Fifth Edition

ORNITHOLOGY
in Laboratory and Field

Olin Sewall Pettingill, Jr.

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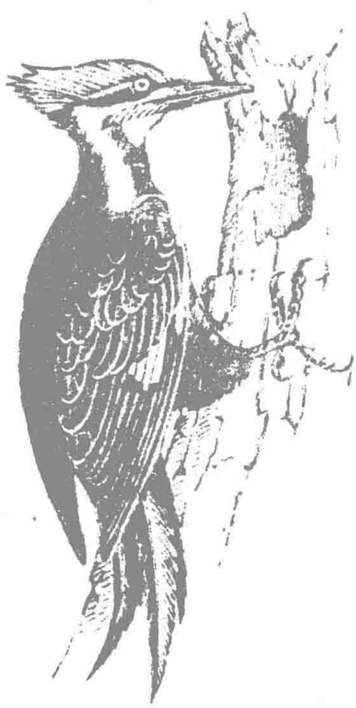

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Academic Press, Inc.
(Harcourt Brace Jovanovich, Publishers)
Orlando San Diego San Francisco New York
London Toronto Montreal Sydney Tokyo São Paulo

To the memory of
Alfred O. Gross
(1883–1970)
Professor of Biology at Bowdoin College,
preeminent ornithologist and inspiring teacher.

Academic Press, Inc.
Orlando, Florida 32887

United Kingdom Edition Published by
Academic Press, Inc. (London) Ltd.
24/28 Oval Road, London NW1 7DX

ISBN: 0-12-552455-2
Library of Congress Catalog Card Number: 84-71089
Printed in the United States of America

Preface

Like its four predecessors, this fifth edition of *Ornithology in Laboratory and Field* is intended for use at the college or university level and assumes that students need have only a background knowledge of general biology. Although the book makes no pretense of covering the realm of ornithology, it treats those major aspects of the science that can be studied during a course in the regular academic year or in the summer.

There are twenty-two chapters, all more or less independent units. Even though they are presented in a fairly logical sequence, they can be taken up in almost any order, and some may be omitted altogether without affecting the value of the others. The instructor may wish to select parts of the book without regard to sequence that will best supplement class work or suit the season of the year during which the course is given.

With few exceptions each chapter concludes with references. While many references are cited in the preceding text of each chapter, many more are included to support or supplement the text, to give views contrary to statements in the text, or to suggest further reading. If the titles are not cited from the text or the titles themselves do not indicate the reasons for their inclusion, they are annotated parenthetically. Students should make a practice of perusing the references after reading the preceding text.

In order to use this book effectively, certain equipment and materials are desirable. The student should have for personal use:

Binocular

Field guide

Key to the bird species in the region where the study is made

Daily field checklists (as many as there will be field trips)

Loose-leaf pocket notebook, preferably with aluminum cover

A set of colored crayons

The institution should make available to students the following:

The American Ornithologists' Union's *Check-list of North American Birds*, Sixth Edition

Annotated checklist of birds in the region of the study

A world atlas

Telescope (preferably the so-called "spotting scope") with either eyepiece or a zoom lens and a tripod

Portable tape recorder

Compound microscope

Meter stick

A Common Pigeon (Rock Dove) and a House Sparrow, properly preserved but not plucked, for external study and dissection

Several nestling House Sparrows preserved in spirit for study of feather tracts

Pigeon skeleton, mounted

Pigeon skeleton, completely disarticulated

Human skeleton, mounted, or a detailed chart of a human skeleton

Human cervical vertebra (fifth)

Hyoid apparatus of a woodpecker

A series of contour feathers illustrating specialized feather types. Some of the more exotic types may be obtained from zoos, which usually save such material for educational institutions.

A semiplume, an adult down feather, a filoplume, a bristle, and a section of the vane of a contour feather mounted on slides for microscopic study.

Parts of feathers with different colors—red, orange, yellow, black, gray, brown, iridescent, blue, green, and white—mounted on slides for microscopic study of color-producing elements

A series of spread wings of a passerine species (e.g., the House Sparrow or European Starling) to illustrate the progress of molt

A collection of bird skins representing all the orders and families of North American birds and all species found in the region of the study. (If possible, the collection should be sufficiently comprehensive to show sex, age, and other constant differences in plumage; abnormal plumage coloration; color phases; eclipse plumage; and plumage changes by wear and fading.) A transparent plastic tube (capped) for each of the smaller skins that will be handled often is recommended in order to prevent damage. (These can be ordered from any biological supply company.)

A record player or tape recorder with reproductions of songs of species occurring regularly in the region of the study

The prefaces to the previous editions of this book tell the story of how it evolved, starting in 1939. In these prefaces I have acknowledged ornithological sources for much of the text. I also acknowledged my many colleagues, former students, numerous friends, and my late wife, Eleanor, who contributed in various ways to the production of all four previous editions. Without the advice or assistance of these generous people I would not have had the framework and much of the authoritative information in this edition.

The cover illustration is by Walter J. Breckenridge and all the illustrations in the text, if not accompanied by credit lines, are his except the following: Figures 1–3, 5–6, and 24 by William Montagna; Figures 4 and 38 by Ray S. Pierce; Figures 8–11 by Robert Gillmor; Figures 12–23, 25–28, 34, and 36 by Robert B. Ewing; Figures 29, 30a, and 31 by Barbara Downs; Figure 33 by Sandra L.L. Gaunt; Figure 41 by Frank A. Pitelka (first published in *The American Midland Naturalist* for 1941); Figures 51–53 by Sidney A. Gauthreaux, Jr., and Figure 54 by Helen S. Chapman.

For the new chapter "Flight" in this edition, I am grateful to the Laboratory of Ornithology at Cornell University for granting me permission to use the drawings by Robert Gillmor and parts of the accompanying text from the Laboratory's *Home Study Course in Bird Biology*, Seminar IV.

I wish to thank the Bird Banding Laboratory at Patuxent, Maryland, for reviewing in Appendix A the procedures and regulations for obtaining permits to capture, band, and mark wild birds, as well as for providing addresses of state and provincial agencies to which inquiries and applications should be made. I also wish to thank Janet G. Hinshaw, Librarian in the Josselyn Van Tyne Memorial Library at the University of Michigan, for help in checking on, and adding to, the titles of various ornithological journals in Appendix C.

In the preparation of this edition I am deeply indebted to the following authorities in their respective fields of ornithology:

Sidney A. Gauthreaux, Jr., for writing the entire chapter "Migration."

Jack P. Hailman, for writing the entire chapter "Behavior" and for reviewing all the succeeding chapters on the breeding biology of birds.

Peter Stettenheim, for again giving detailed attention to the chapter "Feathers and Feather Tracts," further clarifying or amplifying many aspects of feather growth, structure, coloration, and function.

Andrew J. Berger, for reviewing and updating the "Muscular System," and for taking the time to go over all parts of the book pertaining to internal anatomy and physiology.

Abbot S. Gaunt, for describing the anatomy of the syrinx and its function.

Kenneth C. Parkes, for reviewing and, in some instances, revising or rewriting parts of the chapters "Systematics and Taxonomy" and "Plumages and Plumage Coloration"; also for overseeing the exacting work of Jay Loughlin, Collection Manager at

the Carnegie Museum, in updating the synopses of North American orders and families of birds and reconstructing the keys to the same orders and families in accordance with the sixth edition (1983) of *The A.O.U. Check-list of North American Birds*.

Donald E. Kroodsma, for greatly expanding the chapter "Song" and giving the benefit of his expertise in recording bird vocalizations under "Ornithological Field Methods" in Appendix A.

Stephen I. Rothstein, for significantly extending the sections on brood parasitism in the chapters "Eggs, Egg-laying, and Incubation" and "Young and Their Development."

John T. Emlen, for worthy information on bird populations and giving instructions for a new method of measuring populations.

Alan Feduccia, for his critical reading of the ancestry and evolution of birds in the last chapter of this book.

Robert A. McCabe and Ray B. Owen, Jr., for reading and commenting in Appendix A on field techniques applied to capturing, marking, and following wild birds.

Finally, I thank my long-time friend, Edward F. Dana, with his considerable editorial experience, for reading much of the text of this edition when it was in galley proof.

Olin Sewall Pettingill, Jr.

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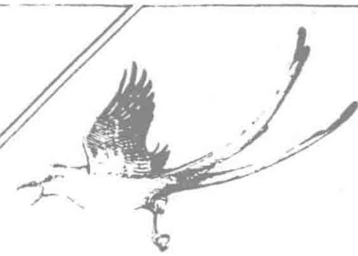
Birds and Ornithology: An Introduction



Birds among all animals offer the most favorable combination of attributes for scientific study. They are numerous, abundantly diversified in form, and easily observed. They are highly organized and responsive with sensory capacities similar to man's and therefore understandable. Pleasing in colors and movements, they are also, with few exceptions, inoffensive in their habits and incapable of physically harming the investigator. Many adapt readily to experimentation. Little wonder that ornithology, the science of birds, boasts so many practitioners, and in turn contributes so significantly to modern concepts of evolution, speciation, behavior, and ecology.

Birds Defined

Birds are unique among all animals in being feathered. Like mammals, they too are warm-blooded, or homeothermous, (capable of regulating their body temperature). And like most of their vertebrate associates, excepting most mammals and a few others, they lay eggs.

Animals move from place to place by running, hopping, walking, crawling, swimming, gliding, and flying. Among birds, flight is the principal means of locomotion, even though some forms—for example, ostriches, kiwis, and penguins—in the course of evolution have lost their ability to fly. Therefore, one recognizes birds as birds because they are formed to fly.

The modern bird, like an airplane, is structurally and functionally efficient. A bird must be able to take flight, to stay aloft, and to reach its destination under the most adverse conditions.

Achievements for Flight

Several achievements have contributed to the bird's mastery of the air.

Lightness Achieved by a covering of feathers—"the strongest materials for their size and weight known"—instead of a thick skin; by the loss of teeth and the heavy jaws to support them; by a reduction of the skeleton and by the hollowing, thinning, and flattening of the remaining bones; by a radical shortening of the intestine and the elimination of the urinary bladder; and by air spaces in the bones, body cavity, and elsewhere.

Streamlining Also achieved by the feathers, overlapping and smoothing the angular, air-resistant surfaces and providing bays, wherein the feet may be withdrawn.

Centralization and Balance Achieved by positioning all locomotor muscles toward the body's center of gravity—leaving the wings, like puppets, controllable by tendinous strings; and by positioning the gizzard, the avian substitute for teeth, and other heavy abdominal organs in the center of the body.

Maximum Power Achieved by the combination of an exceptionally high, steady body temperature for aerial maneuvers in all extremes of climate and weather, by feathers which aid in conserving the heat; by increased heart rate, more rapid circulation of the blood, and greater oxygen-carrying capacity of the blood stream; by a unique respiratory system, which permits a double tide of fresh air over the lung surfaces, synchronizes breathing movements with flight movements, cools the body internally, and eliminates excess fluids; and by a highly selective diet of energy-producing foods, which contain few indigestible substances to cause excess weight.

Visual Acuity and Rapid Control Achieved by large eyes with a wide visual field and remarkable distance determination, and by a brain whose greatly enlarged visual and locomotor centers are capable of recording and transmitting nerve impulses with the reactions of a seasoned pilot

Range in Size

Birds range widely in size The Ostrich (*Struthio camelus*), standing between 8 and 9 feet tall (2.44 and 2.74 m) and weighing nearly 350 pounds (159 kg), is the largest. But it is, of course, flightless. Among the largest flying birds are the Royal and Wandering Albatrosses (*Diomedea epomophora* and *D. exulans*) and the Andean and California Condors (*Vultur gryphus* and *Gymnogyps californianus*) with wingspans approximating 10 feet (3 m). The Marabou Stork (*Leptoptilos crumeniferus*) may be the largest flying bird, if, as reported, its wingspan measures over 12 feet (3.7 m).

The smallest birds include numerous species of hummingbirds, the extreme being the Cuban Bee Hummingbird (*Mellisuga helenae*) that measures 2.25 inches (5.72 cm) from bill-tip to tail-tip and weighs less than 2 grams. Fourteen Bee Hummingbirds would weigh no more than an ounce (28.35 g).

Within a species there is often sexual difference in size, the males averaging slightly larger. In some species sexual dimorphism is very marked with the male slightly more than twice as large, as in the Wild Turkey (*Meleagris gallopavo*) and in the largest of all grouse, the Capercaillie (*Tetrao urogallus*), or with the female a third larger, as in the Sharp-shinned and Cooper's Hawks (*Accipiter striatus* and *A. cooperii*).

There are limits to the size that flying birds may attain. They cannot be as small or as large as many other animals. Because they have a high rate of metabolism for supporting a high body temperature and flight movements, birds need sufficient food to maintain this rate and at the same time compensate for heat loss from body surfaces.

Theoretically, the smaller the bird, the greater is its relative body surface in relation to weight and the greater its heat loss. Consequently, the smaller the bird, the more it must eat in proportion to size. Again, theoretically, a bird smaller than kinglets and chickadees would have to eat all the time, night and day. Hummingbirds exist, small as they are, because they lower their body temperature—that is become torpid—at night or at other times when they cannot eat. Thus they conserve energy.

The larger the bird, the faster it must fly to stay airborne. It needs bigger flight muscles for greater speed. This, in turn, means greater weight because flight muscles are heavy.

The larger birds have attained their size while retaining their ability to fly by developing a dependence on air currents. Albatrosses and condors practically require winds and updrafts in order to fly at all.

Ornithology Defined

Ornithology, simply defined, is the science of birds. For a descriptive definition, there is none more suitable than the one written by Elliott Coues, the perceptive American ornithologist, nearly a century ago:

> Ornithology consists in the rational arrangement and exposition of all that is known of birds, and the logical inference of much that is not known. Ornithology treats of the physical structure, physiological functions, and mental attributes of birds; of their habits and manners; of their geographical distribution and geological succession; of their probable ancestry; of their every relation to one another and to all other animals, including man. [In *Key to North American Birds*, 5e (Boston: Dana Estes and Co., 1903), p. 58.]

One must study ornithology in both laboratory and field because a knowledge of birds "in the hand" is incomplete without a knowledge of birds "in the wild," and vice versa

Form, Structure, and Physiology

Basic to the study of ornithology is an introduction to the form, structure, and physiology of birds. This the student can best accomplish by making direct observations on the physical make-up of a "generalized" bird, such as the Rock Dove or Common Pigeon *(Columba livia)*, and by learning from a text book the role of each organ system in the bird's way of life. Attention must be centered on those features that will particularly enhance an appreciation of birds as biological entities. Frequently, certain features must be compared to their homologues in man, thereby making them more understandable.

The logical sequence to such an introduction is, first, the identification of the different parts of the bird's topography, followed by a study of the bird's feather covering—how the feathers are structured and variously modified, how they develop, how they are colored, and how they are arranged on the body. A detailed knowledge of these exterior features is indispensable not only in describing birds and their actions but also in accounting for many of their adaptations.

With this knowledge, the student is then prepared to investigate the internal organ systems. Avian anatomy and physiology offer many opportunities for research. Indeed, an increasing number of ornithologists specialize in one or both of these fields, dealing particularly with the adaptive and comparative aspects among different species of birds.

Species and Speciation

Although uniformly specialized for flight, birds have nonetheless changed widely in form and action in order to live in particular environments.

Consider, for example, the adaptations for locomotion and feeding. Some species customarily fly swiftly; others fly slowly. Some hover; others soar. Some swim and dive; others wade. Some walk or hop; others climb. To get food, some species probe in the soil, others dabble in shallow water, scratch the ground, chisel holes in trees, make flying sorties, or hunt for prey in any number of different ways.

These adaptations and others, always in complex combination, account for the different shapes of wings, tails, bills, and feet and differences in body shape, plumages and coloration, breeding habits, seasonal movements, and general behavior. Or, to put it another way, thanks to adaptive radiation operating so vigorously in the descent of birds, there are some 9,000 different species today.

In studying birds one naturally thinks of them in terms of species. Therefore, the logical sequel to a knowledge of their form, structure, and physiology is an acquaintance with the many different species in the student's immediate area. This requires understanding the concept of species and speciation and the methods of classifying, naming, and identifying.

Gaining a thorough acquaintance with the 150 to 300 species regularly occurring in the average study area of temperate North America demands a knowledge of the taxonomic characters and other means of recognizing species in both laboratory and field, together with an understanding of changes in plumage and plumage coloration among different species.

The identification of species is not an end in itself but a stepping stone to investigations of many aspects of bird life, or of biological problems in which birds play a role. Some students find speciation per se a challenging field since there is still much to be learned about the origin, status, and interrelationships of species.

Distribution

Although most modern species of birds can fly and thus can rove the earth, each species is confined to a particular geographical range, which may be from several hundred acres, as on a sea island, to one or more continents in size.

The ranges of species overlap so that in any one area there is an aggregation of species—an avifauna. Because the ranges of species are rarely or never identical, avifaunas vary markedly. Students over the years have given attention to the composition, comparison, and origin of avifaunas, yet there is much about them that remains to be investigated.

Geographical ranges are unstable due partly to the tendency among species to invade new areas. Cyclonic storms may help or hasten resettlement by moving individuals to a different place, where they survive and reproduce if the environment suits them. Man has a part in it too, when, for example he transports birds on his ships. House Sparrows *(Passer domesticus)* reached the Falkland Islands in the South Atlantic on ships that first stopped at Montevideo, Uruguay, where the birds, attracted to sheep-pens on deck, came aboard and remained until the ships reached the islands.

Any student, after having observed birds in a given area for a few years, is certain to note shifts in ranges and ponder the reasons. Modern ornithologists pay considerable attention to local distribution as the abundant literature on the subject clearly indicates.

Within its geographical range a species, if normally migratory, is seasonally distributed, appearing in one part of its range in one season, in another part in another season.

Within its geographical range a species is also ecologically distributed. It usually occupies a particular environment or habitat and shares this habitat with other organisms—plant and animal—all of which are adapted to the prevailing conditions of soil, air temperature, moisture, and light. All the organisms in a given habitat collectively comprise a biotic community, since they show relationships to one another.

When any two communities meet, more often than not, there is an area of mixture and overlap, or ecotone, in which the birds and other living forms characteristic of these communities are intermixed and in which are additional forms that, preferring this ecotone, seldom occur elsewhere.

Students soon become aware of the importance of habitat or community in accounting for the presence or absence of species and, before long, learn to associate different species with particular environments—the Red-eyed Vireo *(Vireo olivaceus)* with the deciduous forest, the Horned Lark *(Eremophila alpestris)* with the short-grass prairie, and the Verdin *(Auriparus flaviceps)* with the scrub desert. When students travel northward on the continent of North America or climb a high mountain, they expect a sequence of species as they pass through one environment after another—the Olive-sided Flycatcher *(Contopus borealis)* in the coniferous forest, the White-crowned Sparrow *(Zonotrichia leucophrys)* at the timberline ecotone, and ptarmigan (*Lagopus* spp.) on the tundra.

At the same time students become conscious of several significant aspects of ecological distribution. Rarely do they find one species throughout a community, even though it may be characteristic of that environment. As a rule, it occupies merely a niche and is adjusted to this position in structure, function, and behavior as no other species in the same community. In the forest community, for example, the Red-eyed Vireo occupies a treetop niche and is adjusted to this position in structure, function, and behavior just as the Ovenbird *(Seiurus aurocapillus)* occupies the forest floor. It would be unusual to see the Red-eyed Vireo on the ground or the Ovenbird in the treetops. While a species may appear to share its niche with other species, not one behaves exactly as another does or requires the same food and the same nesting site.

Bird species are of greater variety and density in ecotones than in the pure communities that border them. This phenomenon, called edge effect, is important to anyone wishing to see larger numbers of birds.

Edge effect results in a greater variety of vegetation—grasses, shrubs, and trees—providing a greater variety of food and cover for birds. For example, ecotones where field and forest merge have the plants characteristic of both field and forest and many additional shrubs. Thus they bring together birds of both field and forest and also attract species that require either shrublands or a combination of trees, shrubs, and grasses.

Some bird species are adapted so strongly to a special niche that they cannot live in a different situation. If an element in the niche on which they depend is destroyed or seriously altered, they are more likely to disappear than to make an adjustment. The Snail Kite *(Rostrhamus sociabilis)* probably would disappear in Florida were disaster to befall the big freshwater snail, *Pomacea palludosa*, on which it feeds exclusively. It is likely that the Kirtland's Warbler *(Dendroica kirtlandii)* would disappear in northern Lower Michigan, where it breeds exclusively, if there were no more jack pines 6 to 18 feet high (2 m to 6 m) under which it almost invariably nests.

A good many bird species, on the other hand, are much more adaptable. Sometimes they are so widely tolerant of different situations that their precise niches are unrecognizable. The Blue Jay *(Cyanocitta cristata)*, Black-capped Chickadee *(Parus atricapillus)*, and Cedar Waxwing *(Bombycilla ced-*

rorum) are so adaptable that one may find them almost everywhere in wooded areas through their ranges.

The species that restrict themselves to narrowly prescribed niches generally have small populations within correspondingly small ranges. The species tolerant of environmental changes and variations are mainly the inhabitants of the ecotones; they have large populations and often range widely.

The underlying factors accounting for the ecological distribution of many species still remain to be determined. Here is a study with a degree of urgency. As man steadily destroys the natural environments, an understanding of a species' ecological requirements is the first step in preventing its decrease. The next step is to see that its requirements are maintained through intensive management and conservation practices.

Behavior

The behavior of birds attracts scores of investigators. Birds are ideal animals for behavioral studies. Each species has an impressive repertoire of innate behaviors and, at the same time, its ability to learn compares favorably with that of most mammals. Thanks to a rich variety of bird species, each with a different mode of life, investigators have available for study a correspondingly rich variety of behaviors.

An understanding of the principles of bird behavior is essential for any beginning student, helping as it does to explain the basis of many avian activities. Even more important, an understanding of bird behavior illuminates many of the basic ethological principles applied to human life. Modern psychologists are now paying attention to such phenomena as individual distance and dominance relationships (first noted in birds!) that are so evident in urban societies. Continued, in-depth studies of avian behavior will, almost certainly, further sharpen man's perception of his own social problems.

The procedure in the study of behavior is to identify, describe, and name the behaviors of a species and then to determine what each behavior accomplishes, its significance to the species' survival, its causes, how it has evolved, and whether it is innate, learned, or both innate and learned. Many mating displays are actually derived from such maintenance activities as preening or scratching; or from displacement activities—for example, when a bird breaks off fighting and pecks at some object; redirected activities—when a bird redirects its attack to an object other than one which elicited the response; and intention movements—when a bird makes a move to fly but fails to do so, thereby performing an incomplete act.

Inherited behavior predetermines the extent to which learned behavior may develop. Learned behavior is actually adaptive behavior resulting from experience. A bird inherits the ability to fly, yet it must learn by experience to take off *into* the wind rather than *with* it and to choose the perch that will best accommodate its feet. This is called learning by trial and error. Other forms of learning are by habituation and by imprinting. A few birds show ability to learn by insight. The different methods of learning among birds demand much more research.

Investigators often give considerable attention to social behavior since most birds are by nature gregarious and have consequently developed many kinds of interactions related to attack, escape, defense, flocking, and reproduction. Although the literature on social behavior in birds is already enormous, the subject is still a fertile field for study.

Migration

No aspect of bird life has so excited man's interest down through the centuries as the withdrawal of birds from an area in the colder seasons and the return to the same area when the seasons become warmer. In spite of a great store of knowledge on the initiation and procedure of migration among modern birds, the question of how and when migration originated still remains speculative—an ever-present challenge to one's thinking.

Experimental studies started over 50 years ago demonstrate that a specific day length in the spring stimulates the activity of a bird's endocrine glands, and this stimulation brings the bird into a migratory state. Some external factor then releases migratory behavior. In the fall, with a regression of endocrine activity, the bird reaches another migratory state ready for triggering by an outside cause.

The present wealth of information on the process of migration—starting and stopping times, rate, duration, distances covered, routes, and relation to weather—is due in large measure to direct observations and record-keeping by hundreds of persons and to returns from many millions of banded birds.

Radar and radiotelemetry are useful tools in fathoming some of the "mysteries" of night migration and determining the speed, direction, and elevation of migratory flights.

Migrating birds have obvious navigational ability, otherwise they could not return as they do to their nesting grounds after the winter spent hundreds, sometimes thousands, of miles away. Just how migrant birds orient themselves has been the object of numerous experiments. By using caged birds that display migratory activity by "fluttering" in the direction of migration in the wild, some investigators have demonstrated that birds migrating on clear days may be guided by the sun and on clear nights by star patterns. These and other experiments, although convincing, do not explain orientation by all birds under all circumstances. Undoubtedly different birds use different cues or different combinations of cues, depending on where and when they migrate and the prevailing weather conditions. The whole subject of orientation, complex and fascinating, beckons for continued research.

The Reproductive Cycle

The main stages of the reproductive cycle of most bird species are the establishment of territory, the coming together of the sexes, nest-building, egg-laying, incubation, hatching of the eggs, and the development and care of the young. Involved in the establishment of territory and the coming together of the sexes are two prominent activities—singing and mating displays.

In the past 75 years many investigators have studied the reproductive cycle of different species, resulting in the accumulation of a vast amount of data. Yet, surprisingly, detailed, comprehensive information is available on relatively few species. For only about 5 percent of North American species is the size of territory known; for about 10 percent, the average length of nestling life; for about 20 percent, the average incubation period; for about 30 percent the full description of songs and mating displays.

Anyone beginning a study of birds should carefully observe the reproductive cycle of at least one species from territory establishment to fledging and dispersal of the young. The more detailed information one can obtain, so much the better. Ideally, students will contribute to knowledge of the species, but whether they do or not, they are almost certain to profit by gaining an intimacy with the living wild bird, its behavior and problems of survival.

Longevity, Numbers, and Populations

How long do birds live? How many birds are there in given areas? What are the factors controlling the numbers of birds? These are questions that always fascinate anyone studying ornithology, and the answers continue to be unsatisfactory in scope and often controversial.

Students should familiarize themselves with these questions and gain some first-hand experience in estimating numbers of birds.

Direct counting of individuals of most species generally is futile because they are so numerous and widespread. Time is better used in measuring the populations of all species in a given area and understanding how their populations are controlled. This is a complex undertaking. It includes determining their reproductive rates; the ratio of age groups and sexes; the annual fluctuations of their respective populations because of varying physical factors of the environment (air temperature, precipitation, and others) and biological factors (predation, diseases, food supply); and ways in which their populations are controlled over long periods of time. Although populations normally fluctuate in numbers of individuals per year, they are remarkably stable over a period of, say, 50 years if their habitat is unchanged. Annual fluctuations are scarcely more than wrinkles in the long history of a population.

The study of populations has endless opportunities for investigation. It is of vital—"vital" meaning life-or-death—importance at the present time as man hastens his encroachment upon and destroys the natural environment. Determining when certain populations are showing a sharp decline provides the basis for informing conservation agencies and urging remedial action.

Evolution

Where did birds come from? The story goes back to the Triassic Period some 200 million years ago, when birds arose from a somewhat specialized group of reptiles that had long hindlimbs. The avian line from this reptilian specialty may have begun as tree-climbing forms, which first jumped from branch to branch by using membranes stretched between the sections of their shorter and slightly flexed forelimbs.

As they gradually evolved the ability to fly farther, these arboreal forms acquired greater sailing surface through expansion and modification of the scales on the trailing edges of their forelimbs and along the outer edges of their long tails. At this point birds came into being, for of all the physical features of birds, none distinguishes them more sharply from all other creatures than these outgrowths of the skin.

The remarkable fossil *Archaeopteryx lithographica* possessed feathers and is thus recognized as the earliest known bird. This creature of the Jurassic Period, some 140 million years ago, may have been one of several kinds of similarly primitive birds already existing. Nobody knows. But in any case, one such primitive species, probably of either Eurasian or African origin, acquired the power of flight—that is, the ability to sustain itself in the air for indefinite periods by flapping its wings. And from this stock many species began to emerge as they spread out and filled more habitats and niches.

This evolutionary process, commonly called adaptive radiation, was slow at first but steadily quickened during the next 139 million years, through the Cretaceous and Tertiary Periods. Birds in time inhabited all the earth's great land masses and occupied most of the primitive environments.

But as the continents separated, merged, and separated, as mountain ranges rose and were worn away, as the climates shifted, and as plant forms evolved, flourished, and vanished, so did habitats for birds. The species so precisely adapted to one habitat that they could live in no other disappeared when the habitat disappeared. More species were always evolving, however, to fill new niches.

The primitive birds became extinct through the Cretaceous Period. The "new" birds began to look more and more like modern species, and many birds were recognizable by the end of the Tertiary as ostriches, pelicans, cranes, nuthatches, thrushes, and so on.

With the coming of the Pleistocene Epoch, or Ice Age, about a million years ago, the abundance of birds in number of species attained a peak that has never been exceeded. This period of prehistory could have been called the Age of Birds, had mammals not already taken the ascendancy in size and aggressiveness to dominate the earthly scene.

Toward the end of the Pleistocene and the start of the Recent Epoch, about 15 thousand years ago, bird species began disappearing more rapidly than they were evolving. The decrease of birds was under way. Man had not yet become a major destructive force in the avian environment. How, and how fast, that destructive force grows may determine how, and how fast, the presently extant 9,000 species of birds disappear.

The first bird species definitely known to have been eliminated by man was the Dodo (*Raphus cucullatus*), in 1681. Since that date, no fewer than 78 species have become extinct over the world, nearly half of them destroyed by man. At this rate of disappearance, the future for bird life appears alarming.

And it is alarming! Whenever investigating the attributes of birds, students of ornithology must keep this in mind, being constantly alert to discover ways and means that will insure the protection of birds and thus assure their survival for centuries to come.