest

To have your students understand the skill a bird must have to build a nest, give them string, twigs, leaves, and soil. Have them build a small bird's nest from this material. Tell them this is all that most birds have to work with to build their nests. For older students, challenge them to build their nests with only one hand using just the thumb and index finger to simulate the bird's beak.

Flap Like a Bird

Everyone knows that birds flap their wings, but can you imitate some of your favorite birds? Have your students pretend that their arms are their wings and see if they can do the flapping that these birds do:

Bird Species	Wing Beats per Second
Albatross	Almost none
Crow	2
Pigeon	3
Chickadee	27-30
Ruby Throated Hummingbird	70-80

(Imagine the Ruby-Throated Hummingbird flying, at 70 wing-beats per second, non-stop across the Gulf of Mexico for more than 24 hours on their seasonal migrations.)

Bird Feeder

Buy or build a bird feeder to have outside your classroom window. Have students keep records of what birds visit your feeder. Try different types of bird food (sunflower seeds, cracked corn, millet, thistle seed, suet, peanut butter, peanuts, dried fruit, etc.) and see which birds eat which kinds of food. Scatter some food on the ground. Do different birds feed on the ground than at the feeder? Do the types of birds vary with the changing seasons?

State Birds

Every state has a state bird. Have your students look up the state birds of all the states. This can unite studying birds with using the library, reading, geography and art. What types of food do the different birds eat? Which state birds migrate?

Bulletin Boards

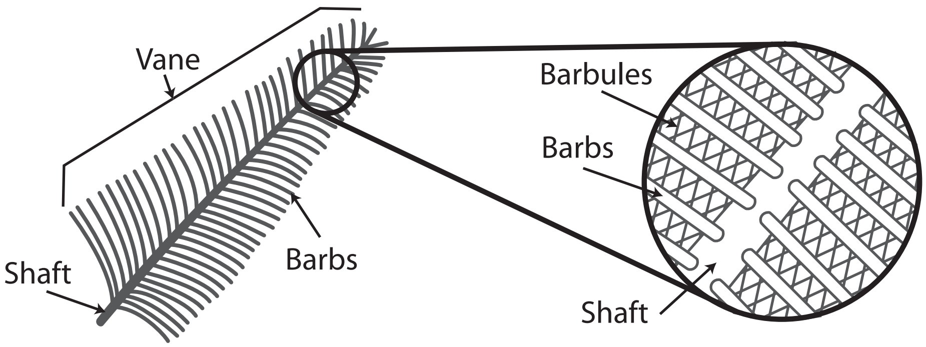
- Create a "Bird Alphabet" by having your students name a bird that begins with each letter. Have them each draw a bird with the letter and place it on the bulletin board.
- Create a bird. After discussing why different birds have specially-shaped beaks, feet, wings, etc., have students make up their own kind of bird using their own combination of different beaks and feet. Have them cut out their "New Bird Creations" and put them on a bulletin board with a scene already on it of a tree with grass near a pond. Have them place their new bird where it belongs in the scene. Would their bird migrate?

Bird Walk

Take your students on a "quiet hike" outside of your school looking for birds. Have them listen very carefully. Often you can hear birds that you might not see. Try to identify the birds you see. Have them make a note where they see them (i.e. air, water, tree, building, wire, etc.). Discuss what the birds were doing. List how many different birds you saw on the walk, what each bird was doing, and which ones you saw most often.

Feathers

Pass out a feather to each student. Have them examine the feather very carefully with a magnifying glass. Note the different parts of a feather. Discuss why birds have feathers. Do they help them fly? Do they keep them warm? Are they ever replaced? Are all feathers alike?



Migrations Aren't Always About Birds

There are many different kinds of animals that migrate. See how many your students can name. Have them research where and when different animals migrate. Some animals to consider: caribou, whales, butterflies, seals, antelope and salmon.

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